Speaking from Experience: Co-designing E-textile Projects with Older Adult Fiber Crafters

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Figure 1: Participants' e-textile prototypes that we co-designed during the remote workshop. The prompt was open ended after teaching them about e-textiles. The prototypes included a Snap-a-zoo fold up animal (P1), Easter bunny (P2), interactive toy for children with developmental disabilities (P3), Magic Question Answering Hat (P4), pre-printed video game panel (P5), and memorial from a friend's 21 gun salute (P6).

ABSTRACT

Researchers support race, gender, and age diverse groups of people to create with maker electronics. These groups include older adults, who are often overlooked as not interested or capable of learning new technologies due to ageist stereotypes. One approach, often involving e-textiles, leverages crafting as a bridge to broaden participation in making. We investigated ways to broaden participation in maker electronics for older adults by remotely co-designing e-textile projects with 6 older adult crafters over the course of 5 workshop sessions for a total of 45 hours. We developed a deeper understanding of their practices, identifying a Planner-Improviser Spectrum for how they approached their craft, and created medium fidelity prototypes. Our design implications draw on our participants' crafting experience and their experience in the workshop to highlight what e-textile toolkit designers can learn from skilled older adult crafters, such as selecting familiar materials, supporting aesthetic goals, and making electronics more attainable.

CCS CONCEPTS

• Social and professional topics → Seniors; **• Human-centered computing → Interface design prototyping**; *User studies.*

KEYWORDS

Older adults, co-design, crafters, crafting, electronic toolkits, maker electronics, remote workshop, crafting technology.

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1 INTRODUCTION

Bridging electronic making with crafting[1] has been a key strategy to broaden participation in making. E-textiles and crafting both use hands-on techniques and creativity to create physical objects. Researchers have built upon these similarities by designing craft-focused toolkits [7, 26, 52], allowing people to use craft skills to create electrified projects. LilyPad Arduino and Chibitronics, two commercial electronic toolkits, have shown how their tools are reaching more gender diverse audiences through crafting compared to craft-less tools [8, 51]. Researchers have suggested that integrating crafting into making may also be a pathway to engaging older adults [26, 39].

Researchers have examined ways to engage older adults in maker electronics [1, 55], including through crafting [26]. This work has generated a better understanding of how older adults create and engage with makerspaces embedded in their communities [10, 39] and how older adults can take part in the design of future technologies, for themselves [1] and the broader population [55]. We also can draw on older adults' skills to engage them more broadly in taking an active role in creating with electronics.

The contributions that craft and crafters can bring to HCI have been recognized in a range of research projects. This includes enriching design practice through studying craft thinking [35], specific processes such as bookbinding [56], or purposes such as crafting for major life events [42] or creating a non-judgmental space for mental health and wellbeing [18]. Craft-focused researchers have explored how craft can bring forth complexities through beauty [61], or help explain how craft is intertwined with problem solving [41] and authenticity [35]. Craftspeople can also offer expert perspectives during the process of designing technologies, particularly at early stages [13]. In this paper, we turn to older adults with decades of crafting experience to provide insights for toolkit designers as they work to continue to broaden participation in electronic making. Understanding how these individuals approach e-textile projects can inform the design of toolkits that support novice older adults to create with these tools.

We remotely co-designed craft-based e-textile projects that integrate maker electronics with 6 older adult crafters through individual workshops with each participant for a total of 44.7 hours of sessions. We brought our expertise in maker electronics, especially e-textiles, while participants brought their complementary expertise in fabric-based crafting. We analyzed participants' interactions during the workshop and the resulting co-designed projects. This analysis helped us understand older adult crafters' practices and how they create e-textile projects.

This paper makes the following contributions: (1) a range of medium fidelity prototypes from a co-design process with older adult crafters and researchers, (2) an understanding of how participants approach e-textile projects, including an empirically-based framework for a Planner-Improviser Spectrum, and (3) design implications for toolkit designers based on our experiences co-designing with older adult crafters.

[1]Craft can have many meanings that has changed over time [33]. By crafting, we often refer to the traditional art of creating something by hand with tangible materials. We want to avoid disregarding it as low-tech and rudimentary and without precision as it can be stereotyped by some technology practitioners.

2 RELATED WORK

This work is situated within e-textile, crafting, and older adult literature. We first outline how e-textile researchers have used crafting techniques to expand who can create and what can be made. We also highlight how electronic making researchers have worked with expert crafters, and the benefits of doing so. Lastly, we describe electronic making research with older adults, pointing out how we plan to build on this prior work.

2.1 Connecting E-Textiles and Maker Electronics to Crafting

Researchers explored using crafting techniques with e-textiles to grow the possibilities of what people can make. Crafting techniques from knitting [11, 43], sewing [6, 7], embroidery [20, 21, 48], weaving [14, 15, 17, 46], batik fabric dyeing [24], and beading [27] provided the e-textile community unique ways to facilitate creating with maker electronics. For example, Lee et al. [29] took inspiration from custom rug making by using a punch needle as a rapid prototyping tool. A punch needle pushes conductive thread through fabric, leaving a loop of thread on the opposite side without knotting it, allowing people to pull the thread back out to undo their stitches. Similarly, researchers integrated embroidery techniques with e-textiles to create soft speakers [48], a smart sock for rehabilitation [20], and a computer vision based system for sketching and embroidering a circuit [21]. In our work, we sought to learn from the fabric crafting techniques of expert crafters to develop new insights for e-textile researchers.

E-textile toolkits have been a common method for supporting people to create with maker electronics, often by connecting e-textiles and crafting [50]. Toolkits have an advantage of being adaptable to a particular group, such as focusing on supporting children with no technical experience [30, 31] by limiting what can be connected and how. For example, MakerWear [31] used custom components built into hexagonal shapes that attached to a powered hub, which was then attached to fabric. By connecting toolkits with crafting, some toolkits focus on supporting a broad range of skill levels to create. For example, commercial toolkits, such as LilyPad Arduino [7] and Adafruit's FLORA[2], are designed to support multiple skills levels while encouraging people to use their sewing skills to create. There are also toolkits that focus more heavily on creating with and connecting to craft by more seamlessly integrating them in, allowing for more open-ended creativity [44, 49]. We build on these custom toolkits in this work by co-designing projects with older adult crafters to support them integrating their expertise into toolkit designs.

Researchers connected crafting skills with e-textiles to diversify who is able to create with maker electronics [9, 50, 57, 58]. By diversity, a broad term, we refer to researchers' goals to specifically increase gender and race diversity among participants. Sewing is a common skill required for e-textile projects and has the added benefit of leveling the playing field across genders because sewing focused projects disguise the male-dominated technology [63]. Commercial toolkits encourage people to sew conductive thread to form electrical connections between components. Buechley et al. [8]

[2]https://www.adafruit.com/category/92

showed how this blending of skills supported diverse groups to build with LilyPad Arduino. Rode et al. [54] used LilyPad to show how it can support computational thinking using crafting skills, which they broadly called computational making. Researchers used quilting projects to connect with youth of color and better understand their needs around learning computer science [57]. We build on this work to support older adults, another diverse group, to electronically make through crafting.

Crafting experts have shared their expertise with maker electronics researchers, expanding both the experts' skills as well as the possibilities of what people can create. Researchers have worked alongside various experts in sewing [28], ceramics [65], silversmithing [60], and weaving [13] to learn from these experts and help them integrate maker electronics into their crafts. This has even included working with quilters to better understand how to connect computer science education and quilting through overlapping analogies [47]. Working with craftspeople, especially early in the process, can lead to innovations while centering them as expert collaborators [13]. We follow in this vein by working with expert older adult fabric-based crafters to see how their expertise can benefit the design of e-textiles.

2.2 Older Adults and Electronic Making

Researchers recently studied older adult-specific makerspaces, which have been growing in popularity as a way to engage a new generation of people in making. Researchers highlighted the importance of offering both high-tech (e.g., 3D printing, embroidery machines) and low-tech (e.g., sewing, button making) tools to appeal to older adults with different technical skill levels [10, 39]. Carucci et al. [10] ran a makerspace in a long-term care facility, filling it with both high-tech and low-tech tools, which improved residents' agency and helped them feel empowered to solve everyday problems. Lazar et al. [39] studied members of an independent living community collaborating on the formation of an older adult makerspace, finding the inclusion of high and low-tech tools gave residents different entry points to making. We look to build on this work by bridging "low-tech" making with "high-tech" making through the combination of crafting and electronic making.

Electronic toolkits are one way researchers involved older adults in the technology design process, often through participatory design and co-design. As we previously highlighted, electronic toolkits have an advantage of being adaptable to a particular group of people. Researchers used both commercial [55] and custom [1, 26] toolkits with older adults to engage them in the design process. Rogers et al. [55] used the commercial MaKey MaKey toolkit in a participatory design workshop to investigate older adults ideas for future technology. The IoT Un-kit [1] was an electronic toolkit designed for older adults to engage with designing new internet of things technologies in the home, but the research team handled setting up the technology for participants. Craftec [26] specifically designed a craft-based toolkit for older adults to create with electronics, but accounted for both toolkits for hard and soft mediums. We build on this work by helping older adult crafters to create with unmodified electronic components, informing how toolkits could be better designed to support novices.

3 METHODS

We remotely co-designed a craft project that integrates maker electronics with 6 older adult crafters. Through co-design, we worked with individual older adult crafters in an equal partnership where we blended their crafting expertise with our maker electronics expertise. The hands-on project offered them a chance to test out electronics in a project of their choice, allowing them to experiment with new skills and give feedback on how to improve electronic making.

We conducted the individual co-design workshop remotely over the course of one 30 minute setup session and four 100 minute design sessions for a total of 45 hours[3]. Conducting it remotely was a necessity of the COVID-19 pandemic, since we conducted it over February and March 2021 prior to vaccinations being widely available. We delivered equipment and supplies to participants before starting sessions with participants to ensure we both had equal access to the same materials. This study was approved by Indiana University's Institutional Review Board (IRB).

3.1 Participants

We recruited 6 older adult crafters for the co-design workshop (Table 1). Older adult crafter participants were over 65 years old, had an internet connection, and owned a device for Zoom calls to participate. For this study, we recruited crafters that created with fiber-based materials, such as fabric, thread, and yarn, to align more closely with e-textile projects. Participants were recruited primarily from a non-profit local organization of about 200 quilters who meet monthly. We gave a short presentation to the guild and posted on their Facebook group page, which included both members and non-members. Final selections of eligible participants were based on (1) living within a reasonable drive of the first author to simplify delivering supplies and (2) selecting for participants who would add to the diversity of both craft and years of experience. Participants were all white, non-Hispanic and identified as women. Each was compensated with $10 for the setup session and $25 per full session, for a total of $110 USD.

3.2 Preparing and Delivering Supplies

We prepared boxes of all study supplies for each participant to collaborate remotely with the same materials. Supplies, including input sensors (e.g., light and touch sensors) and outputs (e.g., LEDs and vibration boards) were carefully grouped into color coded bags based on session activities as shown in Figure 2. We delivered study supply boxes to participants by following best practices at that time for protecting against COVID-19 for at risk people – minimizing contact, disinfecting surfaces[4], remaining outdoors, and wearing masks.

Setup Session. Before starting the co-design sessions, participants individually joined a 30-minute Zoom call to practice the collaborative whiteboard, Miro[5], and walked through a personalized password-protected website we created that acted as a resource hub of workshop materials. We ended by giving them homework

[3] P6 required an extra design session.
[4] Near the end of the study, disinfecting surfaces was removed as a best practice from national authorities, but we continued following it due to an abundance of caution
[5] https://miro.com/

Table 1: Participant Demographics and Crafting Expertise. The craft in bold is participants' most frequent craft. Participants' years of experience is copied verbatim.

ID	Age	Education Level	Crafts	Experience Level	Years Exp.
P1	72	PhD	**Quilting**	Intermediate	25+
			Sewing	Intermediate	65+
P2	67	BS	Crochet	Expert	46
			Cross-stitching	Expert	50+
			Quilting	Advanced	40
P3	66	MS	**Quilting**	Advanced	15
			Sewing	Intermediate	58
P4	77	MS	Bead Embroidery	Advanced	10
			Quilting	Intermediate	35
			Sewing	Intermediate	65
P5	66	MS	Cross-stitching	Advanced	15
			Quilting	Advanced	10
			Sewing	Intermediate	25
P6	75	MS	Free Stitching	Expert	10
			Painting	Expert	60
			Quilting	Expert	35

(a) All Components Included in the Boxes (b) Bagged Components

Figure 2: All of the components included in the boxes, both in an unbagged (a) and bagged (b) state.

to prepare examples of their crafts to show and tell in Session 1 (Figure 3).

3.3 General Session Format

Sessions 1-4 followed a consistent format (Figure 3) – we discussed the homework from the previous session and fixed any issues (e.g., a circuit did not work). We then completed 2-3 activities specific to that session. We ended most sessions with a description of the homework and an interview, where we asked for feedback on the day and made connections to their practices and expertise. In the following section, we outline the unique activities from each session.

3.4 Session 1: Intro and Craft Practices

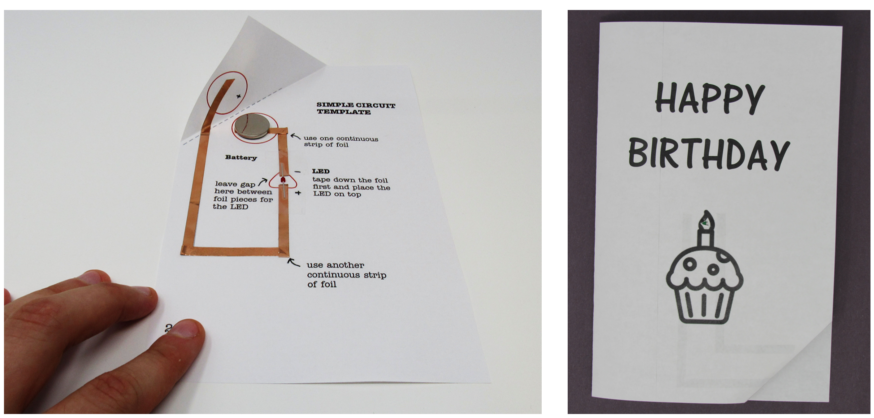
The first session focused on introducing participants to the study and establishing their crafting practices. We described the study, administered a pre-survey, and conducted a show and tell activity.

The pre-survey included questions about demographics, their craft experience, and the modified Computer Self Efficacy (mCSE) questionnaire [37] which formally measured how confident they felt about creating with a hypothetical electronic toolkit that facilitated project creation.

Next, we had a *show and tell* activity, common in crafting workshops, to establish participants' crafting practices. Participants shared examples of what they regularly craft. We then asked several

Setup Session		Session 1: Intro and Craft Practices		Session 2: Scaffolded Activities and E-Textiles		Session 3: Project Planning		Session 4: Prototype and Challenges	
Activity	Min	Activity	Min	Activity	Min	Activity	Min	Activity	Min
Informed Consent;	10	Study intro;	5	Review Homework;	10	Discuss homework;	15	**Prototype exploration**;	35
		Pre-survey;	10	**Toolkit activities**;	20	Toolkit connections;	25		
Zoom and Miro setup;	20							Toolkit connections;	15
		Craft show and tell;	20	Interview "survey";	15	(Break)	10		
								(Break)	10
Homework;	1	**Crafting Practices**;	20	(Break)	10	**Brainstorm project ideas**;	35		
								Toolkit challenges;	25
		(Break)	10	**E-Textiles Presentation**;	30			- Abstractions discussion (If Time);	(10)
						Homework;	5		
		Paper circuits;	20						
				Homework;	5	Interview	10		
		Homework;	5					Post-survey;	5
				Interview	10				
		Interview	10					Interview	10
Total	31	Total	100	Total	100	Total	100	Total	100
Homework: Items for Show and Tell		Homework: Paper Circuit Birthday Card		Homework: E-textile Circuit		Homework: Prototype		Homework: N/A	
Day 1		Day 2		Day 4		Day 6		Day 10	

Figure 3: Overview of the co-design workshop with lengths of each portion listed in minutes. The bold portions are the key activities in each session.

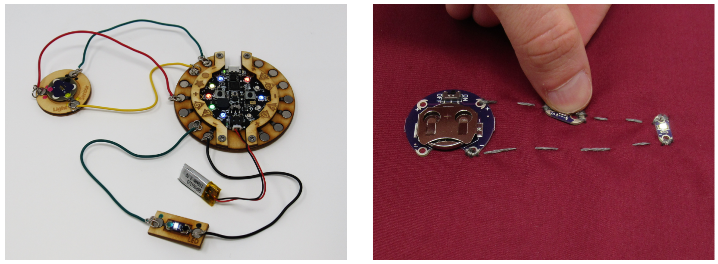


(a) Paper Circuit (b) Birthday Card Template

Figure 4: Paper circuit activities. (a) Example paper circuit we created using a paper template from Qi et al.'s Circuit Sticker Notebook [52] with copper tape, a battery, LED, and cellophane tape. (b) Birthday card template for Session 1 Homework.

questions about their crafting practices to help qualitatively categorize them along the "planner" (i.e., step-by-step, pattern following, process-oriented thinking, similar to computational thinking [64]) or "improviser" (i.e., on-the-fly, situated thinking [59]) spectrum of crafting.

Finally, we introduced participants to maker electronics and built up their familiarity with them through scaffolded activities. We discussed the key concepts for the paper circuits activity, which included circuits, polarity, and positive/negative, before building a paper circuit (Figure 4(a)) based on a printed template from Chibitronics [52].



(a) Toolkit Activity (b) E-textile Homework Project

Figure 5: Session 2 activities with a toolkit and e-textile components. (a) Toolkit activity with a toolkit similar to Craftec's [26] toolkit for older adults. (b) Researcher's copy of the e-textile homework project using LilyPad Arduino components, including a coin cell battery holder, conductive thread, LilyPad button, and LilyPad LED. As the button is pressed down, the light turns on.

For homework, participants created a light up card using their paper circuit skills. We provided a template for a Happy Birthday card (Figure 4(b)), and suggested that they light up the tip of the candle.

3.5 Session 2: Scaffolded Activities and E-Textiles

The second session continued scaffolded activities by introducing participants to e-textiles. Participants explored electronic making using a toolkit similar to Craftec [26], a toolkit designed to support older adults to craft with electronics (Figure 5(a)) by exploring input and output concepts.

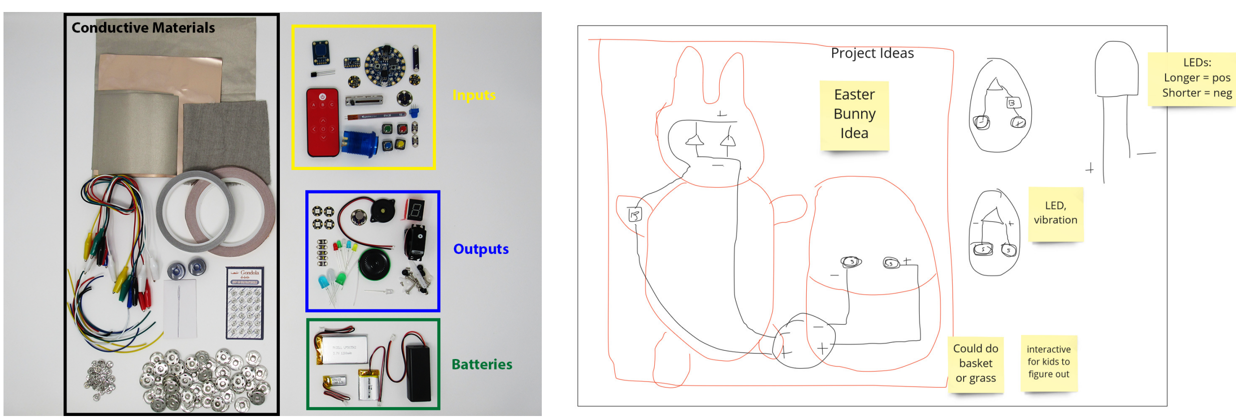
We introduced e-textiles by sharing examples so participants could see the possibilities while finding inspiration for projects and preparing them for their homework.

For homework, participants made a simple e-textiles circuit with a battery source, button, and LED, using step-by-step directions and provided supplies (Figure 5(b)). This gave participants practice building with electronics using familiar sewing skills. We taught about short circuits to ensure they did not cross any threads and create a fire hazard.

3.6 Session 3: Project Planning

In Session 3, we focused on integrating electronics into their craft by planning a project for them to complete.

We reviewed study materials that could be connections. This built on their e-textile homework experience while exploring possibilities beyond conductive thread (e.g., metal snaps). We co-designed the e-textile project each of us would prototype for homework before Session 4. Many participants already expressed ideas for what they might make, so the first author recapped those options before brainstorming more. Participants' prototypes were co-designed to avoid needing programming and instead relied on disrupting connections (e.g., a button) to control outputs. We discussed which components would be good to include in a project and diagrammed the project in Miro, including a circuit diagram from the researcher (Figure 6(b)).



(a) All Components in the Boxes (b) P2's Miro Board Example

Figure 6: Supplies and Miro Board from Session 3. (a) All of the components in the boxes. The components are sorted into conductive materials (left), inputs (top right), outputs (middle right), and batteries (bottom right). (b) Miro board drawing with circuit diagram from P2's Easter Bunny Interactive project.

For homework, we both reviewed the medium-fidelity prototype we brainstormed together and used supplies to build it. Both participants and researchers used additional materials on hand for crafting projects, such as fabric. Participants were encouraged to work on their own, but they could ask the researcher questions. Participants were encouraged to spend as much time as they wished, but the first author spent 4-6 hours per project.

3.7 Session 4: Prototype and Challenges

The goal for the final session was to discuss our prototypes and co-design solutions for common issues.

We started by helping participants troubleshoot issues with their project as needed, and then shared what each of us prototyped, including discussing challenges participants had with their design.

Next, we discussed how we could make improvements on the process of creating their prototypes and the prototypes themselves. We revisited the challenges they faced throughout the workshop, as well as six common issues researchers experience when working with e-textiles and electronic toolkits (e.g., preventing short circuits [26]).

We concluded with a post-survey, which included the mCSE [37], and conducted the wrap up interview.

3.8 Analysis

We analyzed the qualitative data first through an inductive, bottom-up approach, and then a deductive, top-down approach [5]. During each session, research notes were taken. Within 24 hours, the first author reviewed these notes, annotated them, and used them to identify potential areas for customizing the workshop for each participant. Later, we systematically analyzed the data using an inductive approach by re-watching each session's recording while reviewing and further annotating the researcher notes, the Miro boards, and pictures of study artifacts captured afterwards[6]. The first author then reviewed and annotated the transcripts, taking a deductive approach by focusing on emergent themes from the bottom-up approach. Throughout this process, three authors reviewed the analysis to form agreement around the final results. Furthermore, we compared the prototypes participants and researchers each built in two ways – comparing what they made and what researcher made, as well as comparing across participants.

Determining the Planner-Improviser Style Spectrum. The planner vs. improviser spectrum was a research question the first author had developed before this study through observing and participating in crafting sessions with older adult crafters. Crafters who plan rely heavily on developing a course of action early in the process and then follow it with only a few deviations. A planning style of crafting aligns well with computational thinking [64] – both involve heavy planning, abstract thinking in patterns, and problem solving. On the other hand, people who improvise take action quickly, making decisions as they go without laying out several next steps. Improvisers are more akin to Suchman's work on situated action [59], in how they respond to the current state as they work. Some crafters took actions that fell along the middle of the spectrum and had one primary style, but included elements of the other. For example, a crafter who leaned towards the planning end of the spectrum would often plan ahead, but occasionally be struck by inspiration to think on-the-fly as they create.

To determine where participants fell along the spectrum, we used responses to questions about participants' crafting and our analysis of the data to confirm those decisions. We asked them to self-describe their style, their crafting process, their planning process if they had one, how they solved problems, and their motivation for why they craft. We concluded by asking participants their opinion of where their style was along the Planner-Improviser Spectrum. Later, we analyzed where they fell by considering their self-description and looking for similarities across participants that aligned with the core descriptions for planning and improvising.

[6]P4's Session 4 did not record in Zoom due to an issue. The first author spent additional time capturing notes immediately after the study ended to capture as much detail as possible.

3.9 Researcher Demographics and Positionality Statement: A Male Planner Style Crafter

The first author, who solely interacted with participants, was a 30 year old man and approached crafting as a beginner quilter along the planner end of the spectrum. The first author built co-design relationships with participants during the study. Age and gender differences may have impacted our co-design partnerships, such as participants deferring on some technical decisions not only because of the author's expertise, but also because of age and gender stereotypes. The first author's primary craft is quilting for the previous 5 years. He had a fair understanding of the terminology and practices of quilters, but little familiarity with other crafts. For style, he is on the far end of the planner spectrum – he approaches projects methodically and plans ahead of time. He typically did not deviate from his plan. He worked to remain neutral and operate with an open mind, but this may have impacted both the design and analysis of this co-design workshop as the author may have geared it more towards participants who plan. The first author mitigated this tension by reviewing his study plans with two co-authors.

3.10 Limitations

Our work is limited based on the population we recruited – participants were well-educated, identified as white and not Hispanic, and had the resources to have an internet connected device with internet access. Representation is an important issue within HCI we must continue to make progress towards to avoid only representing those who are more privileged.

4 FINDINGS

The co-design workshop was an opportunity to explore how older adult crafters would approach e-textile projects and draw insights for e-textile toolkit designs. We co-designed medium-fidelity e-textile prototypes with participants. We compared these prototypes and collected insights from participants about how to best support older adult crafters to create with maker electronics. Through this study, we learned about how they approached crafting their e-textile prototypes and their insights for supporting novice older adults to craft e-textile projects.

4.1 Crafting E-textile Prototypes

Participants' prototypes gave them the chance to experiment with maker electronics. In this section, we provide a brief description of the other prototypes and highlight two examples of prototypes which demonstrate varying approaches to crafting with e-textiles (see subsection 4.3 which goes into depth on the Planner-Improviser Spectrum). For more details on all prototypes, see Appendix C.

Participants made e-textile projects that demonstrated their exploration of what they could create (Figure 7). P1 and the first author built a "Snap-a-zoo" (Figure 7(a)), a children's toy that could be snapped together to make various animals, such as a walrus or elephant. P2's Easter Bunny Interactive Children's Toy (Figure 7(b)) built on her quilting experience, particularly her use of appliqué techniques, which is a method for pasting or gluing fabric shapes on top of other fabric. P3's Removable Interactive Lap Quilt for Children with Developmental Disabilities (Figure 7(c)) built on her experience as a special needs educator and extensive knowledge of quilting and sewing projects, especially given her work as a part-time employee of a local quilt shop. P4 crafted a Magic Question Answering Hat as a potential Halloween costume for her community's Costume Contest (Figure 7(d)). She sewed the hat from scratch since it was too risky to go purchase one at the time. P5 typically crafted small sewn projects and quilts, which was reflected in her choice to light up a video game "panel" – a piece of fabric with a pre-printed design on it – for her Video Game Wall Hanging (Figure 7(h)). Wall hangings are art pieces usually hung on the wall to be enjoyed, but not touched. P6's Light Up Memorial used a bullet casing from a friend's gun salute[7] at their funeral to create a memorial for them (Figure 7(i)).

Participants on the planning end of the spectrum (P1-P4) followed the co-designed plan, while participants who improvised (P5, P6) altered our co-designed plan as they crafted (Figure 7). The researcher, more on the planning end of the spectrum, stuck more closely to the plan compared to the crafters who improvised. Thus, the improviser projects are just as well crafted as the planners but noticeably different compared to the researchers. The researcher worked to reflect the craft and interests of improvisers in their prototype.

4.1.1 *Detailed Planner Style Prototype: The Magic Question Answering Hat.*

P4, a planner style crafter, was an expert in making clothes and costumes. We co-designed a Magic Question Answering Hat (Figure 8(b)), which she would use to answer any yes/no question by lighting up an LED under a yes or no on the hat. We planned to have the yes or no be controlled by different button switches[8] (Figure 8(a)). P4 followed the plan closely, crafting "yes" and "no" labels, and placing buttons on detachable straps to stick in sleeves of a shirt to control the LEDs. She made her hat from scratch since she did not have one available and it was not safe to shop for one. The researcher decided to add slightly more complexity to the prototype by using three color changing LEDs for yes, no, and "?" when the wearer was ready for a new question. A slide potentiometer controlled which lit up instead of buttons. P4's prototype worked flawlessly without needing any troubleshooting help from the researcher. Her main challenge was with planning the *"order of operations"* given she had to sew the components on a 2D surface initially and then sew it into a 3D hat.

4.1.2 *Detailed Improviser Style Prototype: Light Up Memorial.*

P6, an improviser style crafter, often crafted fabric-based visual arts. Her Light Up Memorial (Figure 9(b)) drew on this approach when she used the bullet casing as a conductive materials used as a single source of power for a ring of LEDs that was controlled by a button. We originally co-designed a different project in Session 3 – she planned to make a representation of Zoom screens with LEDs lighting up different areas, but P6 expressed she would likely change her mind after she explored the materials in the box more. P6 attempted the Zoom LED project but had difficulties in designing and crafting it – she tried to reuse the toolkit from the earlier activity instead of the components we discussed, and she misunderstood that the toolkit was pre-programmed to require a sensor – so we decided to rerun Session 3. We then co-designed a new project with the bullet casing, which she followed closely (Figure 9(a)). The researcher altered the researcher prototype in response to her uncertainty about the Zoom project and her interest in more of the box's materials – the first author made a Color Changing Swirl, which was inspired by P6's use of indigo swirls she shared in Session 1. The prototype had a color sensor on the back, which set the color of the LEDs on the Circuit Playground Express and two color changing LEDs. These LEDs were animated to blink in a spiral effect. Although we did not create the same project, we both expressed an admiration for what each other had prototyped. P6's prototype worked without any issues.

4.2 Electronic Toolkit Insights: Drawing on Older Adult Crafters' Workshop Experiences

The workshop activities provided opportunities for participants and the first author to discuss possible design considerations for crafting with e-textile materials, including conversations about possible electronic toolkit designs. These insights were drawn from participants' activity experiences, their feedback, and our conversations about the design space. We offer three key themes from the results – (1) select materials with familiarity in mind, (2) support aesthetic goals, and (3) make crafting with electronics attainable.

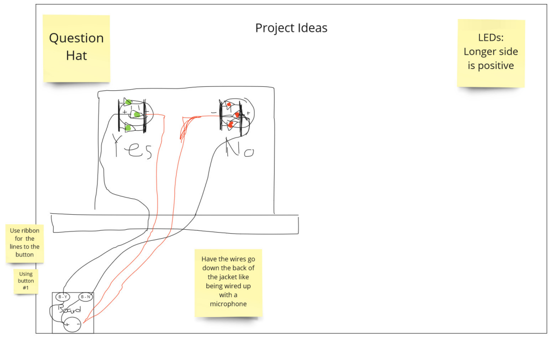
4.2.1 *Theme 1: Select Materials with Familiarity in Mind.*

Crafters looked to find the intersection of their craft and electronics to build on what they knew already. Participants could brainstorm anything they wanted to, but they all built prototypes that riffed on something they had made previously or that clearly aligned with their skill set. For example, P1 discussed snaps, which she had experience with, as a possible conductive material for connections, inspiring her to suggest prototyping the snap heavy Snap-a-zoo and add in LEDs. P4 had extensive sewing experience including making costumes, so she did not have any issues with sewing together her Magic Question Answering Hat, even though she had never made a hat before. Some participants shied away from materials that were unfamiliar to crafting projects, such as visible wires. P3

[7] A gun salute is a ceremonial practice typically found in the armed forces where guns or cannons are shot to honor a dignitary, such as the leader of a country. Some armed forces provide one to honor veterans at their funerals.

[8] Her prototype, like all participants' prototypes, did not require programming. She used two separately powered circuits that could be closed by a button.

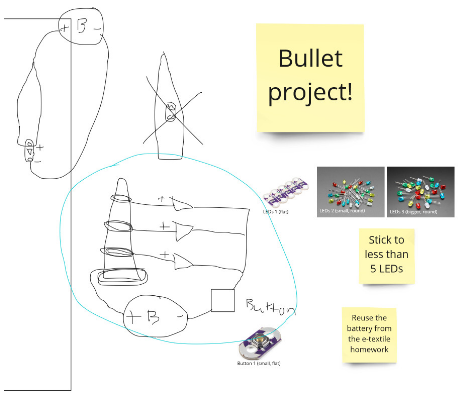
Figure 7: Prototypes made by participants and the first author for Session 4. These prototypes gave participants a chance to explore creating with electronics. For more detailed descriptions, see below for P4 and P6, or see Appendix C for the rest.



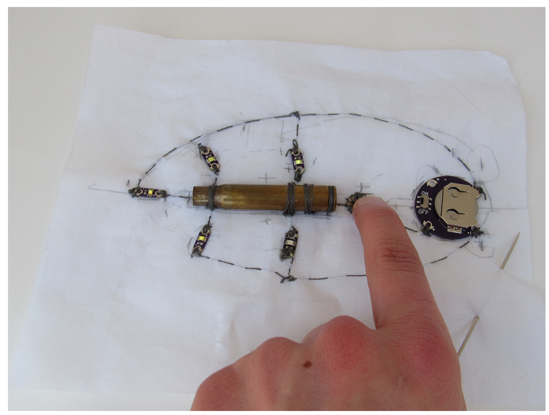
(a) P4: Prototype Plan

(b) P4: Participant's Completed Prototype

Figure 8: P4's Magic Question Answering Hat. We diagrammed the prototype plan (a) and P4 created the resulting prototype (b).



(a) P6: Prototype Plan



(b) P6: Completed Participant Prototype

Figure 9: P6's Light Up Memorial. We diagrammed the prototype plan in the second run of Session 3 (a) and P6 created the resulting prototype (b).

wanted to make sure children felt the vibration in her prototype, but she declined our suggestion to use a larger vibration board for her project because she, *"...wouldn't have to worry about the red and black wires."*

In some cases, past experience using certain kinds of materials could pose challenges when familiar materials were used in unexpected ways. For example, all six participants expressed confusion about conductive fabric because it did not fit their typical mental model for how they use fabric in their craft. Fabric is often a base everything is built on, so it was not clear how to safely channel electricity if it could go anywhere. Participants had less confusion with conductive thread, and often chose it over other options. In one session, P2 explained that she did not think about using conductive ribbon for a particular application where it may have been more suitable than the conductive thread, noting, *"I'm used to thread."* But having thread function as an electronic material led P2 and P5 to have concerns about continuity of the thread. P5 came to Session 4 asking, *"I wondered if I run out of a thread, can I just tie off and keep going or does it have to literally be the same piece of thread? I don't have an answer for that."* Normally, crafters could restitch over an area to resume sewing an area, but with conductive thread, some assumed they had to completely tear it out if a line of thread was too short or broke.

Participants suggested that we select training and practice activities to help blend their crafting practices to more easily create with electronics. Trying out a fabric for a project is part of many crafters' process of creating. Both P2 and P6 suggested being able to test their prototypes before they started sewing them down. P2, a planner style participant, wanted to plan out components early to visualize where they would be. Conversely, P6, an improviser style participant, wanted to "audition" components and materials to learn more about how they worked as she explored them. Participants also suggested more activities to scaffold learning and build up their familiarity with the materials as they crafted a prototype. P1 suggested an intermediate step between the e-textile homework and prototype that included more examples with challenges to push crafters to try new skills, such as hiding the components behind the fabric.

4.2.2 *Theme 2: Support Aesthetic Goals.* Older adult crafters highlighted the importance of supporting aesthetic goals in their projects. Every participant hid electronics (i.e., components and batteries) on the back of their prototype (P1, P2, P4, P5, P6) or inside of a pocket (P3), even though we did not ask them to do so. P5, when describing her Wall Hanging prototype in Session 4, explained, *"...but then, of course, I went a step further and I wanted the battery to be on the back so it was hidden."* P1, P3, and P4 decided to use conductive tape rather than conductive thread to prevent the hand-sewn thread from showing through on the front. P1 mentioned *"I chose to use the white [conductive] tape because this particular project really doesn't want to have stitches showing on the exterior, so using the gray [conductive] thread would have meant showing stitches or putting another piece of fabric in the middle that I would use the stitches through and then sealing it up."*

While some electronic components were hidden to preserve aesthetics, participants envisioned the use of electronics as providing an aesthetic purpose, such as adding eye catching fabric to a project. P2, P3, and P5 suggested using several components to add attention drawing features to a project. P3 suggested electronics could be a material that provides "movement" to draw people's eyes – *"...you could take little bitty lights or sound things and add them to fabric art and give them movement or give them life, because we talk in quilting about something's flat or everybody wants your quilt to have movement, and that means your eye moves around it."*

Participants carefully selected materials so that the aesthetics of their project could match the purpose. This was most evident in crafters' choices of LED lights (Figure 10). P6 chose LilyPad Arduino (LPA) LEDs for her Light Up Memorial prototype, explaining that bulb-style LEDs seemed too childish given the context of her memorial piece. Three participants (P1, P2, P3), who all made prototypes meant for children, took efforts to make them more playful by using the brightly colored bulb LEDs and buttons. P3 also noted that the brightly colored buttons make an engaging noise, *"Actually, I think [the brightly colored button] is going to be perfect, because it also makes a satisfying clicking sound."*

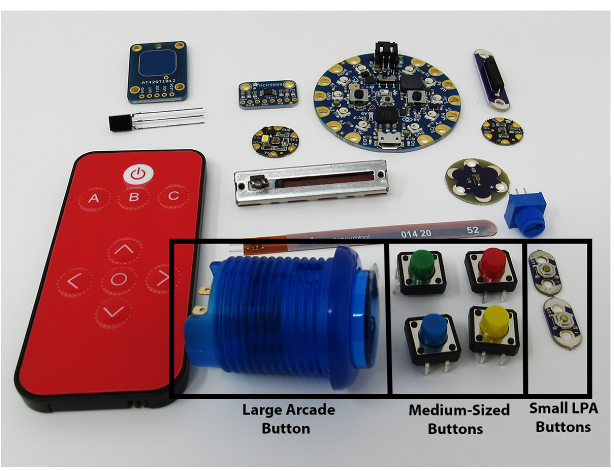


Figure 10: All three button options highlighted with the rest of the input components.

4.2.3 *Theme 3: Make Crafting with Electronics Attainable.* Older adult crafters found crafting with electronics more difficult with far more to learn than they expected. P2 and P3 both commented how creating something with electronics was deceptively difficult.

> *"[Crafting with electronics is] harder, I think, than most people would think it would be. Basically if you were to teach a class on it, you probably would have everything put together and they would just have to set it up, so to speak, like a day class, or they'd have to do the wiring bit... I look at that stuff in that box, it's like, 'I have no idea what that stuff is,' and that's okay because I have learned a bunch of stuff..."* – P3

P3 and P6 commented that it felt like the workshop activities were merely the tip of the iceberg, while P4, P5, and P6 wanted to know more about all of the supplies in the box, but the researchers' intention was never to go through every item in box, only to have every component safely on hand since we were co-creating remotely during a pandemic.

Participants noticed how electronics require more precision than crafting. P5 and P6 (both crafters who improvise) pointed out how crafting is very forgiving – there is a broad spectrum of how "good" something is – but electronics is not forgiving at all – there is a hard cut off of whether it worked that makes crafting with electronics less approachable. Similarly, P4 and P5 noted how creating with electronics requires more precision compared to crafting, *"I would say one thing that some precision is needed because if you don't connect the stuff in the right spots, nothing is going to happen."*

Participants suggested improvements specific to crafting with electronics that would make it easier for older adults, such as making electronics more accessible to see and to sew. P1, P5, and P6 proposed including a magnifying glass as a part of the supplies to help with any vision challenges. P6 explained, *"These [components] are really tiny. I talked to you about how it was hard to read positive or negative. I kept my magnifying glass out so I'd be sure I got it right every time making those differences."* P5 and P6 suggested making the pieces bigger in general to make them easier to work with. For example, the tiny on/off switch on the LPA battery holder was so small that P6 could neither see nor easily switch it, so she relied on trying her prototype with it switched one way, then the other until it worked. Larger pieces would also allow for larger fonts for any names or directions printed on the pieces, which P4 recommended. P3 and P5 suggested using colors to indicate where to make connections without needing to rely on labels. P3 explained, *"The plus and minus poles of any of these objects could be in different colors, ...it would be even more obvious, and I wouldn't need my magnifying glass."* Lastly, P4 encouraged choosing conductive materials and needles that were easy to push through by hand to make sewing conductive circuits easier. When we suggested possibly using a sewing machine, she felt reluctant to do so since sewing machines are such a precious tool that are increasingly difficult to repair if they break.

The design of the components and materials could also be improved to make them easier for a crafter of any age wanting to create with electronics. Names and directions on the pieces could better help people identify components and what they do (P4). P1, P2, and P3 preferred the medium-sized button for their projects,

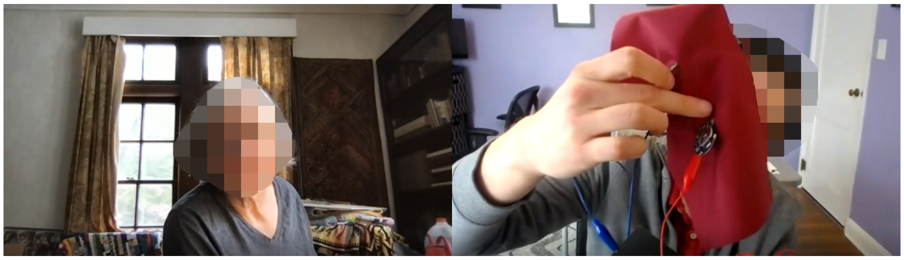


Figure 11: We demonstrated to P6 how to make a conductivity tester out of alligator clips and the e-textile homework, which she then recreated to test the conductivity of the bullet casing.

which was larger but more intuitive to use than the LPA button with its common button appearance, but smaller than the large arcade button (Figure 10). Additionally, P5 owned some multicolored embroidery thread and suggested using colored conductive thread to make it visually clear that you were not sewing a short circuit, such as having red for all positive threads and black for all negative threads.

Video recordings and a glossary of terms would also help participants more easily create and learn to craft with electronics. P1, P2, P3 P3 explained her use of videos when learning something new, *"YouTube is my friend. I will sit and watch YouTube over and over and over. That's the best thing because you can stop it, and go back and stop it..."* Similarly, P6 suggested offering YouTube videos with each of the activities so she could follow along with it while she synchronously worked on her circuits, *"If I were to get something, some little kit like this, I would very much like to go to a YouTube video and watch it because I could see while I was doing it."* Half of the participants (P2, P4, P5) talked about needing to learn the terms as they were learning to craft with electronics. P6 suggested offering a glossary so older adult crafters could search in other places for help resources, such as knowing that negative and ground are synonyms.

Participants suggested adding tools and training options to help them recover from mistakes, making electronics more approachable. P4's husband conveniently had a multimeter to test the conductivity of a metallic New Year's Eve hat, which they found conducted electricity, so she could not use it for her hat prototype. Without a multimeter, the researcher brainstormed a way to test malfunctioning circuits with alligator clips by connecting alligator clips directly to the LPA battery holder terminals and the component in question (Figure 11). Alligator clips helped P1 and P6 resolve problems they had, but P5's difficulties still required seeing it in person before we could determine she had too many LEDs connected. P5 wished she had training on starting simple, then adding more LEDs as it worked.

4.3 Understanding Crafters' Practices: Planner-Improviser Style Spectrum

We found that participants differed with regards to the way they approached crafting, and these differences carried over to their approach to e-textile projects. We qualify these differences along a Planner-Improviser Spectrum (Figure 12). The four participants

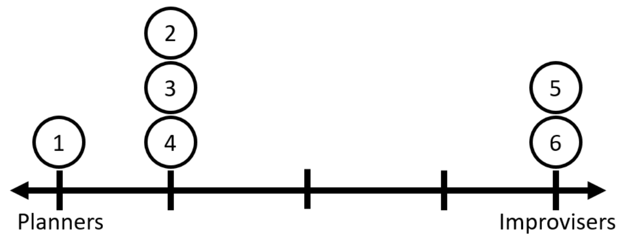


Figure 12: The style spectrum with participants placed along it.

who more closely aligned with a *planning* style planned several steps ahead and often followed patterns. They also did not tend to deviate much from their set plans until they were forced to (e.g., they ran out of fabric) – both in their crafts and their e-textile projects. Conversely, the two participants who *improvised* made decisions as they crafted and often looked to find inspiration or ideas for their crafts, akin to the ways that hobbyist jewelers design with "serendipitous discovery" [12]. They frequently adapted as they went, making changes or exploring possibilities as the project developed, which carried over into their e-textile projects as well. We highlight these different approaches to similar tasks, because they can impact how toolkit designers support crafters to work with e-textile toolkits.

Training materials, such as step-by-step directions, supported participants to create, but not always in the same way. The planners followed them closely, especially when they were looking for guided troubleshooting help. Improvisers, instead, explored completing their activities first before returning to the directions for help if they were having issues. For example, P6 informed us she tried to complete the e-textile homework initially, but had to revisit the directions when it did not work right away – *"Before I read actually, in your directions, I kind of skimmed around thinking 'Oh, yeah, I know what I'm doing let's go try this.' Then when it doesn't work, I go back and read them very carefully. Probably most people don't like [to do it that way]."*

4.3.1 *Planner Style Similarities.*

Though planners shared the traits described above, they varied along the planning-improvising spectrum. P1 sewed for her craft, including quilting, and exclusively approached her craft as a planner by planning heavily before each project and not deviating much once the plan was set, noting how she sticks *"... pretty close to [a plan] unless there's a problem."* P2, P3, and P4 all leaned towards planning, but still approached some situations as an improviser by sometimes adapting plans. For example, P3 often spent time looking ahead to envision what the outcome was going to be if she continued down a particular path. However, she sometimes adapted, *"I'm not opposed [to not following a plan], though, to doing something and realizing, 'Hmm, I could do it this way,' and ripping it out and doing something different."* We saw this with her prototype after Session 3 when we re-solidified the plan several times over e-mail.

Planners were cautious in how they approached the workshop activities and troubleshot more methodically than those who improvised. P2 and P3's caution showed during the description of Session 2's e-textile homework where we first addressed the safety concerns about potentially catching the project on fire. They were quite worried about short-circuiting connections, especially P3, whose father was an electrician and instilled in her a strong respect of electricity. By Session 4, she said *"...You've got me convinced I'm going to catch everything on fire."* P2 often came to homework review sessions with partially-finished projects because she had questions or concerns when something was not listed in the directions. For example, she came to Session 3 with unknotted conductive thread connecting her components since she was unsure whether knotting would damage the connections between components. Planner style crafters' caution was apparent in their prototypes, too, since they used only 1-3 outputs, compared to the 5 and 13 components of participants who improvised.

Participants who planned were more methodical about troubleshooting issues with their homework, carefully describing their thought process for how they would resolve it. For example, P1 came to Session 3 with a list of all the steps she took to figure out why her e-textile homework worked initially and then stopped working (Figure 13). Eventually, she resewed the circuit to get it working, but we were unable to determine exactly why it failed. Similarly, P2 and P4 ran into issues sewing the incorrect connections on their prototype and e-textile homework respectively, but they were able to quickly identify the connection issue and re-sew it.

4.3.2 Improviser Style Similarities. The participants who improvised, P5 and P6, were on the far end of the improviser spectrum, often diving right into a project with only a rough idea and adapting as they explored options. Both changed their minds about the co-design project to make something else and also expressed some dislike for patterns – P6 described her work as art quilting, which she defined as *"...it shouldn't be something that somebody else has done before. It shouldn't be from a pattern."*

Participants on the improviser end of the style spectrum were slower to agree on a co-designed prototype and troubleshot through trial and error. P5 and P6 wanted to spend more time brainstorming prototype designs in Session 3 compared to those who planned. For P5, she could not decide because all of the options we brainstormed sounded great to her, so we had to slowly narrow our ideas. We discussed lighting up a needle-point tree, recreating a color-changing scarf that we showed as an example in Session 2, quilts in general, and adding stars to a painting. We then narrowed down to focusing

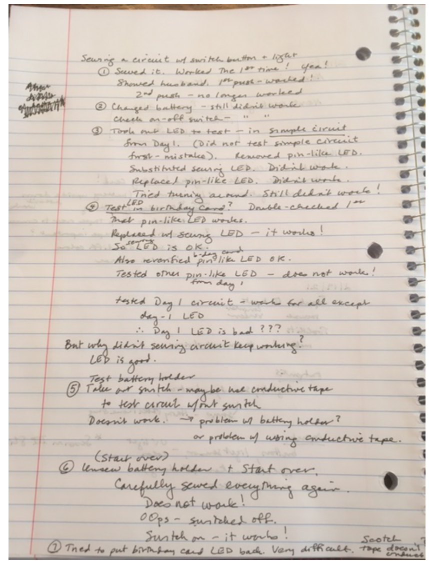


Figure 13: P1's list of all the steps she took to figure out why her e-textile circuit (Session 2's Homework) stopped working.

on a quilt with a pre-printed design – first Christmas, then eventually settling in on a videogame pre-printed design. Similarly, P6 did not want to stop exploring component options as we were brainstorming and kept trying to integrate new components that we had not talked about yet. Improvisers' approach further showed in their prototypes, which were quite different than we had co-designed in Session 3. P6 explained in Session 3, *"I usually think after I start making things."* P5 and P6 troubleshot primarily through trial and error, and often ending up redoing the circuit completely when nothing seemed to work. For example, P5 had difficulties with her videogame quilt prototype, which she wanted to light up with LEDs (Figure 7(i)). She tried several different combinations of LED lights, methods for connecting components, and fabrics, but she tore it out and redid it several times – *"I tried every permutation I could think of."* Ultimately, it did not turn on, and she was disappointed.

5 DISCUSSION

Our study investigated co-designing e-textile projects with expert older adult crafters and what that means for designing e-textile toolkits for older adult crafters. Key to this project was the crafters' expertise in planning and executing crafting projects, working around barriers and unexpected outcomes, working with materials and tools, as well as their aesthetic sensitivities. Their expertise was valuable since crafters' expertise and involvement early in the design process broadens the design space and includes these experts as technical collaborators [13].

5.1 Advancing E-textile Toolkits to Support Older Adult Crafters to Craft with Electronics

Older adult crafters' experiences crafting co-designed e-textile projects in our workshop advances the design of e-textile toolkits to better support people to create with these tools. In particular, the three electronic toolkit themes – (T1) select materials with familiarity in mind, (T2) support aesthetic goals, (T3) make crafting with electronics attainable – add structure to the lessons toolkit designers can take away.

To select materials with familiarity in mind (T1), we first call for a return back towards soft toolkits, where many of the materials are familiar, fabric compatible, and can easily integrate in with e-textile projects. Leah Buechley's original LilyPad Arduino (LPA) was created with layers of felt containing electronic components, but LPA was pushed towards stiffer plastic as it moved into commercial production [4]. Jones et al. [28] have also recently called for a shift back towards softer toolkits, which integrate better with traditional fabric-based crafting. One challenge with softer toolkits is the production costs that might come from softer toolkits. Researchers are exploring how to create e-textile tools with softer materials (e.g., weaving techniques for integrating conductive components [46]), but it is unclear whether that could bring down costs. Better integrating with these materials can help expert crafters to make the connection between their crafts and e-textiles by being a familiar material.

Selecting materials with familiarity in mind (T1) also includes a particular emphasis on working with familiar materials and making it clear how to use unfamiliar materials. Recent work with crafters made similar calls for teaching about e-textile materials [28, 54], where they recommend teaching crafters about the essential materials needed for crafting with electronics. We encourage e-textile designers to show clear parallels between these familiar materials, such as thinking about how conductive thread is similar to standard thread – both can secure an object or fabric to another fabric. This is critical for connection materials, such as conductive thread, conductive ribbon, conductive fabric, and metallic objects (e.g., snaps). Conductive thread was easy for fabric with crafters to understand how to use, but conductive ribbon and conductive fabric will require additional training – every participant was confused how to use it, viewing fabric as primarily an aesthetic choice instead of seeing it as a way to form a channel for electricity to travel to electronic components. For example, we would recommend introducing conductive ribbon and conductive fabric with an assignment similar in size as our workshop homework – connect one LED via conductive thread, one LED via conductive ribbon sewn down with thread, and a third LED via conductive fabric cut into a non-standard shape sewn down with thread. This would demonstrate the parallels between these materials while making comparisons to typical fabric crafting materials.

Tools for older adult crafters to create with e-textiles should consider how the tool will support crafters to reach their aesthetic goals (T2). Researchers found that crafters often tend to focus more on aesthetics compared to makers [16]. In our study, participants suggested supporting their aesthetic choices by hiding electronics in their projects and facilitate e-textile components as eye catching aspects of their project. We recommend that e-textile toolkits focus on these specific instances, such as supporting the use of conductive ribbon to facilitate connections since conductive thread can show through, but also to think more broadly about how to support crafters' aesthetic choices. We add to calls for researchers to ensure they are supporting crafting with electronics, rather than supporting electronics with craft [47]. We encourage researchers to continue investigating tools to support these choices with tools, such as digitized visualization tools for improvisational quilters to plan out their next quilt [40].

We encourage e-textile toolkits to carefully tailor their training materials to their target audience. Researchers have trained people to use maker electronics through workshops [2, 26, 31, 55], training videos [51], and printed materials [26]. For older adult crafters, this means supporting them to help themselves no matter which end of the Planner-Improviser Spectrum they are on, making electronics more attainable (T3). Training materials can carry on a long tradition started in the 19th century of democratizing sewing skills to reach broader groups of people through distributing paper patterns [62]. First, we recommend including video demonstrations of creating the example of each toolkit, so participants can get asynchronous help. Clear step-by-step directions for each of the activities and toolkit examples will help crafters complete projects, just as they did during the co-design workshop. The directions should also include detailed troubleshooting for planner style crafters, since they often look for how to go about systematically debugging projects. Improviser style crafters will have the added benefit of seeing video examples of completed projects, giving them ideas for projects as they explore.

E-textile toolkit designers can also learn more about the importance of quickly prototyping with components to make electronics more attainable (T3). Recent work on the e-textile prototyping tools, such as the Threadboard [23], and Punch Sketching [29], have had similar goals to support more rapid prototyping and testing through innovative uses of conductive e-textile materials. Our work highlights why it would be particularly beneficial for older adult crafters – fast prototyping would allow crafters who plan to develop their plan with more certainty while crafters who improvise would use prototyping to test out ideas quickly and explore sensors. We acknowledge that developing faster prototyping with e-textile toolkits will not be easy – one challenge with faster prototyping will be the trade off between prototyping speed and permanence. For example, Craftec's [26] Hard toolkit used magnets and wires for connections, allowing faster prototyping speed, but magnetic connections are less permanent than Craftec's conductive fabric-based Soft toolkit which required sewing down connections. Finding a fast, temporary prototyping step with a toolkit before making a connection more permanent could be one way to deal with this trade off.

5.2 Building on Older Adult Crafters' Practices: Supporting the Planner-Improviser Spectrum

Older adults are a diverse group of people, and researchers encourage designing technologies to support them without making ageist assumptions about homogeneity of older adults [36]. Older adult crafters are no exception – we saw how they had quite different approaches to crafting e-textile projects along the Planner-Improviser Spectrum. Our co-design workshop study built on this diversity to highlight the unique crafting styles of older adult crafters and shed light on how we might support and learn from those styles to help older adults to create with electronics. Older adult crafters have a wealth of experience in crafting to share as researchers work to design technologies that avoid stereotyping, and the Planner-Improviser Spectrum provides a reference point for considering the extremes of the approaches older adult crafters take as they create with maker electronics.

Older adult crafters who have a planning style were more plan-centric and cautious, which requires designing teaching materials and toolkits that support that style. Planners, overall, have aligned more closely with the principles of computational thinking [54, 64] or computational making [54], highlighted by their preference for step-by-step, sequential teaching materials, and align with the logical, ordered thinking we often see in computational thinking or making. Therefore, toolkit teaching materials should include step-by-step directions and troubleshooting guidance. Planner style crafters' caution requires alleviating their concerns to ensure their success. For example, several planners were concerned about catching their homework projects on fire. We worked to alleviate their concern by developing teaching materials that described how to avoid it and strove to give them enough practice that they could feel more at ease, but some participants still voiced concerns. More scaffolded practice could alleviate their concerns as they gain experience with e-textiles.

On the other end of the spectrum, older adult crafters who approached crafting with an improviser style were more tolerant of failure and were exploratory in their approach, which requires designing teaching materials and toolkits that give them room to explore. Improvisers often set off in a general direction with a loose plan, but they relied on making decisions as they were creating and often deviated from their initial plans. They also used trial and error for troubleshooting, only falling back to the instructions when they ran into a roadblock. These qualities about improvisers make it imperative to provide more opportunities to explore, while giving enough guardrails to prevent common issues. Crafters who improvise align well with the recent interest on materiality as a way to support better user experiences [19, 22, 25, 38, 60]. Improvisers often use the materials themselves to think through their project designs, so any teaching materials or toolkits should facilitate an exploration of electronic materiality as they work with a toolkit. For example, littleBits [3] has guardrails for novices, encourages exploration as people mix and match components, and supports people to integrate electronics as a material in projects. These qualities have even resulted in littleBits being used by researchers during the prototyping phase (e.g., [32]).

We demonstrated how the toolkits and training materials can help both older adult crafters who have a planner and improviser style to create with electronics, but not always for the same reasons. For example, planner style crafters would use the step-by-step directions as a guide and followed them closely, while improviser style crafters would start with trial and error, but use the directions as a backup when they could not get it working on their own. Common toolkit goals of making it easier to create or abstracting technical knowledge [31, 44, 45, 52, 53] equally helped both to create as they used the training materials in accordance with their crafting style. We encourage providing examples of completed toolkit projects to help both styles of crafters to see how the toolkits could be used. These examples may not be used the same either. Planners discussed how they would consider and test how to integrate the example into their planning, while improvisers would likely consider the examples a data point in their exploration. Considering both ends of the spectrum promotes better toolkits and training materials, and researchers who recognize how their toolkits and materials will be used can help support the Planner-Improviser Spectrum of older adult crafters.

6 FUTURE WORK

This formative work on the Planner-Improviser Spectrum could be expanded to more groups of people and crafting-oriented research. We intend to investigate how this spectrum could apply to other crafts or demographics of crafters. For example, children are often the target for e-textile based STEM projects, and if the Planner-Improviser Spectrum applies, it could shed light on how they could be better supported to learn computational thinking skills. We see this as an opportunity for the community to apply these methods and investigate if this spectrum helps support more people in tangible e-textile research. This spectrum also lends itself to furthering the conversations around design thinking and experiential learning in craft thinking [33–35]. For example, we saw how participants procured conductive materials that were on hand (e.g., the bullet casing in P6's Light Up Memorial). This aligns more closely with craft practices and could lead to a blending of toolkits and untoolkits [45].

We also plan to further explore the remote co-design methods used in this study. Remote co-design presented many challenges and opportunities that could be discussed at length, such as how the sharing of open ended boxes of electronic supplies could create a shared co-design experience.

7 CONCLUSION

We described a remote co-design workshop with 6 individual older adult crafters where we co-designed and crafted e-textile prototypes. Through this study, we explored the co-designed prototypes made by participants and researchers, such as the Magic Question Answering Hat. These prototypes showcase how older adult crafters approach e-textile projects with their crafting expertise, and later informed the design implications for developing e-textile toolkits that incorporate this expertise. We also developed a deeper understanding of older adult crafters' practices, highlighting how participants fell along a Planner-Improviser Spectrum. This spectrum in turn helps with understanding their approach to integrating maker electronics into a crafted project. Lastly, we discussed the implications around electronic toolkit design, including the three themes we drew from supporting older adult crafters to prototype their co-designed projects – select materials with familiarity in mind, support aesthetic goals, and make crafting with electronics attainable. These themes draw on their expertise, including highlighting how to advance the design of future e-textile toolkits and better support crafters along the Planner-Improviser Spectrum.

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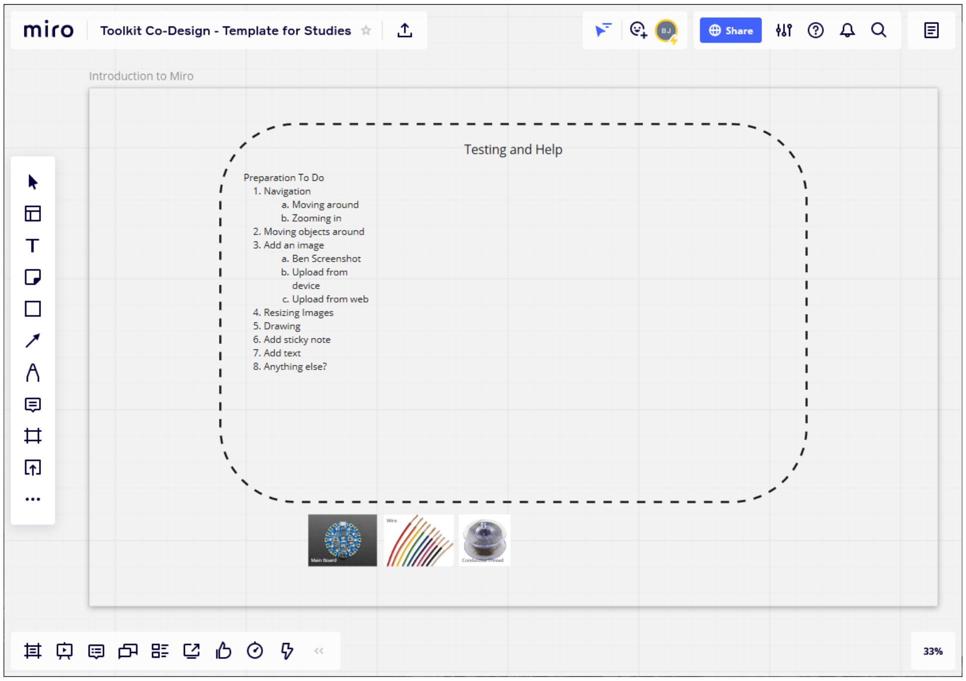
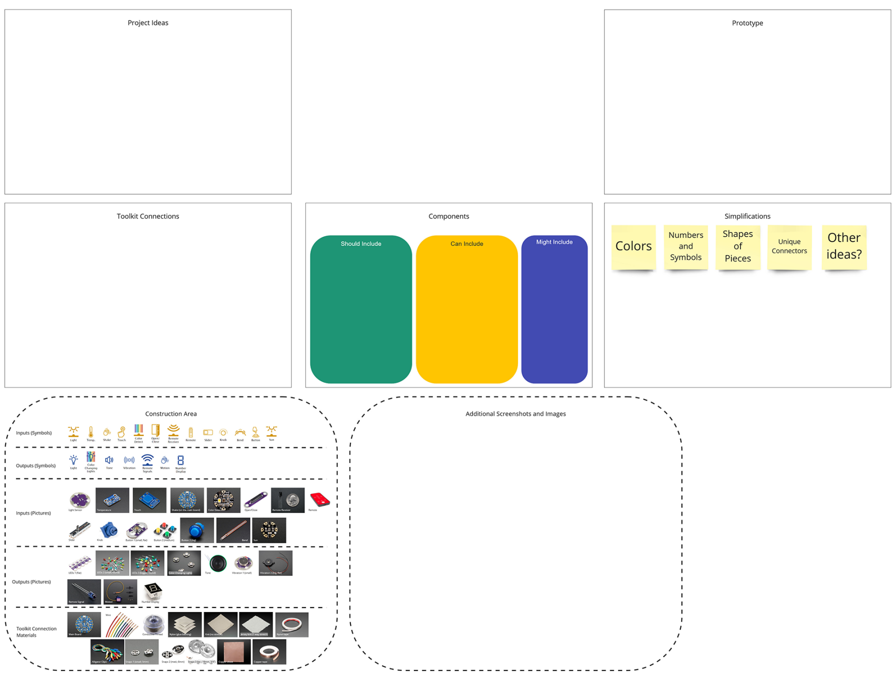
A REMOTE CO-DESIGN STUDY SUPPLIES

Figure 14: Bagged conductive components included in the box, demonstrating how each component was individually bagged and labeled with a colored label.



(a) Miro Setup Session Template



(b) Miro Session Template

Figure 15: Miro was a digital whiteboard tool we used to take collaborative notes and draw together. (a) The testing area during the setup session with tasks listed. (b) The template Miro board. Each dotted line block goes with an activity we anticipated we might discuss via Miro. The images in the "Construction Area" were all the components and materials, which saved time taking pictures later.

B PARTICIPANTS' MIRO BOARDS

In this section, we include screenshots of each participants' Miro board, the digital whiteboard we shared with participants, collected at the end of Session 4 for each of their co-designed prototypes.

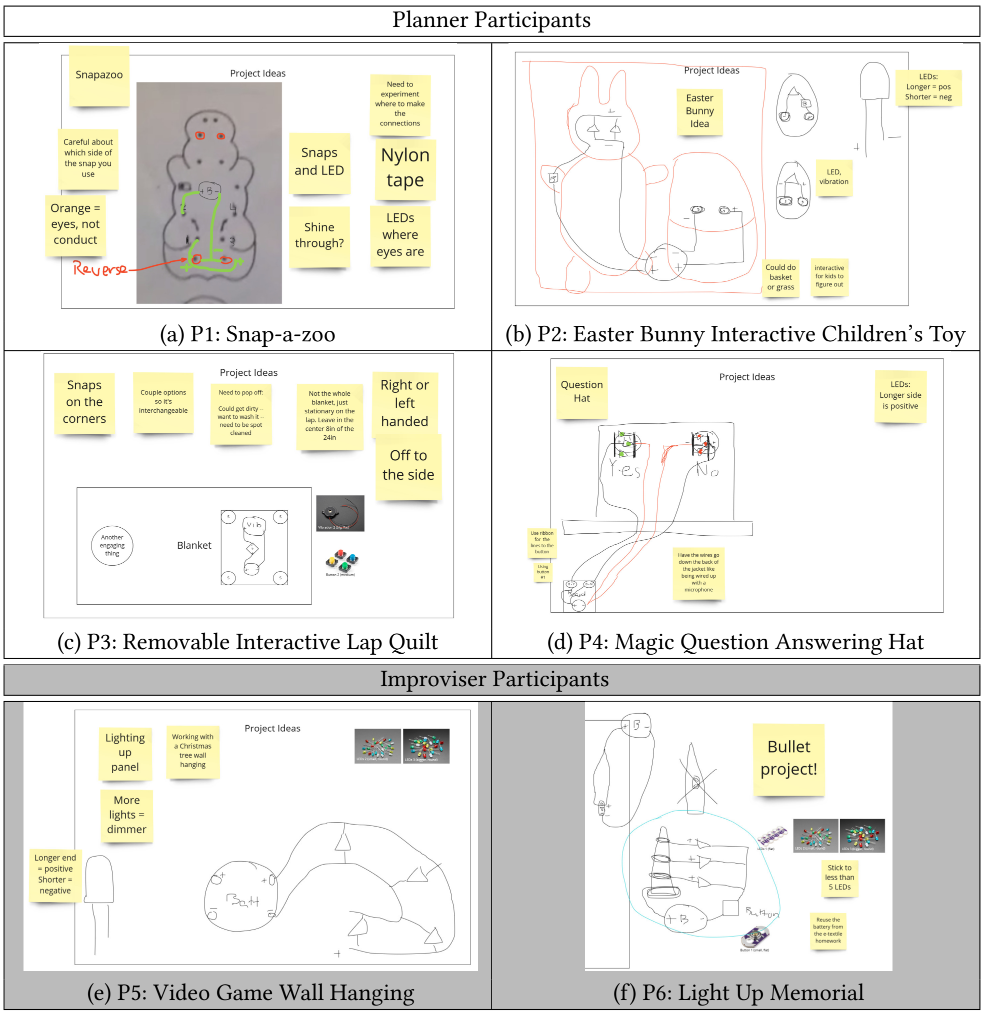


Figure 16: Co-designed plans for the prototypes from the end of Session 3. Planner style participants often followed their plan fairly closely, but improviser style participants tended to deviate from their plan as they explored.

C PARTICIPANTS' E-TEXTILE PROTOTYPES

C.1 Planner Style Prototypes

P1 was an expert in quilting and sewing projects on the far end of the planner spectrum. We built a "Snap-a-zoo" (Figure 7(a)), a children's toy that could be snapped together to make various animals, such as a walrus or elephant. This was a project she recently started, but she restarted with felt and added in LEDs for the workshop. We planned to have different snap pairings light up different LEDs (Figure 16(a)). P1 followed the plan closely, lighting up the Snap-a-zoo's LED eye when snapped together in a particular way. She hid the electronics between two layers of felt. The researcher's prototype had two LEDs for eyes that lit up when snapped together, and another set of snaps that would cause the eyes to alternate blinking. P1 primarily had difficulties with a finicky connection to her LED, which was the result of not tying it down well with conductive thread and she did not realize the conductive ribbon had a glue backing to hold it in place.

P2 primarily quilted, but was also an expert in crochet and cross-stitching. We co-designed an Easter Bunny Interactive Children's Toy (Figure 7(b)) built on her quilting experience, particularly her use of appliqué techniques, which is a method for pasting or gluing fabric shapes on top of other fabric. We planned to make it interactive by having outputs turn on when connected via snaps. (Figure 16(b)). P2 followed the plan closely, making both the bunny and egg removable via snaps, and light up when connected to the base. In the researcher's prototype, the bunny is static, but the two interchangeable eggs snap into the basket – one lit up an LED with a potentiometer for control, and the other turned on a vibration board with a slide potentiometer. P2 primarily had issues with needing to remove the thread to completely redo a project, and we discussed better ways to fix issues (i.e., tying one thread onto another to fix a connection).

P3 was a quilter with sewing experience who worked part-time at a local quilt store. Her Removable Interactive Lap Quilt for Children with Developmental Disabilities (Figure 7(c)) built on her extensive knowledge of quilting and sewing projects, especially given her part-time work. Her project also built on her previous career as a middle school special needs educator, since it was designed to soothe children who may be feeling distressed. We planned to have removable parts on one side and room for another interactive piece on the other (Figure 16(c)). P3 largely followed the plan, but decided to slip it inside a cover to protect the electronics more after she had made it. P3 crafted a vibration board with a battery on a separate piece of fabric that was covered by a pocket to make it easy to wash. The researcher similarly made a removable quilt square with a light up touch-sensitive smiley face made from conductive fabric and a button activated LED. P3 did not complete her prototype in time for Session 4, but finished it afterwards once we answered some additional questions about how to use the buttons and vibration. When we later picked up her prototype, it did not work since she had made the mistake of connecting both sides of the vibration board to the positives of the battery.

For a description of P4's project, please refer to subsection 4.1.

C.2 Improviser Style Prototypes

P5 typically crafted small sewn projects and quilts, which was reflected in her choice to light up a video game "panel" – a piece of fabric with a pre-printed design on it, colloquially called "cheater's cloth" by quilters – for her Video Game Wall Hanging (Figure 7(h)). Wall hangings are art pieces usually hung on the wall to be enjoyed, but not touched. During planning, we discussed a wide range of possible ideas for projects she could light up – a scarf, the sky in a Christmas panel, and a tree cross-stitch. We settled on co-designing a series of lights to light up a panel of some kind, but left open the possibilities of exactly what the panel would be (Figure 16(e)). She roughly followed that plan, but went further than we anticipated. P5 worked to add in all 13 LEDs in various places, but only two ended up partially working. The researcher's prototype was inspired by P5's prior work on a throw pillow with 4 scenes of a tree in different seasons – each sewn scene could be swapped out as the year progressed. The researcher made a tree with color changing LEDs that randomly changed between fall colors. One LED was powered by conductive fabric placed over the branches of the tree since P5 was interested in conductive fabric but did not know how it could be used. Once we were able to see P5's prototype in person, the researcher determined there were too many LEDs attached to the same battery. It required too many fixes to do it quickly while we were there and would have required a complete overhaul to address.

For a description of P6's project, please refer to subsection 4.1.

D COMPONENTS USED DURING CO-DESIGN

Table 2: List of components we discussed during co-design (D), we suggested to participants (S), and the ones included in Participants' Prototype (P).

		P1			P2			P3			P4			P5			P6		
Item Name	**Cat.**	D	S	P	D	S	P	D	S	P	D	S	P	D	S	P	D	S	P
Light Sensor	Input				x			x			x						x		
Temperature	Input																		
Touch	Input							x			x								
Shake	Input				x												x		
Color Detector	Input													x			x		
Reed Switch	Input																		
Remote Receiver	Input																		
Slider	Input				x	x					x						x		
Button 1 (LPA)	Input				x			x			x	x	x	x			x	x	x
Button 2 (Small)	Input				x	x		x	x		x			x			x	x	
Button 3 (Large)	Input				x			x			x			x			x		
Knob	Input				x	x		x									x		
Bend	Input				x														
UV Detector	Input				x														
Remote	Input				x									x					
Snaps	Input	x	x	x	x	x	x	x	x		x								
Lights 1 (LPA)	Output	x	x	x	x	x		x			x			x	x	x	x	x	x
Lights 2 (Small)	Output	x	x		x	x		x			x	x		x	x	x	x	x	
Lights 3 (Large)	Output	x	x		x	x		x			x	x	x	x	x	x	x		
Color Changing Lts.	Output				x						x			x			x		
Tone	Output				x						x								
Vibration 1 (LPA)	Output	x	x	x	x			x		x	x			x			x		
Vibration 2 (Large)	Output				x			x	x					x			x		
Remote Signals	Output													x					
Motion	Output										x								
Number Display	Output																		
Battery 1 (2 AAA)	Battery																x		
Battery 2 (Small)	Battery																x		
Battery 3 (Medium)	Battery																x		
Battery 4 (Large)	Battery																x		
Coin Cell Battery Holder	Battery	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Main Board (CPX)	Board																x		