Craftec: Engaging Older Adults in Making through a Craft-Based Toolkit System

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ABSTRACT
We present Craftec, an extendable toolkit system to engage older adults in maker technology by supporting their use of crafting skills. Craftec is comprised of LilyPad Arduino-based toolkits to promote easier crafting with hard and soft mediums. We describe the system's design, a pilot test with 8 younger adults, and 2 two-hour single session workshop evaluations by 17 older adults. We found Craftec facilitated efficient integration of circuits in crafted items, including fewer short circuits as compared to a basic LilyPad Arduino kit. We discuss how to create a toolkit for prototyping rather than facilitating STEM education.

Author Keywords
Electronic toolkits; construction kits; maker technology; Arduino; older adults; evaluation workshop; crafting; crafting technology; DIY.

CCS Concepts
•Social and professional topics → **Seniors; •Human-centered computing** → **Interface design prototyping;** *User studies;* User centered design; **•Hardware** → *Emerging technologies;*

INTRODUCTION
The making community is comprised heavily of middle-aged men with disposable income [15]. Researchers have encouraged more diverse groups to join in the DIY and Maker Movements, including children, women, and those with disabilities, [2, 8, 10, 40]. When children are engaged, researchers found hands-on, Science, Technology, Engineering, and Math (STEM) oriented "let's try it" exploration particularly successful [31]. Although researchers have studied older adults' views of maker technology and how they might design for them [51], few have designed maker technology for them.

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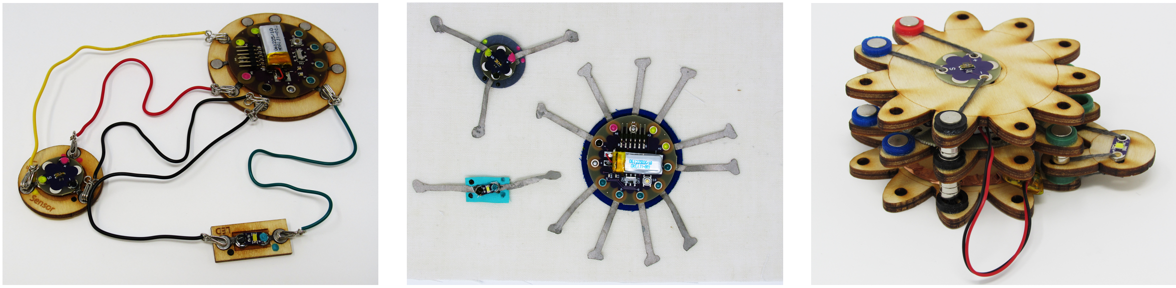
Researchers typically engaged diverse groups in making through electronic toolkits, which often built on accessible and widely adopted crafting practices. Commercialized toolkit systems, such as MaKey MaKey [52], littleBits [4], and Chibitronics [48], use electronic components to engage children in exploring the possibilities of creating captivating artifacts while learning STEM topics, such as logic and electronic circuitry. Non-commercialized researcher toolkits have built upon the maker community's STEM education work through projects such as MakerWear [31] to create personalized, wearable systems and the "untoolkit" [41] for inexpensive personalized projects. E-textiles toolkits, such as the LilyPad Arduino [8] and Adafruit's Flora [27], explicitly build a bridge between computing and crafting practices by enabling a more diverse community of digital crafters [18]. We see their pioneering crafting-computing work as an opportunity to engage older adults – a common group of crafters.

Older adults could benefit from an electronic toolkit that engages them in the maker community as innovators of technology that is often designed for them (e.g., [3]) *rather than by them*. Society often points to the "digital divide" – the notion that older adults and younger people drastically differ in technology acceptance [19] – as a barrier to older adults contributing to a growing community like the Maker Movement. We see older adults as poised to contribute to such a technological frontier despite ageism biases [5, 28, 34]. Indeed, older adults are quite capable of learning computer programming [25] and tinkering with electronics [51]. Empowering older adults with an electronic toolkit can assist them in altering technology that is designed with good intentions, but may not support their goals [42].

We built Craftec, an extendable system of electronic toolkits, to engage older adults in making through the use of familiar crafting skills (Figure 1). The toolkits facilitate making through crafting with multiple mediums, such as wood and fabric. By supporting multiple materials, Craftec appeals to a wide range of crafts from woodwork to quilting. The toolkits



(a) Hard Toolkit (b) Soft Toolkit (c) Stackable Toolkit

Figure 1. The Craftec system is made of three toolkits. Each toolkit is shown with a microcontroller, an LED, and light sensor. Note that after the pilot study, the Stackable toolkit was discontinued and not used during the workshop.

integrate a modified LilyPad Arduino that simplifies electrical connections thus providing older adults the ability to quickly and safely craft innovative prototypes.

This paper makes three primary contributions: (1) we present Craftec, an electronic toolkit designed to support older adults in making and innovation using common crafting skills; (2) we describe findings from a pilot study of 8 younger adults and evaluation workshops with 17 older adults demonstrating the toolkit efficiency; and (3) we discuss implications for designing electronic toolkits for older adults to engage in maker activities.

RELATED WORK

HCI researchers have created hybrid computational and crafting approaches by exploring crafting for tangible interaction and improved maker electronics toolkits. We focus on the relationship between crafting and electronic toolkits.

Crafting and HCI

The HCI community has a growing interest in how crafting relates to people's tangible interactions with technology and the physical artifacts people create. Many researchers have focused on integrating digital technology into crafting [11, 18, 44, 22, 48, 58, 59]. Buechley et al.'s [8] creation of the LilyPad Arduino abstracted low-level electronics knowledge and integrated maker electronics into fabric projects via alternative, fabric-oriented conductive materials. Tsaknaki et al. [56] explored hybrid crafting – the integration of physical crafting and digital media [21] – with silversmiths to integrate small sensors into their crafted artifacts. Materiality – the feel for the materials and their inherent properties – is often discussed in conjunction with crafting in HCI [14, 18, 35, 41]. Giles and van der Linden [20] conducted e-textile workshops with blind and visually impaired, including several older adults. Similarly, we aim to use crafting as a bridge between older adults and maker electronics.

By integrating crafting and technology, researchers have reached more diverse populations than typical makers [18]. Hybrid crafting projects, such as LilyPad and Chibitronics, reach diverse audiences, particularly crafters, artists, and educators [10, 47]. Much of the craft-focused research has seen similar gender diversity in their participant pools [21, 41, 44]. Supporting diverse communities, especially older adults, creates opportunities for equitable technology literacy levels that can benefit broader communities, improve quality of life, and teach future generations [25]. Stewart et al. [54] actively sought out e-textiles as a way to support gender diversity in the design of engineered audio systems. Similarly, we see the integration of crafting practices into maker electronics as a way to create an inclusive atmosphere for older adults to build electronically enhanced artifacts, especially for a group that globally is largely women [45]. Lazar et al. [33, 35] engaged older adults with cognitive disabilities in creative practices as a part of art therapy which assisted participants in expressing themselves more clearly. We built upon this success with older adults by incorporating crafting.

Maker Electronic Toolkits

Maker-oriented electronic toolkits have facilitated more accessible creating and building with electronics by lay people. Blikstein [6, 7] provides an overview of the development of electronic toolkits for children's education highlighting how toolkits have developed from programmable bricks [50, 49] to focusing on specific form factors [4, 8] and computers on chips [16, 17]. Blikstein [6] discusses the importance many toolkits have in abstracting technical knowledge so children can focus on more important ideas. Blikstein's framework, which informed Craftec, includes differentiating between toolkits based on level of selective exposure, detection of error correction, and ability to influence power [7].

Many maker electronic toolkits promote electronics concepts and encourage building electronically-enhanced artifacts. littleBits, which caters to STEM education programs [4], consist of pre-programmed electronic modules that snap together with magnets, allowing people to "*play with electronics without knowing electronics*" and explore computing logic while avoiding such issues as polarity reversals [4]. littleBits requires tape or Legos to create an artifact that integrates objects outside of its modules (e.g., wearable testing [32]). MakerWear expanded the concept of magnetic connections by providing children with pre-programmed hexagonal modules that snap into stiff boards sewn into objects to create different effects [31, 30, 32]. MakerWear demonstrated that they supported children's engagement in maker electronics by creating wearable artifacts while teaching them computing logic. mCookie [26] uses Lego-style stacking of components to create artifacts. Craftec builds upon these successes in easily building artifacts, but supports mediums such as wood and fabric to include broader groups of older adult crafters.

Some maker toolkit designers approached creativity by integrating crafts – such as sewing with fabric in the LilyPad Arduino toolkit [8] and exploring paper craft with Chibitronics [48]. Posch and Fitzpatrick [46] designed a series of prototype tools for e-textile makers and demonstrated the value of creating tools grounded in a particular craft.

People benefit in creating their own personally meaningful artifacts because it increases their satisfaction with the end result – a phenomenon known as the 'IKEA' effect [43]. Eduwear, a toolkit designed for the construction of wearable technology, capitalizes on this principle by enabling novices to create personally meaningful artifacts [29]. Building on this finding, Ananthanarayan et al. [2] found that those who spent over ninety minutes crafting their wearable device (electronics and design), used it more often. We extend these findings by emphasizing the hands-on crafting of electronically enhanced objects with Craftec.

THE CRAFTEC SYSTEM

The Craftec system is composed of interchangeable toolkits that are extendable to incorporate commodity inputs and outputs within the LilyPad Arduino power and pin constraints. We started with three toolkits – Hard, Soft, and Stackable – before narrowing down to the Hard and Soft toolkits after the pilot study. We chose different crafting mediums and orientations to facilitate prototyping with hard and soft materials while being mindful of space constraints by increasing component placement degrees of freedom (i.e., the flexibility to orient and attach components in multiple dimensions).

System Overview

The Craftec system is a medium-fidelity set of toolkits geared towards supporting older adults to prototype new technologies, such as IoT systems, where interchangeable components can be switched between toolkits. With Craftec, participants created examples using an LED and a light sensor.

One key benefit of integrating crafting into Craftec is that older adults participate in crafts already (some list it as their favorite activity [55]), making it ideal for expanding maker technology to them. Crafting can bridge between diverse groups and maker electronics as craft-focused toolkits have demonstrated [10, 39, 47]. Crafters can select the Hard toolkit for projects like woodworking, or the Soft toolkit for soft-mediums, such as fabric. We caution, however, that since Craftec integrates with combustible materials (e.g., fabric and wood), short circuits are of particular concern because they can cause fires, injure people, destroy crafts, and question one's confidence in creating with electronics.

The Craftec system builds on the rich design space of maker toolkits. The core of the design are modified LilyPad Arduino components [8]. Similar to other toolkits, we adopted snaps [1, 9], wires [23, 52], and magnets [53] to facilitate safe, secure connections. We iterated on snaps to form connections by leveraging conductive fabric for easier integration with sewing. We appreciated the quick prototyping of the 4 pin cables in Phidgets [23], so we integrated cables into the Hard toolkit. Based on the success of abstracting pins with colors [31] and differentiating inputs vs. output with shapes [48], we integrated both to accommodate varying visual acuity. In Craftec, we investigated how these affordances worked together in one system to empower older adults to build electronics using their crafting skills.

Craftec is the only system of toolkits designed for older adults to engage in maker activities by creating electronically enhanced artifacts using their crafting skills. Craftec's support for hard and soft craft mediums and the high component placement degrees of freedom is a unique combination.

Hard Toolkit

The Hard toolkit is designed to connect components in a malleable orientation to allow for freedom of movement when placing components (Figures 1-a). Each component in the Hard toolkit was laser cut from balsa wood and engraved with the component name. We soldered a 5mm snap to each pin on the LilyPad Arduino sensors and outputs. We used the LilyPad Arduino SimpleSnap[1] and sewed the corresponding 8mm snaps into the laser cut base. Conductive thread established connections between the snaps on the bases and the magnets. Components snap into the base and each snap is conductively connected to a magnet. Insulated wires with jewelry clasps on the end connect magnets of different components to hold the connection in place. The Hard toolkit differentiates between outputs, which are rectangular, and inputs, which are circular. Colored puffy paint on the edges of the base guides users in creating correct electrical connections to other color-coded LilyPad components with yellow indicating analog, teal indicating digital, black indicating ground, and pink indicating power.

Soft Toolkit

The Soft toolkit provides long conductive fabric strips that extend from the LilyPad Arduino, as shown in Figure 1-b, to provide room to machine or hand sew the circuit. The fabric strips were made from woven conductive fabric[2] that we laser cut. The conductive fabric strips were soldered to the LilyPad SimpleSnap Protoboard[3], so the LilyPad Arduino SimpleSnap could be securely snapped into place. Since the conductive fabric strips were smaller, we sewed the snaps directly into the strips using conductive thread.

The fabric strips eliminate difficulties involved with securing thread around the small pin holes of the LilyPad Arduino by allowing for machine sewing. Electronic components snap into the fabric circuit extensions, permitting their safe removal for washing and reuse in future projects with the interchangeable Craftec system. The fabric backing on the Soft toolkit's circuit extensions are differentiated by shape and color, with inputs being gray and circular and outputs being teal and rectangular. Pins were color coded the same as the Hard toolkit. The conventional power pin (+) was not used, and the conductive fabric strip was intentionally absent to decrease the likelihood of short circuits. Instead, the A5 pin was indicated as the power pin to reduce short circuits. Most sensors for the LilyPad

[1] https://www.sparkfun.com/products/10941
[2] https://www.adafruit.com/product/1168
[3] https://www.sparkfun.com/products/10940

Arduino require a connection to an analog pin, power, and ground, but the arrangement of the pins on the sensors make it difficult to use the conventional power pin (+) without crossing ground. We decided to simplify circuit creation by indicating A5 as the power pin, thus reducing the occurrence of short circuits.

Stackable Toolkit

The other hard-medium circuit toolkit, Stackable, connected electrical components in a vertical orientation similar to the Lego stacking of mCookie [26] (Figure 1-c). The circuit extension bases were laser cut from balsa wood and marked with an image that represented the sensor or output to be used with the base. Electronics were secured to the Stackable toolkit bases by winding conductive thread through the circuit extensions' base and the pin holes of the electronics. Then, color-coded 3D printed magnet holders were glued onto the circular openings of the circuit extensions. The magnet holders contained 6mm x 2mm nickel-copper plated magnets onto the appropriate plastic magnet holders to facilitate electronic connections. The color of the magnet holders correlated to different pins, with red indicating power, green indicating digital pins, blue indicating analog pins, and black indicating ground. To reduce the occurrence of short-circuits, the red-colored power source on the base of the LilyPad Arduino was repositioned from its traditional location beside the ground pin to a location corresponding to the LilyPad Arduino's A2 analog pin. Because of the vertical nature of the circuit extensions, sensors must be placed on top of other electronic components to ensure full detection of environmental stimuli (e.g., Figure 1-c). As we discuss later, usability issues with the Stackable toolkit caused us to remove it from the Craftec system.

PILOT STUDY WITH YOUNGER ADULTS

Method

We conducted a two-hour ethics board approved pilot study with 8 younger adults to test the effectiveness of all three Craftec toolkits – Hard, Soft, and Stackable (Figure 1) – in comparison to an unmodified LilyPad Arduino. Six participants were men, and ages ranged from 20 to 31 years old (average = 26 years old) from Bloomington, Indiana using snowball sampling and personal contacts. They were Caucasian (5), Asian (2), and African American (1). We recruited computing-oriented college students who would give us unfiltered feedback about Craftec without thinking mistakes reflected on their own skills. Participants were matched with a researcher and completed four activities in separate rooms. The participants were compensated with $20 for their time.

Procedure

We administered a pre-survey first to gather basic demographic information and gauge participants' prior knowledge of maker electronics concepts. Participants tested the three Craftec toolkits and an unmodified LilyPad kit for comparison by creating two circuits. The first circuit consisted of an Arduino and an LED, and the second circuit added the light sensor to the first circuit. The four kits were purposefully randomized so that the participants did not interact with the kits in the same order.

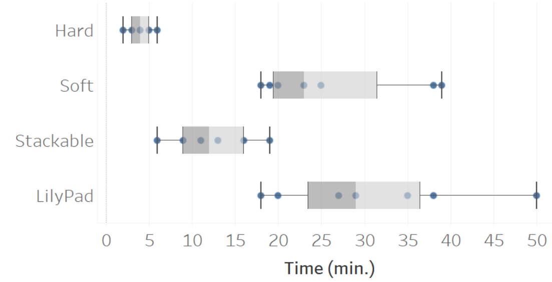


Figure 2. Box and whisker plot of the total time to complete building both circuits during the pilot study.

After working with each version of the toolkit, participants filled out a questionnaire about what they enjoyed and what they disliked about each version they used. When finished with each toolkit, participants completed a questionnaire gauging any change in circuitry or electronics knowledge and commenting on the toolkits.

Analysis

We recorded details on participants' interactions with the toolkits including the circuit completion times, number of short circuits, whether connections were secure, and challenges they faced. The surveys, researcher notes, video, and audio were analyzed using a mixed methods approach similar to other toolkit evaluation workshops [2, 31, 41].

Results

Participant Backgrounds

The majority of participants considered their sewing skills as beginner-level, and most had programming experience. Two of the eight participants demonstrated a familiarity with electronic circuits, breadboards, and LEDs; and three of the eight participants demonstrated a familiarity with small electronics, sensors, and robots.

Toolkit Efficiency

We measured toolkit efficiency by evaluating circuit completion times (a common toolkit evaluation measure [36]), how frequently short circuits occurred, whether participants completed the circuits correctly, and difficulties encountered when working with each toolkit.

Circuits that required sewing took more **time to complete** than those that used magnets. Participants took about the same amount of time with the unmodified LilyPad Arduino (avg. 29.6 min) and Soft toolkit (avg. 25.1 min.), however, creating a circuit using the Stackable toolkit took less than half of the time (avg. 12.3 min.) as shown in Figure 2. Using the Hard toolkit was the fastest (avg. 4.5 min.).

Participants created significantly more **short circuits** when using the unmodified LilyPad Arduino as opposed to the Craftec system. No participants created a short circuit when working with the Soft or Stackable toolkits, but 1 of the 8 participants created a short circuit while using the Hard toolkit. In total, 7 participants created a short circuit while using the unmodified LilyPad Arduino. Most of the short circuits from the unmodified LilyPad were attributable to the conductive thread crossing.

Circuit correctness varied depending on the toolkit used, but people were largely successful. For the Hard toolkit, two participants had their LED circuits corrected by researchers, but all participants correctly completed the light sensor circuit. All participants completed the LED and light sensor circuits correctly with the Soft toolkit. Everyone completed the LED circuit correctly for the Stackable toolkit, but 1 participant did not correctly complete the light sensor circuit. One participant did not complete the LED circuit correctly with the unmodified LilyPad Arduino; similarly, another participant did not correctly complete the light sensor circuit.

Participants faced several **obstacles constructing functional, reliable circuits** while experimenting with the bases. Participants sometimes struggled with forming secure connections between the Hard toolkit's wires and magnets, and had issues working with inflexible wire connections. Soft toolkit problems included piercing the conductive fabric with a needle and overlapping strips of conductive fabric. Stackable toolkit difficulties included the magnetic strength and polarity, reliability of the magnets, and getting a good visual of the structure. With the LilyPad Arduino toolkits, participants experienced difficulties sewing, ensuring that the conductive thread formed a secure connection to the pins, avoiding loose or overlapping conductive thread, tracing electrical connections without the guidance of color, and creating tight stitches.

Design Considerations

Participants noted that the Hard toolkit was quick to use, enabled intuitive prototyping, helped guard against short circuits due to insulated wires and color coding, was less of a hassle to use, and was more visually appealing. Participants praised the Soft toolkit for its reliable connections, color coding, and innovative combination of sewing and electronics. They noted that the conductive thread is a good visual representation of electrical connections and that the long fabric strips make short circuits less likely. Participants appreciated the novelty of the Stackable's structure, however they found manipulating the magnets in a vertical orientation challenging. They had difficult checking the magnetic connections unless the whole base was taken apart, keeping the bases level with each other, and the design's overall stability. Participants noted the versatility and design freedom that the LilyPad provided, but wanted more affordances in the design.

Based on these findings, we chose to narrow our evaluation of toolkits to the Hard and Soft toolkits by removing the Stackable toolkit from the system. The relative success of Hard and Soft compared to the difficulties people faced with the Stackable toolkit pushed us to narrow Craftec's focus. We made small changes to the Hard and Soft toolkits to resolve minor issues such as tighter connections between the Hard toolkit's wires and jewelry clasps to improve connections.

EVALUATION WITH OLDER ADULTS

Methods

We evaluated the Hard and Soft toolkits from the Craftec system in comparison to a LilyPad Arduino with 17 older adults in two 2-hour, ethics board approved, single session workshops. Ten participants (P1-P10) completed the first workshop, while the second workshop was run with 7 participants (P11-P17). Ten participants were women. All were white, and their ages ranged from 65-75 years old (average = 70.1). We collaborated with Parkview Research Center, a not-for-profit community health system in the US, who recruited participants on our behalf from a cardiology practice embedded in the health system's provider group - Parkview Physician's Group. Participants received $20 for their time and travel expenses.

Procedure

Participants began with a pre-survey on demographics and their prior knowledge of maker electronics. Participants then read training materials discussing important electronics basics (e.g., input vs. output, circuit definition) and completed a second assessment of their circuits knowledge. Then, participants organized into self-selected groups of 2-4 people at each table to start individually working with a toolkit. One researcher was assigned to each table.

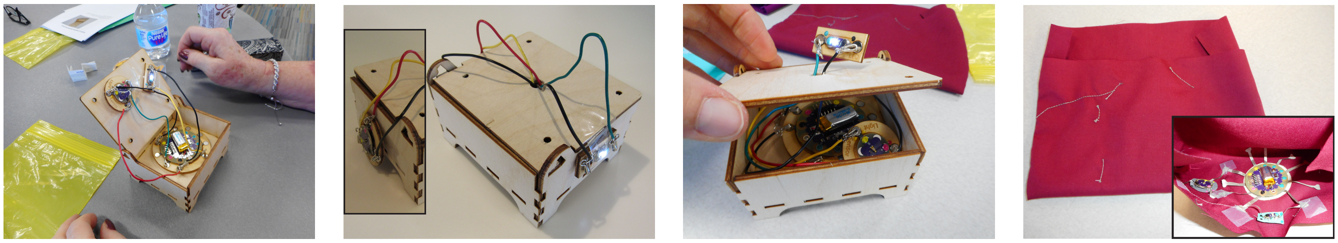
Participants tested as many toolkits as time allowed depending upon how quickly they were able to complete the activities. We did not set time constraints per toolkit because we were interested in correct completion and did not want to pressure participants. As in the pilot, they were asked to complete two circuits using an LED and light sensor for each toolkit. In addition to creating the circuits, in the workshop we asked participants to construct a craft-like artifact using their kits to envision how they could be incorporated into a craft project. Hard toolkits were adhered to a laser-cut balsa wood box, while Soft toolkits were sewn into a bag (Figure 3).

We altered the toolkit activity ordering procedure slightly between workshops to improve the participant experience and data collection. For the first workshop, participants determined their first toolkit by choosing a table to start at, but in the second workshop, everyone started with the Hard toolkit before continuing with the Soft or LilyPad Arduino toolkits. Starting participants with the quick success of the Hard toolkit was important to finishing all 3 toolkits in the 75 minutes allotted to working with the toolkits.

After completing each kit's circuits, we administered a brief survey to identify what participants enjoyed and struggled with. As the workshop concluded, participants completed a questionnaire reflecting on their overall use of the toolkits and an assessment of their circuit knowledge.

Analysis

We collected researchers' notes of participants' interactions with each toolkit version to get a sense of how well they were able to complete the activities. Note that due to stricter data collection limitations of the medical center research environment, we collected audio and non-identifiable pictures of participants rather than video. The results were analyzed using a mixed methods approach similar to other toolkit workshops [2, 31, 41].



(a) Completed Box (b) Completed Box (c) Completed Box (d) Completed Bag

Figure 3. These are examples of crafted boxes and bags. The boxes (a-c) use the Hard toolkit in feature different ways participants organized the components. The bag (d) uses the Soft toolkit.

Results

Participant Backgrounds

Most workshop participants were unfamiliar with sewing or electronics. Most (12 of 17) rated their sewing skills as beginner. Only 2 participants said they were familiar with small electronics (e.g., LEDs, sensors) and programming, while 3 were familiar with circuits. For 4 participants, high school was their highest level of education, 2 had vocational school degrees, 8 had completed college, and 3 completed graduate or professional education.

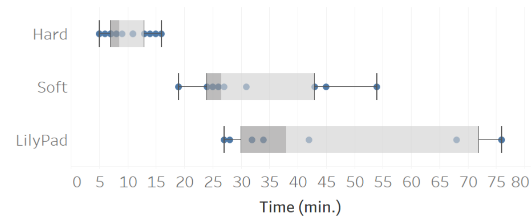


Figure 4. Box and whisker plot of the total time to complete building both the LED and light sensor circuits during the workshop evaluation.

Toolkit Efficiency

Similar to the pilot study, we measured toolkit efficiency by evaluating the data collected during the workshop – circuit completion time, the number of short circuits, and the issues older adults faced with the toolkits. These included tearing conductive fabric, small port labels, and usability challenges for the LilyPad Arduino. Overall, 3 participants attempted only one toolkit with 1 completing their attempt, 11 attempted two toolkits with 10 completing both, and 3 attempted three toolkits with 2 completing all three. In total, 14 evaluated the Hard toolkit, 10 evaluated the Soft toolkit, and 10 evaluated the LilyPad Arduino toolkit.

Older adult participants took more **time to complete** the LED and light sensor circuits than the pilot participants. As displayed in Figure 4, workshop participants were the fastest with the Hard toolkit (avg. 9.6 min.). The Soft toolkit was the next fastest (avg. 31.3 min.), followed by the LilyPad Arduino (avg. 47.9 min.), which saw P3 and P6 struggle to complete in the 76 minutes allotted for circuit building.

Most participants were able to build circuits with more than one toolkit, especially in the second workshop where we started participants with the Hard toolkit. Some participants were able to build both circuits and the crafted box without any help from the research team. Several noted how the Hard toolkit was "Easier to understand" (P8) and "... easier to work with" (P7). By starting P11-P17 with the Hard toolkit, everyone in that workshop was able to complete more than one toolkit activity so they could compare between them, including P12 and P15 who completed all three. Several participants commented how much they enjoyed turning on the LEDs and learning new skills.

Short circuits were a common problem with the LilyPad Arduino toolkit, while the Craftec system saw few. Half of LilyPad Arduino participants (5/10) created a short circuit, especially as a result of loose and overlapping conductive thread. Two of 10 participants caused a short by crossing over threads they sewed into their fabric, while no one caused one with the Hard Toolkit.

Obstacles Creating Reliable Circuits

A common issue for the Soft toolkit was the **torn conductive fabric extensions**, which slowed people down until the research team was able to fix them. The conductive fabric's soldered connection to the LilyPad SimpleSnap Protoboard would tear as participants operated the sewing machines or, in one case, when a participant shook their crafted bag. P14, who had experience with small electronics, was slowed by taking the time to fix his own connections.

With each kit, older adult participants disliked how difficult it was to read the **small port labels** on the Arduinos and components. We hoped that Craftec's reliance on coloring and shape would suffice, however our code was only set for specific ports.

There were a few **unique issues specific to the unmodified LilyPad Arduino toolkit** reflecting on the Craftec design decisions. Several participants disliked the difficulties they had with handling the tiny LED. They struggled to decide what length of thread to cut. If it was too short, then they were constantly rethreading the needle. If it was too long, then they were likely to tangle up the conductive thread. In addition, some participants struggled making tight connections with the ports, which requires looping the conductive thread through the pin holes several times, leading to finicky connections.

Crafted Boxes and Bags

Craftec provided the older adults with the ability to quickly integrate maker electronics into a crafted balsa wood box and a fabric bag (Figure 3). Nearly everyone who worked on a box or a bag completed it shortly after completing both introductory circuits. For the Hard toolkit, participants often quickly reconfigured the LED and light sensor as they were constructing the box so it would function as they envisioned. They placed the Hard toolkit in several arrangements with some choosing to turn the light inside the box on when opened (Figure 3-a), while others lit up the box top when opened (Figure 3-c). Participants' most common concern was undoing their wired connections to place the LED and light sensor where they wanted.

The Soft toolkit bag offered fewer degrees of freedom for placing components since we gave participants a fabric template to machine sew their LED and light sensor circuits (Figure 3-d). Thus, the bags all lit up when opened.

When asked how they could use their crafted object or what project they could complete with one of the toolkits, participants highlighted several crafting projects. In the post-survey, most participants either agreed or strongly agreed that they could see opportunities for how electronics could be used. P12 suggested using the Soft toolkit to create a bag for their cell phones similar to the workshop. P10 said she would use the Hard toolkit for a kid's box or bag, or the LilyPad Arduino to modify her Christmas tree.

DISCUSSION AND CONCLUSIONS

This paper contributes the Craftec system – an extendable maker electronics toolkit that supports older adults to incorporate electronics into their crafts. Craftec builds on Blikstein's educational children's toolkits framework [7] because it offers more selective exposure to concepts and power with embedded error correction (similar to PicoCricket [12] and Lego Mindstorms [24]). Craftec's support of multiple craft mediums and component placement degrees of freedom makes it a valuable addition to the toolkit community, who are often focused on STEM education. Our findings demonstrate that older adults – an overlooked group not often contributing to the DIY and Maker Movements – were able to efficiently build with the Hard and Soft toolkits. We discuss the implications of designing electronic toolkits for older adults to engage in maker activities through crafting.

Craftec compared favorably to the LilyPad Arduino [8] during the pilot study and workshop. Simplifying the connections between components with wires, magnets, conductive fabric, and conductive thread was key to Craftec's success. The Hard toolkit was much faster to complete than the unmodified LilyPad because it facilitated the ability to quickly prototype and modify the circuit configurations with magnets and wires. More work is needed to *investigate how to transition the Hard toolkit from prototyping to more permanent connections for an IoT object* in a living environment.

The Soft toolkit was faster on average for older adults using sewing machines than the LilyPad despite several participants having issues with torn conductive fabric. Similar results hold for the number of short circuits; the Craftec toolkits had very few (7.5% for both toolkits during the pilot and workshops), while many participants using LilyPad Arduino ran into issues (66.7%). Thus, we show the potential to *further abstract toolkit connections and increase degrees of freedom to facilitate safer making.*

Although machine sewing requires knowledge and resources, it *provides easier mechanisms to make secure, permanent connections that even novice participants can complete.* Hand sewing requires dexterity and visual acuity to thread the needle and stitch tight connections without bunching up thread. The Soft toolkit simplified this by allow participants to machine sew between conductive fabric strips – providing a large sewing area and tight pin connections.

Implications for Designing Older Adult Toolkits

Crafting is a great way to engage older adults in maker electronics. Researchers found similar results with other demographics when bridging digital technology and crafting [11, 18, 44, 22, 48, 58, 59]. Allowing for varying crafting mediums opens up the possibilities of what older adults with diverse crafting skills can create. In the pilot, many younger adults viewed the Hard toolkit as an effective tool for teaching others about electronics, but the crafted boxes encouraged older adult participants to think of unique ideas for what projects to build. We encourage future toolkit creators to *take advantage of crafting to engage older adults in making with electronics* through a crafted object.

Several workshop participants who crafted their boxes used the Hard toolkit's extra **component placement degrees of freedom** to experiment with the physical design of the completed box. After seeing the initial interactions, participants reconfigured the sensors and LEDs to ensure the interaction worked as they envisioned. Older adults could have also tested their Soft toolkit bags by temporarily holding together the conductive fabric prior to sewing to envision how their toolkit interacted, allowing them to alter the layout of their components, however most did not because it would be awkward with the flexible bases. Currently, the design of Craftec connections imply permanence to participants – magnets could move, whereas sewing was a one time endeavor. *Toolkits should offer flexibility in how they are configured so participants can quickly see intended interactions and modify circuitry – providing participants with the ability to move from prototyping to permanent connections.*

Older adult participants struggled to read port numbers despite color and shape abstractions and expressed frustration if they accidentally connected to the incorrect port number. We *encourage toolkit researchers to integrate* ***flexible programming*** *with pins to increase degrees of freedom in creating circuits* and decrease programming pin constraints. We will improve the ease of use of Craftec's toolkits by leveraging recent toolkit advances such as Adafruit's Circuit Playground[4] to use onboard RGB LEDs for users to dynamically indicate ports with I/O based on the Craftec color abstractions.

Limitations

We acknowledge both single session workshops should have been conducted identically using within-subjects study design. Since older adults needed more time to complete sewing kits,

[4] https://www.adafruit.com/product/3333

we altered the order in the second workshop to collect quality data. We were able to recruit a more gender diverse group in comparison to older adult HCI studies [13, 37, 38, 57] by working with a medical research center. However, we were restricted to collecting researcher notes, audio, and unidentifiable images. Since we did not have video in compliance with stricter medical research rules, some interaction data may have been lost.

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