Outside the Brick: Exploring Prototyping for the Elderly

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ABSTRACT
We report on the necessity, design, proof of concept implementation, and initial evaluation of a basic prototyping kit for senior citizens. Even though elderly users have a rich level of experience and are increasingly computer literate, the maker culture largely ignores them as a productive group. This study presents the development of an explorative prototyping kit especially for senior citizens. Its qualitative evaluation was conducted in multiple small workshops with 15 participants in total. The results indicate positive acceptance of the developed tool overall but also show challenges in the design and a lower-than-expected connection to pre-existing work experiences in the participants. It calls for a review of a purely constructivist approach and a necessary re-framing of computing classes in senior education.

Categories and Subject Descriptors
• **Human-Centered Computing~Human Computer Interaction (HCI)~Interactive Systems and Tools**

Keywords
Prototyping; making; senior citizens.

1. INTRODUCTION
Older adults are the fastest-growing group of Internet users [13], have free time to pursue new activities, and a wealth of life experience to contribute but they are largely ignored by the thriving maker culture. There are no electronic construction kits and next to none physical computing workshops for senior citizens. While many senior centers offer classes and workshops in basic computer literacy, they do not offer few opportunities to learn computer programming and none in physical computing, leaving a growing gap especially as basic computer literacy classes will become less necessary for aging digital natives. At the same time, maker communities are open but not geared to fit the particular needs of elderly citizens.

This project offers a proof of concept for introducing older adults to basic physical computing projects. Participants in this project used a modified Arduino-based electronic construction kit in a one-hour introductory workshop. The paper reports on the design, implementation, and evaluation of this kit – not as a complete tool set but as an explorative first step into a prototyping culture for senior citizens. This work was motivated by multiple questions:

Would such a kit be enjoyable and enriching for an older adult? What are the attitudes and assumptions older adults have about their ability to use an electronic tool kit? How can an Arduino starter kit be modified to maximize interest and ease of use for an older adult audience?

Ultimately, this project argues for the development of a well-established framework with an under-represented audience and for inclusion of physical computing as part of a lifelong learning perspective. It implies that senior citizens should have access to programs that empower them as makers.

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2. BACKGROUND
The “older adult” audience encompasses a wide age range and varied interests and ability levels [17]. The group is characterized by age (often age 60 or 65 and older) and occupation (retired from full-time work). This period of life is associated with increased free time, self-reflection, and personal growth [12]. Those who are social and actively engaged within this group are less likely to be depressed [11]. At the same time, their activities are increasingly shaped by digital technology [4]. To address the necessary computer literacy amongst senior citizens, educational programs have been developed for ICT [23]. But such educational programs are missing on the rapidly emerging “maker” culture. Instead, the learning styles of children and adolescents are a far more popular in the maker movement than those of older adults. The narrative is geared more to the emergence of a new, young generation of empowered makers (often supported by their parents/ fathers) than to the needs of a generation of retirees with their own history and expertise. But if “making” truly has a *democratizing* component [2] then senior citizens need to be included. Through work and hobbies, senior citizens have used and adapted to a variety of electronic and mechanical tools and gadgets over their lifetime [18]. This expertise was already identified as an entry point for senior citizens in other cultures [25] but is underused in the US. Unlike in K12 education, where “making” approaches are used to educate a new generation for future jobs, senior citizens already had a working career and build from a different expertise. This fits an approach into maker culture via “repair” activity [9]. Thus, it was anticipated that such experience would positively impact their engagement with prototyping technology.

2.1 Constructivist Learning Tools
This project follows the tradition of construction kits designed to teach basic principles of physical computing through making. These kits consist of a programmable device, a combination of inputs and outputs, various components, and connectors to facilitate the construction of a physical artifact.

The majority of existing educational technologies follow constructivist or constructionist frameworks as proposed by scholars like Papert and Resnick. Building on Piaget, they argue that people construct their own meaning from subjective experiences [20]. Rather than providing direct instruction, teachers can create a rich environment of materials for students to explore, empowering them to construct their own knowledge. Applying these principles to digital learning tools, students use the digital "materials" (for example, the LOGO Turtle) to invent, draw, or program. In that process, Papert suggests, students can develop a deep understanding when they form a relationship with the program ("getting to know the Turtle") rather than memorize facts [19]. Systems like the Scratch environment and the LEGO Mindstorms system provide a "sandbox," where learners have materials at their disposal and are free to make discoveries through a process of trial and error.

Working within the constructivist framework, toolkit designers face a challenge. Constructing an electronic device requires specific components and a particular order of operations. The tension is often resolved with a compromise: packaging components into modules or *programmable bricks*.

Resnick's work combined the LOGO programming language and LEGO bricks, ultimately leading to the development of the LEGO Mindstorms system. The goal was to "make ubiquitous computing accessible to children" and allow them to "build behaviors" rather than structures [21]. They achieve this by simplifying access through technological design. In that spirit, the Pico Cricket kit and littleBits are two additional examples that consist almost entirely of electronic bricks that simplify usage. These kits require minimal wiring and lead to fast results in simple prototyping. But these modules are often expensive and limited because they "black-box" their underlying technology to make it more accessible [16]. For example, users cannot easily combine Pico Cricket modules with littleBits modules. Another challenge is knowledge transfer. When users are competent with any kit, they should be able to continue with more difficult projects. But simplifying proprietary approaches threaten the transfer of skills to new projects that require different technology.

The design of our workshops and exploratory toolkit critically draws from these constructivist approaches. But it also incorporated the different learning requirements of older learners who are used to structured activities and prioritizing for themselves [24]. Our workshop design was further modeled to provide a non-threatening, informal setting and encourage collaboration with people from a similar age group [6].

2.2 Arduino Starter Kits and "untoolkits"

Arduino is an open source programmable microcontroller that is widely available and used in Maker communities and educational settings. Its accessibility and extensive documentation established it as an introductory system for people new to computer hardware and programming [1]. Retailers, like Sparkfun, Adafruit, or Jameco, offer "starter kits" that include Arduino boards and off-the-shelf components like LEDs, servos, and potentiometers. Likewise, researchers have designed open-source kits that feature materials like conductive ink, copper tape, and conductive textiles [3, 15, 16]. These kits often pair prototyping with traditional craft materials like paper and cloth.

Based on such a craft-inspired approach, Mellis et al. suggest an "untoolkit" following an approach that "provides tools and techniques that allow existing components and materials to be leveraged in new ways or by new groups of people" [16]. Their model avoids "programmable bricks" as it combines existing components with low cost solutions to attract and engage new users. Our kit followed the same philosophy and workshop approach but specifically focused on a design for senior citizens.

3. IMPLEMENTATION

3.1 Design Principles

Driven by constructivist approaches, the design of the proof-of-concept prototype evolved 1) through a definition of design criteria related to general accessibility and maker culture approaches; 2) a preliminary kit and workshop design, which was tested in a pre-study at one of the testing locations (a public library) and re-iterated; 3) a final kit and workshop design, which was tested in two different locations with the target group. Overall, the design followed three principle criteria:

- *The components must be open source, DIY-friendly, and exclude elements that require special manufacturing to remain accessible*. This principle was derived from the maker culture's call for general accessibility [10] as well as the above-mentioned concerns to counter the new digital divide among seniors. A low price for the kit was also a guiding factor.

- *The specific needs and physical limitations of an older audience must be taken into account*. This principle depends on different physical capabilities in the senior population. Their fine motor control or poorer eyesight [8] can differ and cause difficulties in computer usage [13], or elderly participants might be unfamiliar with technical terminology [14].

- *The kit should include standard components to remain compatible to other electronic toolkits*. This principle was included to relate as much as possible to systems outside the kit and avoid the aforementioned black-boxing.

3.2 Components and Alterations

3.2.1 Microcontroller

Among the microcontrollers explored for the project were the Arduino Uno, the Lilypad, and the Adafruit Flora. However, the Adafruit Gemma was chosen based on its low cost and simplicity. The Gemma is powered by an ATtiny85 and is directly programmable via USB cable. Unlike the LilyTiny or the Mellis' "untoolkit's" use of the bare ATtiny85, users can plug the Gemma into the computer without using a separate programmer. Each Gemma features two power pads, one ground pin, and three General Purpose Input Output pins (GPIO). The first task was to simplify access to these pins.

Figure 1. Preparing the Gemma Microcontroller.

Dividing the pins on the Gemma board into color-coded "pie wedges" created a transparent organization schema. To further simplify access, standard 5mm sewing snaps were soldered onto the pins. This adjustment did not change the performance but were the main hardware modifications in our approach. The color-coded snaps helped to address the vision and motor-skills limitations of an older audience.

The main drawback of the Gemma is the upload process. It can be difficult to operate the on-board button for that procedure and this poses a challenge for users with dexterity issues.

3.2.2 Wiring

In pilot testing, the breadboards confused the participants more than any other component in the kit. They had difficulty understanding the layout of the breadboard and placing LEDs and resistors in the right locations. Even dramatically enlarged diagrams of the breadboard did not help. However, breadboards play an important role in prototyping; eliminating them entirely would leave users lacking critical skills necessary for future projects.

A simple alteration on the existing breadboard provided the scaffolding needed. To assist participants with the use of the breadboard, colored wires acted as guides, creating "lanes" for each of the pinouts on the Gemma. The wires re-use existing materials, are easily assembled, and can be quickly removed.

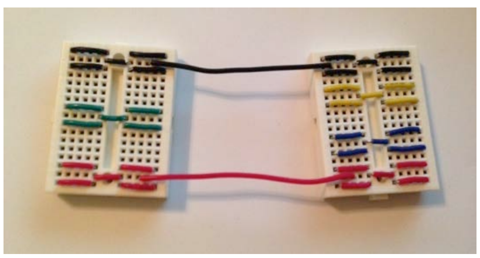

Figure 2. Preparing the Breadboards.

During the pilot test, users identified another issue with the breadboard: physically inserting the wires into the holes. Using 22 gauge wire rather than flexible jumper wires meant that participants had to bend and twist the wires in order to snap them into place. Wires unsnapped too easily from the Gemma. For the final user tests, shortened wires cut down the amount of bending. Ideally, a breadboard with larger holes and thicker wires would be easier to manipulate, like the PicoBoard SMD's audio jack plugs. But this board depends on special cables and was not an option for this test.

3.2.3 Components

Initially, we included a potentiometer, a Piezo buzzer, and a servomotor in the kit. After pilot testing we eliminated these components and resistors, LEDs, and a moisture sensor remained. Participants in the pilot study reported that the leads on the LED were too similar in length to tell them apart. To address this, the LED leads were color-coded by stripping insulation from black and blue wire and slipping it on each lead. The LED now corresponded more closely to the breadboard and Gemma. Creating the color-coded "lanes" helped organize the breadboard but limited the arrangement of the LED and the resistor.

To address this, the resistor and LED were combined into one module by wrapping the resistor tightly around the positive lead for the final study. This was a compromise: it eliminated one wiring step but did not hide it, nor did it require new material.

The final explorative kit contained: one Adafruit Gemma microcontroller, USB cable and hub, coin cell battery pack, LED with resistor attached, breadboard, moisture sensor, 22 gauge wire with snaps soldered to one end, cards with simple circuits to complete, booklet, and a wooden storage box. Each user also needed a laptop to program the Gemma controller. During the evaluation each participant was provided with a laptop that had the Adafruit Arduino software pre-installed and open at hand. As our project focused on hardware components we did not evaluate the programming environment. However, the kit did include its own booklet that offered further documentation.

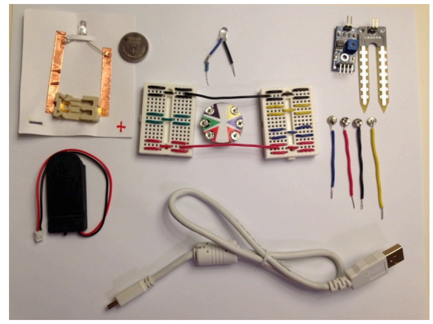

Figure 3. The Components of the Final Kit.

3.3 Study Design

The main study included a recruitment phase, the completion of a pre-test questionnaire, testing phase in a hands-on workshop situation with the researcher as guide by not interfering with the practical work, and a post-test questionnaire. Finally, informal and largely open-ended discussions after the main test finished the study set up. The work was documented through field notes, non-identifying photographs, and in some cases, video and audio recording.

Participants completed pre- and post-study surveys based on the Attitudes Toward Computers Questionnaire [11] to document their familiarity and comfort with computers, current and former hobbies, and impressions of using the kit. The subjects were asked to either "agree" or "disagree" with a serious of statements on a scale from one to five. Informal group discussions after the workshop gathered additional insights. Seven different mini workshops were held, each with one to three participants per workshop. Fifteen people participated in total. Each workshop started with participants reviewing and signing the consent form and filling out the pre-study survey. Using the included booklet as a guide, the workshop leader initiated the conversation about the kit and its components, identified the elements, and encouraged the participants to build a basic circuit that still excluded the Gemma but familiarized them with the use of the wires, batteries, and LED. Then, the Gemma and the breadboard were explained. Using a poster featuring the code from a basic programming sketch, the code was explained and participants created a simple circuit that made a LED blink controlled by the Gemma. Functionality of the Gemma was described (e.g. the uploading process) and modification of the code (e.g. the blinking intervals) was encouraged. Leaving the LED in place as an output, the hygrometer was introduced as a sensor. The necessary wiring was shown in a diagram and participants were expected in this final step of the technical part of the study to complete the circuit for the hygrometer with minimal guidance. The result was a basic moisture sensor with the LED as its output. The last step was to upload the necessary code onto the Gemma. Due to the more complex nature of this code sketch, it was not explained in full depth, but instead we focused on the familiar part of the sketch that turns the LED on when the sensor is moist. Participants were asked how to make the hygrometer more effective by changing the sketch. For example, users could change the code so that the LED lights up when the sensor is dry, indicating that the plant needs to be watered. The build project was tested on a moist paper or a small potted plant. Finally, we asked participants to come up with other possible extensions for this sensor, distributed the post-study surveys, and held an open discussion. A full study lasted approximately 90 minutes.

3.4 Recruitment

The kit was tested in workshops conducted at a public library in Sheboygan, WI and a retirement home in Atlanta, GA. Users were age 60 and older, retired from full-time work, and able to use their hands to complete a simple project. Participation was voluntary and presented as part of the optional educational programming at these centers.

Notably, we heard repeated variations on the phrase “this is not for me” over the course of the recruitment. Many potential users shied away as soon as they heard words like “computer,” “wires,” or “electronics.” The retirement home already offered a variety of classes using new techniques, including alcohol ink jewelry making, silk painting, and other activities that were likely unfamiliar to members. Computer classes and tutorials, however, were presented as “services” not “activities” and did not emphasize fun or creativity in the descriptions. Within the framework of workshops and classes, computing can be perceived not as a playful, creative activity but as alienated work. Despite bright, fun promotions for the workshops, many people perceived the topic as too technical to be a leisure activity.

4. RESULTS

All participants successfully constructed the blinking LED and soil moisture sensor tasks. Design elements, such as the color-coded controller and the breadboard proved to be helpful scaffolding and all users successfully placed the wires within the guiding lanes. Eight participants required some degree of assistance, primarily during the upload procedure.

Nearly all users reported difficulty with two actions: pushing the tiny reset button on the Gemma and inserting wires into the holes on the breadboard. Both issues were partially addressed in the design but since the kit is comprised of off-the-shelf products, the size of the materials could not be changed. Notably, visibility was a smaller issue. No participant used the magnifying stand.

4.1 Role of Gender

In this study, 80% of the users were female. The gender imbalance can be attributed to several factors. First, women tended to recruit other women. Secondly, several male potential users had health issues or physical impairments that prevented them from participating – their wives participated instead. Notably, at least three female participants mentioned that they are the “handy” members of the household. “My husband calls me ‘gadget girl’,” said one participant.

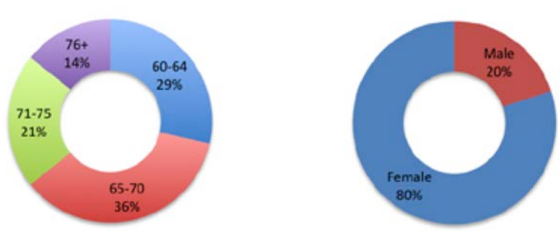

Figure 4. Age and Gender Breakdown of Participants.

In the follow up discussions participants did not see the activity itself as gender specific. On the one hand, when asked to whom they might recommend a similar kit, most users gave a male name or mentioned a grandson, nephew or male acquaintance. On the other hand, at least half of the participants asked why a survey question about gender was included. The participants who asked about this particular question were quick to describe such a statement as old-fashioned. This reaction indicates that attitudes toward gender in computing have shifted considerably since the study by Jay and Willis was published in 1992.

4.2 Positive User Attributes toward Computing

In the pre-study survey, nearly all participants self-identified as frequent computer users (80% report daily computer use) who view computing as worthwhile and fun. Over half of the participants said that they “strongly agree” with the statement that “computers are fun.” Like previous studies [15, 22] it shows that seniors are not averse to computer use. The increasing popularity of tablet devices and ubiquitous computing also affected some of their answers. “A year ago, I would have answered some of these [questions] differently,” a new tablet owner said. Another asked “Is this part of the ‘Internet of Everything’?” These statements suggest that participants were familiar with specialized terms and developments.

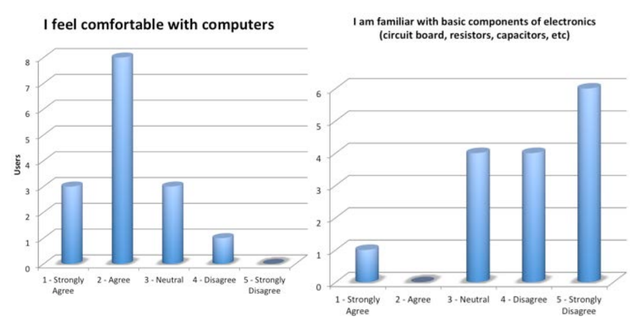

Figure 5. Seniors feeling comfortable with computer user (left) vs familiarity with electronic components (right)

As with all educational programs in the target institutions, this imbalance might be connected to self-selection of participants. Only interested seniors did participate and the workshops were not obligatory. While the computer as media device was largely accepted, the interest in hardware was much lower. Only one participant reported a strong familiarity with electronic circuitry and only three participants expressed a strong willingness to attempt to repair a broken non-digital appliance.

4.3 Enjoyment and Enrichment

In the post-study surveys, the majority of participants reported that they enjoyed working with the kit and felt a sense of accomplishment afterward, but were not certain about continuing to use a similar kit.

Most people indicated that they would recommend a kit to another person in their age group and indicated that their adult children or grandchildren would enjoy it, too.

We had projected that coding would pose particular difficulties for the participants as we anticipated basic computer literacy, but no familiarity with any programming language. However, one female participant was acquainted with C, another took a programming class in college, and a male participant had recently retired from a technical position that required a deep understanding of complex software systems.

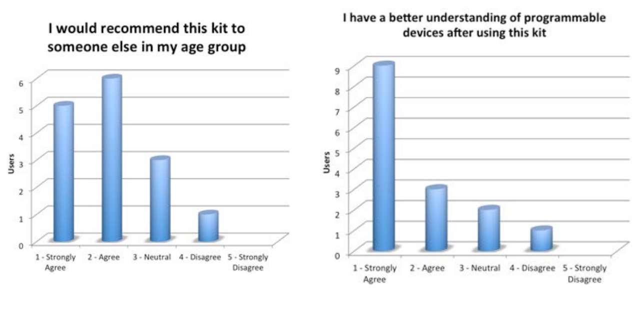

Figure 6. Recommending the kit to own age group (left); better understanding of programmable device after workshop (right)

All of the participants were able to handle the basic concepts in the first blink sketch. The Arduino software and the laptops themselves were more challenging for participants. MacBooks were provided, but some participants were more familiar with a mouse and had difficulty positioning the cursor or clicking on icons using the touchpad. The delicate timing of the uploading operation on the Gemma proved especially challenging. It required them to quickly move from the Gemma to the laptop screen. Some needed as many as five attempts to successfully upload the sketch to the Gemma. This issue was, by far, the biggest problem in using the Gemma over a larger board with an easier and more seamless uploading process.

4.4 Constructivist Approach with Older Adults

Older users were very tentative with the materials. Several participants expressed concerns about breaking or damaging the components and most were initially reluctant to bend the wires until assured that it was fine to do so. In this age group, the feeling of anxiety has been noted as one the biggest barriers to learning [6]. Studies suggest that training can ease these anxieties by creating positive experiences for participants to build on [5]. Explorative handling of technology, failing, and even destructive activities are part of maker culture. We thus see a lot of potential to use a “making” approach in providing such positive re-enforcing conditions. As one participant noted, “I guess you can’t be too afraid to really bend these wires.”

The facilitator ultimately played a larger role than anticipated: she became more of a teacher than a coach, particularly in the introductory sections. The importance of the instructor’s role in senior education has been noted before [7] but a leading instructor role also reduces explorative behavior among participants. They almost asked for permission to complete an operation rather than engage in exploration.

A strict constructivist toolkit framework seems not to be the right fit for an older adult audience at this introductory stage. One study suggests that, among older adult learners the 55 to 65 age group prefers to “learn by doing,” while the older age groups both prefer to learn by watching and listening [26] (our study had 71% participants above 64). In our introductory workshops, participants preferred to follow the lead of the instructor. They did, however, extrapolate from familiar actions like inserting the color-coded wires into the breadboard to complete a circuit. Particularly situating the participants in a group helped spark conversations and allowed the facilitator to step back into a coaching role, especially when two users shared one computer.

4.5 Role of Life Experience

We had hypothesized that a rich variety of work and life experiences would help older adults learn how to build a simple gadget. But the results suggest that around half of the participants had difficulty connecting their existing skills with the use of the kit. Four participants strongly disagreed that their hobbies were helpful. This might indicate that they viewed the use of a programmable microcontroller as a “new” skill, unconnected to their previous experience. Participants reported a wide variety of hobbies and six of them cited craft activities with some relevance to the workshop (jewelry making, sewing, model making, knitting). Sewing skills were noted as the most helpful and two participants specifically cited the familiarity of sewing snaps. These answers indicate that incorporating familiar materials in a kit increases a senior user’s comfort level, not unlike Mellis’ “untoolkit.” Nearly all the participants indicated that they were at first intimidated by the materials in the kits. Including “everyday” items, such as snaps, may put users at ease.

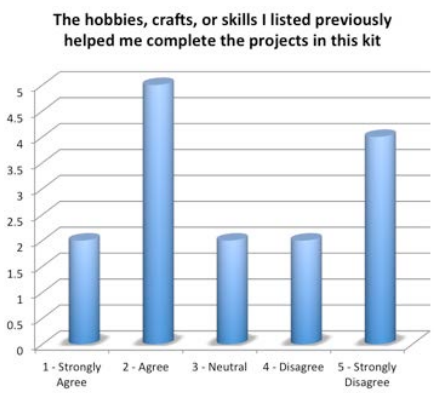

Figure 7. Importance of Past Hobbies for the Prototyping

Users were by and large unfamiliar with circuitry. One notable exception was a man who enjoyed building model cars and railroads. He was easily able to come up with ways in which to integrate a microcontroller into these hobbies. For example, he suggested working with his grandson to create a model car with working headlights. We assumed the users would have a stronger base of knowledge in this area and more of a willingness to “poke around” inside their appliances. Instead, eight of the participants (53.3 %) disagreed or strongly disagreed that they would tinker with a broken appliance.

Participants clearly distinguished between their ability to use a personal computer and their lack of familiarity with basic electronics. In each discussion, participants cited computer literacy as a “necessity” for everyone, while electronics were a topic for a much smaller group of experts. That does not mean they were adverse to it or incapable of learning, though.

80% of participants agreed that they had a better understanding of programmable devices after the workshop and half of the participants noted during the closing discussions that they had a better sense of how their everyday gadgets work. In these follow up discussions, a majority of the users imagined practical uses for homemade gadgets (medication reminders, security systems). This indicates the interest in mainly practical applications for a further customized maker workshop.

5. CONCLUSION

We presented the design approach toward an explorative prototyping kit to investigate issues for novice senior users. A facilitator with basic soldering and wire-stripping skills could reproduce the kit and lead a workshop with minimal adjustments. All parts are off-the-shelf components, inexpensive, and largely accessible. One of the advantages of this DIY approach is that modifications function as scaffolding and can be easily removed when users become familiar with the kit. The user is not left with a set of proprietary modules but works with a toolkit that can grow as he or she acquires more knowledge and components. Much like our kit design, our approach did not aim to provide a complete solution but to explore our original questions regarding particular challenges to engage seniors as makers. The design and its evolution describe key challenges, but do not yet provide a conclusive design framework.

The same applies to the instructional design. The workshops proved to be effective in engaging senior citizens, were largely appreciated, and provided a sense of accomplishment. When working with the kit, older adults responded best to a combination of instructionist and constructivist methods.

Off-the-shelf electronic components are key to an open source approach but are not optimized for beginning users or users with special needs. While the modifications helped the participants in the study, the small size of the un-modified materials was a major hindrance to all of the users. To avoid special products like littleBits or Mindstorms that fall back into "programmable brick" approaches, creating off-the-shelf electronic components in a large size could be a solution. Not unlike large-print books, the goal would not be a change of the functionality but of the scale.

This is supported by the fact that it was not the computer that intimidated the participants, but the wires and breadboards. We had hypothesized that older adults would feel more comfortable with physical components due to their (expected) personal work experiences with technology. Instead, participants were initially not comfortable with electronics at all. This might already be a trace of the results of black-boxing of technology in otherwise computer literate senior citizens. The generation that witnessed the rise of the computer remains puzzled by its basic inner workings. However, even though the subjects in this study were initially uncomfortable building circuits, every participant successfully wired and programmed the moisture sensor. They also reported increased understanding of the underlying technology and clearly showed sparked interest in the follow up discussions: over half of the participants asked to take home the guides or requested additional information to share with friends and family. Others asked for copies of the photos taken during the workshops. Despite their initial apprehension, most felt pride in their work and their ability to learn a new set of skills. The question is not whether there is a huge untapped group for creative computing – but how to find ways to engage them effectively.

The possible perception that computer science is work and not a creative outlet might discourage older adults from exploring activities that go beyond computer literacy. This perception is reinforced when computer skills are described as enhancing primarily a new work prospects instead of highlighting the general importance of computing as a cultural and creative practice.

The exceptions were participants who came in with an existing interest in a hobby that could be augmented with a microcontroller: one participant was recently retired from a technical profession where he worked with complex software. This user not only completed the circuits more easily than the other participants, he came up with several ideas for additional uses for the microcontroller as he worked. He also recognized that his existing skills were put to good use with the toolkit. This tying of digital technologies into existing expertise through an accessible kit stands out as possible continuation of the here suggested approach.

But such a connection depends on the context. The senior centers and retirement communities visited for this project categorized computer literacy classes as utilitarian tutorial sessions and this category posed challenges starting in the recruitment phase. In contrast, craft-based classes were framed in a way that encouraged gradual skill building, creative expression, and sharing expertise. We project for future work that physical computing workshops for older adults should be offered in the same format and context as knitting or woodworking groups: regular meetings led by a knowledgeable facilitator, where group members receive guidance on own creative projects, which they develop based on their own interests and expertise.

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