CULTIVATING DESIGN CITIZENSHIP
A PARTICIPATORY DESIGN EXPLORATION ENGAGING PEOPLE WITH DISABILITIES

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1. INTRO AND BACKGROUND

The Arduino for Disabilities Project was the first project in a multi-year program of faculty led design research sponsored by the Corzo Center for the Creative Economy at the University of the Arts (UArts) in Philadelphia, PA. In this project five people with disabilities were partnered with five design students in a collaborative environment to explore the use of a powerful low-cost open-source micro-controller called the Arduino. Each team was challenged to apply their new Arduino skills toward solving a real life problem for the team member with the disability. This was not a case of “teaching the disabled” but rather a case of building a community of practice. As noted by anthropologist Jean Lave and social learning theorist Etienne Wenger a community of practice is formed when people engage in a social process of collective learning around a shared topic (Lave & Wenger, 1998). This community of practice engaged design students as well as people with disabilities with little or no prior skill with the Arduino in a process of learning. What unfolded powerfully impacted all who participated.

According to the US Census Bureau’s American Community Survey of 2009, 12% of our population, or 37.6 million Americans, have a disability. These Americans often have unique needs that are not readily met by off-the-shelf products. Consequently, specialized products are frequently the only option but can be unaffordable. According to the same survey, 64% of the non-institutionalized people with disabilities, ages 21-64, were unemployed. This project evaluates one low cost approach to empowering people with disabilities to address these unmet needs.

The Arduino is an easy-to-use low-cost micro-processor that offers the possibility for customizable solutions to communicate or manipulate the environment. The use of the Arduino is now being taught in colleges and even some high schools. The Arduino can use input from sensors to switch on and off various devices such as motors and lights. This technology can offer more control of personal space and daily tasks. It can foster independence for a population that often must rely on others for even simple tasks. This tool, once understood, can equip an individual to solve their own problems, especially as their needs evolve.

The Arduino for Disabilities Project was an open-ended project that explored a rich intersection of disabilities, microcontrollers and design education. It uncovered a new understanding of the negotiations, tools, and systems needed to successfully implement such a project. For the people with disabilities, the project offered new knowledge, a powerful tool, and the possibility of more control. For the design students there was the sense of doing good, learning about an unknown population segment, and working with a new technology. What was not fully expected was the depth of relationships that would emerge in this process. Nor did anyone anticipate how profoundly the design students would be affected by their partners with disabilities.

A few words about nomenclature and abbreviations used in this paper: In many circles it is considered best practice to use a “person first” descriptor such as “person with disabilities.” This places the emphasis on the person rather than the condition. For the remainder of this paper the persons with disabilities will be referred to as a “participant from Liberty” or on occasion a “Liberty participant”. In explanation, Liberty Resources is a non-profit group that advocates for and promotes independent living for people with disabilities in the Philadelphia region. The Academy at Liberty Resources assists people with disabilities to enter or re-enter the workforce. Both of these organizations have been strong supporters of this project. All the people with disabilities in this project were
recruited from either Liberty Resources or the Academy at Liberty Resources. The Design and Multimedia students were recruited from the University of the Arts (UArts) in Philadelphia. They will be referred to as the “participants from UArts” or as the “UArts students.”

2. PURPOSE
The project objectives were:

a. Empower the individuals with disabilities to co-design (Sanders & Stappers, 2008) and produce solutions to their self-identified challenges using the Arduino micro-controller.

b. Identify the obstacles that present themselves in this process.

c. Determine what tools, structures, methods, technologies and learning systems might improve this learning and making environment.

d. Document the dynamics of this community of practice and the consequent benefits to the UArts students.

e. Evaluate the project as an educational model for encouraging design citizenship in young designers.

3. PARTICIPANTS
To recruit participants we first built a playful demo project to showcase the possibilities of the Arduino. With the demo in hand, five participants from Liberty were easily enrolled. Students from the Multimedia and Design Departments of UArts were then enrolled. Five students committed to full participation and three additional students committed to part time support roles. We held an “Ice-Breaker” event to introduce the project and all of the participants to each other. We agreed to meet for 3 hours every Friday morning for 11 weeks.
The participants from Liberty included three males and two females, who ranged in age from 28 to 49. Three of the Liberty participants had some college education, and two had completed high school or received a GED. Four rated their health as “good” or “excellent;” one rated their health as “fair.” They all lived independently and were able to perform activities of daily living (bathing, dressing, toileting, transferring from their chair, eating).

At the beginning of the project, all reported using the internet occasionally or frequently, and reported owning an electronic device such as a Blackberry or iPhone. All reported being either “comfortable” or “very comfortable with math and science,” although two reported being “not comfortable” with computer programming. Two participants from Liberty expressed interest in learning about technology.

The disabilities that the participants from Liberty identified included lymphedema, cerebral palsy, scoliosis, multiple sclerosis, severe arthritis, paraplegia, congestive heart failure, hemiplegia, constant pain, memory and vision issues. All use a motorized wheelchair.

The full-time participants from UArts were three males and two females, ranging in age from 21 to 31. Two were current students and three had recently graduated. Their majors were in Multimedia and Industrial Design. Their experience with the Arduino ranged from “None” to “Expert: Have taught to others.” Four of the UArts participants had experience teaching topics other than the Arduino, and in general characterized their patience as ranging from “Extremely patient” to “Patient.” Three additional part-time participants were also from UArts: Kyle M., Kyle S., and Brigid.

Three of the full-time participants from UArts knew someone (family member, friend) who was a person with disabilities. One student had worked with persons with disabilities of all kinds: developmental as well as physical. Another student had a family member with disabilities caused by a stroke.

In general, the UArts students were looking forward to working with the participants from Liberty. One of the UArts students commented they wanted to experience the dual challenge of teaching the Arduino and “learning what it is like to live with disabilities.” Another was “excited to see how creative technology can positively influence the lives of individuals with disabilities.”
4. WHAT WE DID

A curriculum was developed to teach elementary circuits and the basic use of the Arduino. Given that we were unfamiliar with the disability community, we adopted an approach that was slow and patient and included a significant amount of listening. We quickly found that the UArts students had to each discover the boundaries of what can be asked and how much to do for their partner. Keeping a sense of humor was a key ingredient as mistakes were inevitable.

The following critical document from Liberty Resources guided us in understanding the perspective of our Liberty partners. In this document the term “consumer” refers to a person with a disability.

![Consumer Rights and Responsibilities]

The curriculum itself was based on the pedagogical principles of “reducing complexity” and “making things visible.” These principles have been identified by noted cognitive scientist Donald Norman (2002) to improve product usability, but here are applied to curriculum. The use of these principles can be illustrated by the lesson
plan for Class 1. Here circuits are introduced and built starting with the simplest circuit of one button battery and one LED (Figures 5 & 6).

After learning basic circuits, the breadboard was introduced and each participant built a circuit using a breadboard. Lastly, switches were introduced including a knife switch, a micro-switch and a tilt-switch. All of these steps helped the participants make the conceptual leap that the Arduino is simply a switch - a complex and programmable switch, but a switch nonetheless.

The pedagogy was actively hands-on. Each time a new concept or component was introduced, everyone immediately began building it. We limited the scope of the curriculum to teaching how to control only two sensors and two outputs. This basic education would later be expanded through the context of the individual projects.

After five weeks of basic instruction, partners collaborated through participatory design process to address a problem drawn from the life of the participant from Liberty. In some cases co-design was engaged, though this was not appropriate for every team. Project development continued for 9 weeks.

5. DATA COLLECTION AND ARTIFACTS

- **Initial Surveys of Liberty participants.** Structured surveys were taken of the participants from Liberty at the start of the project to collect basic demographics, functionality (ADLs and IADLs), and desire and attitude toward technology.

- **Initial Surveys of UA Arts students.** Structured surveys were taken of the students from UA Arts at the start of the project to collect basic demographics, knowledge of, empathy with, and desire to help people with disabilities.
• **Audio records.** Informal debriefings were recorded after each class and work-session.

• **Photographs.** 1,513 photos were taken throughout the course of the project.

• **MidPoint Video Interviews.** Open ended questions were asked halfway through the project of both Liberty and UArts participants.

• **Home Visits.** Three participants from Liberty invited their partners into their homes. Photos and stories were collected to capture insights gathered during these visits.

• **Blog Entries.** All were invited to share impressions through voluntary entries on a public blog. [http://arduinofordisabilities.wordpress.com](http://arduinofordisabilities.wordpress.com)

• **Written Exit Interviews.** All the UArts participants produced written responses in their closing interview to open ended questions: what did you learn, what was difficult, what was surprising, are there tools that could be designed to facilitate this project in the future.

• **Video Exit Interviews.** All participants from Liberty were given a set of questions to consider and then filmed answering them. These open ended questions prompted responses on what was learned, what was difficult, what was surprising, how did the project impact you, did you change your environment as a result, did you develop more confidence or independence.

These interviews were transcribed and analyzed using content analysis. AtlasTI software and a grounded theory approach were used to uncover themes.

6. **OBSERVATIONS**

We quickly learned how difficult ordinary tasks such as commuting can be for the Liberty participants. We learned the nickname for Para-Transit is Para-Stranded. The Liberty participants generally remained very cheerful despite their difficulties. The UArts students found this inspiring. In the debriefing after the first class, Michael (from Liberty) declared his deep appreciation that able bodied college students wanted to spend their summer hours working with people with disabilities. He confessed how little interest he had for people with disabilities prior to his stroke. The candor we witnessed in the first class was both startling and refreshing.

By the second class, we observed how difficult it was to handle the small parts with precision for most participants from Liberty. We observed how some could only work in their laps and could not work at a table. One person could only use one hand, which revealed that even keeping parts in a ziplock bag was an obstacle.

By the third class, we witnessed personal space dissolving as everyone began sitting and working closer together (Figure 8). Trust had been built, and we found the Liberty participants willing to very openly discuss their lives. Each UArts student continued to negotiate the boundary of how much to do themselves and when to allow their partner from Liberty the opportunity to struggle with the components.

![Figure 8. Christine’s hands intermingled with Mitchell’s.](image1)

![Figure 9. Branden in complete absorption.](image2)
When individual projects began, we observed that the task of identifying a project problem was surprisingly difficult for the Liberty participants. This may have been from a deeply embedded acceptance of the constraints of their conditions. In several cases it was only by being in their homes that we could discover an issue for their project to address. This became a clear role for the UArts students – to help open up new possibilities where they could not have easily been seen.

In the homes of the participants from Liberty, we observed a notable propensity toward repurposing and modification rather than creation from scratch. This can be seen in the following photographs from our visit to Mitchell’s apartment:

![Figure 10. Two chairs repurposed as a table base for a laundry table.](image1)

![Figure 11. A dislodged shelf used to create a sloped drafting table.](image2)

It is also worth describing a specific finding from the visit to Mitchell’s home. Upon arriving Mitchell generously offered to give us a complete tour of his apartment. Standing in his bedroom a series of gently probing questions illuminated a difficult problem that had previously gone without note. We learned just how precarious it is to transfer unassisted from the wheelchair to the bed at night. If it doesn’t go well you may end up on the floor for a long time. What exacerbates the danger is that Mitchell has to make this transition in darkness because he has no way to control his overhead light from his bed. We found that several of the other Liberty participants shared the same problem. This discovery led to projects using the Arduino to turn off the bedroom light once in bed.

**Toward Citizenship:**

The design students commented on their increased skill in teaching, as well as changes in knowledge of / advocacy for / empathy with persons with disabilities. Personal, close connections were formed between the two groups, which included the sharing of technical skills and information, but also went beyond it to include empowerment of both the Liberty and UArts participants:

“… the excitement, and the connection that is being formed in this whole project between the students and the individuals from Liberty, is one level, which is a real positive. And I think there is a sense of empowerment which comes out of that aspect, which I think is hugely positive. And then I think there is a real possibility that some devices may come out of this, that will be meaningful to people’s day to day lives - and people may even learn how to adapt it to new circumstances as they go forward.”

For many of the UArts students, they perceived their roles within the project as instructors:

“So far, it’s only my third week, but I definitely feel I’m working on my teaching skills. I think it’s always something I’ve wanted to improve on, and so far it’s to tutor, to get into people’s minds while you’re
tutoring - to understand tutoring. I've tutored before in the past, but doing one on one help with people I'm learning a lot, what pace you should move at, and how to get the ideas across which is really important.”

UArts students were impressed and somewhat surprised with the enthusiasm their Liberty partners showed:

“so far I'm really happy to see how well the people are grabbing the ideas, I would say it's not the exact same pace as everyone in college, it's a lot faster - that's something so far, is how people are really getting into it, and the fact that people are showing interest is really amazing, because it's something that usually if you bring it up to your relatives or parents, they go “oh I don't know what that is…” just let it go, let it slide, so it's interesting to see people latch onto it - it’s an interesting environment…”

An aspect of the UArts students’ learning was an increased understanding and empathy with the participants from Liberty- not only of their physical difficulties but also within the design process itself:

“Being a part of this experience allowed me to better understand the types of struggles that individuals with disabilities endure on a daily basis.“

“it’s material for them to think about - for example how their wheelchair works. And maybe it’s not very practical for them to … create their own tools, but maybe I think they can come up with ideas - because they are the people who encounter those problems. So I think for them to come up with ideas can help some other designers to improve those tools for them.”

“We had a breakthrough sharing knowledge between each other. Each of us always had something to offer the other. There was a heightened sense of involvement and I felt as if the knowledge that I offered was supporting the project’s progression.”

This sense of identification with the Liberty participants’ problems also supported a sense of their own growth as designers:

“This experience has provided me with insight for how to effectively utilize design psychology when building for individuals with disabilities, ultimately allowing me to be a better designer or maker in general.”

“I learned that a person’s attitude is key in overcoming any disability and that a bad attitude is a major disability in itself.”

UArts students ended their experience commenting on their interpersonal rather than technical learnings:

“…my feelings about the class: I learned that each person is different and has their own way to solving problems, and each is unique and funny. Each one of us has our own way of bringing humor to the program too so it was never boring. I learned that I was a person that needed to learn more and to open my mind”.

Themes from Liberty interviews:

For the Liberty students, learning about the Arduino had a few different dimensions: it was a journey of mastering technical concepts and skills, but it also included creativity and friendship. We saw less fear and more confidence in using new technologies among the participants from Liberty; several also expressed improved cognitive and social abilities. Liberty participants also noted that their experience of learning electronics and programming changed over the course of the sessions:

“I’m having a ball. When I first started I thought ok, this is going to be tedious, I’m not going to like it - I originally thought should I stick with it, or abandon it? And I love it, because the more I come, the more I
I’m kind of upset because pretty soon I have to be back at work. But I would like to continue this. And it’s more than just learning, you grab so much from here - like Kevin and I, we formed a friendship that goes beyond here. So even the amount of friendships that are formed based on something like this - you know, is incredible!"

“Yes, it’s been really really - better than I expected. Because I’m not a hands-on mechanical person. I know how to sew. I can sew really good but as far as equipment, that kind of stuff - no, I have no (shaking her head) I was like, where does this go? What is this? But I’m getting it together now, and in the beginning I had a lot of difficulties seeing because the stuff was so small - but I can see the stuff a lot better now, and I thought to bring a magnifying glass to class but I didn’t have to. I really like this class. I’m really glad I was in the lobby that day when he was talking about it so I could be in the class ‘cause I would have really missed out on something good if I wasn’t there”.

For some of the Liberty participants, the project also supported improved cognitive and social skills, and an increased feeling of confidence and independence. One noted an increased awareness of mechanical processes:

“I’m a little bit more aware about how things work now. When things break around me now I tend to take them apart (laughs) - small things, not big things like (a toaster) - when small things come apart I try to see if I can put it back together - before would just throw them out, but now, now I’ll say “well maybe I could fix this.” You know - sometimes I actually do fix it”.

Another participant noted changes in his cognitive abilities:

“...basically a small amount of knowledge was opening up where I was starting to remember things - my past, what I did - what I’ve noticed lately is that seems like some things come to me a little quicker - yeah - I wouldn’t say a great improvement but like maybe like having a conversation, talk about a topic, I might forget the exact topic, but a day later I’m clear again. And I thought that was interesting because it seems like more fruitful…”

Lastly, participants commented on an increased feeling of independence and confidence, as well as an appreciation of increased knowledge:

“... that I’m not as slow as my kids think I am. My kids think they have to do everything for me. And they don’t. I keep trying to tell them that. I’d rather do stuff for myself. But they still think they have to do everything for me. But they don’t know I’m looking for an apartment. Trying to find me an apartment so I can leave my house (interviewer: and you feel you could do that)… I am going to do that”.

“It is all about seeing the simple and realizing the possibilities you have to do bigger things. I now realize that by learning how to do these simple things, I can increase my independence. I never feel like you should ever stop learning because without knowledge you become complacent. The knowledge that everyone from UArts brought to the class is something that I really appreciate”.

7. PROJECT OUTCOMES

Note – the projects themselves were not the sole objective and some of the tangible results achieved by means of an Arduino could certainly have been achieved by other simpler means. Given that the point was to empower the participants from Liberty to learn to use the Arduino, the choice of project could even be viewed as arbitrary.

Completed projects included custom controls for lighting, a knee-actuated and wheelchair mounted camera, and a wheelchair accessory for signaling in traffic. At the last class, each team demonstrated their project either by showing a functioning prototype or by showing photos and video of the off-site installation.
Figure 12. Brandon (right) and Kevin led off with their prototype showing wheelchair actuated floor switches that would turn on and off Brandon’s lamp in his room.

Figure 13. ChiaYing worked with Marsha to develop switches for Marsha to turn off her lights from her bedside table. Marsha got out her acrylics and customized her switches as well as helped with the overall concept development.

Figure 14. For Marsha’s project the Arduino and a solid state relay were packaged in a plywood box with an acrylic cover so Marsha could see the electronics.
Figure 15. Mitchell (right) and Christine worked on a project that will actuate a bedroom light for Mitchell triggered by an ultrasonic rangefinder.

Figure 16. Michael (left) and Joe’s project was a wheelchair mounted and knee actuated camera. It allows Michael to take photos while driving his wheelchair.

Figure 17. Glenda (right) and Ben’s project was a wheelchair accessory for use in traffic to signal when her wheelchair is turning. While the electronics are completed they still have to be assembled into the bright orange cover that Glenda produced with her sewing skills. This cover will be slipped over the back of her wheelchair.
8. CONCLUSIONS

The participants from Liberty all expressed enthusiasm and empowerment and felt some success in learning a new technology. All five participants from Liberty subsequently enrolled to continue with this project during the summer of 2012.

Obstacles and key areas for improvements were documented and are noted in the next section below.

The UArts students learned a new technology, increased their skill in teaching, expanded their understanding of design research methods, and made significant changes in their knowledge of / advocacy for / empathy with persons with disabilities. Profound life-lessons were absorbed by the UArts students by working closely with such an open and candid group as the participants from Liberty.

9. NEXT

We identified several concerns that could be addressed in future iterations of this project:

1. Components were difficult to handle and hard to see. They also required fine motor skills to manipulate. New shields for the Arduino could be considered. These might also be entirely separate circuitboards that use larger components. Much larger banana jacks or 4 mm headphone type jacks could be considered rather than delicate jumper wires.
2. Laptop electronics workspace could be designed to enable work from the wheelchair. The inclusion of clamps and clips would make it much easier for people working with only one hand.
3. The Arduino instruction could be improved and clarified and should be documented.
4. Instructions on paper should be provided for those participants that have no internet access or no laptops.
5. Better coaching could be provided to help define boundaries between the responsibilities of the design students and the Liberty participants.
6. More reflection should be included to help draw out the learning.
7. More data collection through more surveys. More tests would also better verify understanding.

REFERENCES


