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Peer-reviewed paper

TalkBox: a DIY communication board case study

Foad Hamidi, Melanie Baljko, Toni Kunic and Ray Feraday

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Abstract

Purpose – *The purpose of this paper is to present TalkBox, an affordable and open-source communication board for users with communication or speech disorders. Making and tinkering methods are combined with community engagement and participatory design to create a democratic and accessible approach to assistive technology design.*

Design/methodology/approach – *The authors employed a community-engaged participatory design methodology where we incorporated input from stakeholders into the design of the interface. Close collaboration with our community partner allowed us to make informed decisions on different aspects of the design from sourcing of the material to testing the prototype.*

Findings – *Through describing TalkBox, the paper presents a concrete example of how assistive technology can be designed and deployed more democratically, how collaborations between academia and community partners can be established, and how the design reflects different aspects of the methodology used.*

Originality/value – *This paper explores the question of how can open-source technology and making methods contribute to the development of more affordable and inclusive designs through a concrete example.*

Keywords *Participatory design, Community engagement, Communication boards, Do-it-yourself (DIY), Making and tinkering, Open-source hardware*

Paper type *Research paper*

1. Introduction and background

In recent years, several technological design and fabrication trends have emerged that have supported "citizen designers"[1] to realize and fabricate their design ideas in new ways. The Maker Movement (or do-it-yourself (DIY) movement) refers to the body of amateur and professional designers who engage directly with every stage of the creation of their customized, small-batch designs through the use of novel (e.g. 3D printing) and/or traditional (e.g. glassblowing) manufacturing methods (Anderson, 2012). Many Makers use open-source hardware and software that can be tweaked and reused freely. Open-source hardware is able to make use of electronic components and microcontrollers that have become more readily available and increasingly affordable. Online support communities are flourishing, providing extensive coverage of practically every aspect of the design and fabrication process for novel physical, digital objects. Barriers to necessary software are increasingly mitigated: the barrier of cost through increased availability of free or open-source packages, and the barrier of knowledge through the proliferation of more user-friendly, less-specialist software user interfaces (Lindtner *et al.*, 2014).

Although some researchers and activists have identified the possibilities of these developments for digital assistive technology, the potential has not yet been fully explored (Hurst and Tobias, 2011). The use of open-source hardware and software to make customizable designs that differ from

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extant solutions can be considerably easier than other approaches (e.g. trying to hack commercial off-the-shelf technologies or designing from scratch). However, barriers exist for people who would like to adopt the DIY approach, such as knowledge barriers (having limited knowledge of programming and/or electronics), cost barriers, and physical and cognitive barriers (Hook *et al.*, 2014; Hurst and Kane, 2013). In this work, we present a case study of an open-source customizable communication board that demonstrates the possibility of using Maker methods for the development of digital assistive technology and specifically communication aids.

Conventional computer access tools, such as conventional keyboards, mice, and touchpads, among others, present significant accessibility barriers for individuals who do not have the required motor skills, and a variety of alternative input devices and techniques have been developed to address this barrier (e.g. single-switches, modified keyboards, eye-gaze, and speech-based input, among others) (Beukelman and Mirenda, 1998). These devices provide a large variety of possibilities and address the needs of many users. And yet there are individuals who cannot easily use them. Users with disability form a very diverse population and many users have complex needs arising from multiple disabilities. The fit of the device to the user's needs is a known factor in assistive technology abandonment (Phillips and Zhao, 1993), which unfortunately, occurs at a high rate (approximately 30 per cent (Scherer, 1997)). While there are many factors affecting assistive technology abandonment (Wessels *et al.*, 2003), several researchers have recommended more consumer involvement in both the design and choosing of technologies as a key strategy to decrease abandonment (Phillips and Zhao, 1993; Riemer-Reiss and Wacker, 2000; O'Rourke *et al.*, 2013).

Furthermore, as digital technologies become complex, it becomes harder for users to understand how the tools they use work, forcing them into a passive consumer role. Design visibility, the idea of supporting user clarity on how a system works, provides the potential for the user or other stakeholders to understand how the system works, be less intimated about attempting to customize or fix it, and to learn about interfaces and electronics through hands-on use (Perner-Wilson *et al.*, 2011). Finally, other factors such as delays in funding and local service delivery makes the development of easy-to-deploy technologies that can be used until a suitable solution is adopted desirable. The DIY movement offers the possibility of increased consumer involvement, since the user can be directly involved in the design and fabrication of the technology he or she will be using (Hurst and Tobias, 2011). This is inline with assistive technology design research that recommends participatory and inclusive methods that involve users with disabilities and their experience directly into the design and improvement of assistive devices and systems (O'Rourke *et al.*, 2013).

An increasing number of open-source digital assistive technology projects and products are available. Projects that provide access to open-source software include the ITHACA framework (Pino and Kouroupetroglou, 2010), projects COMSPEC (Lundälv *et al.*, 1999) and ACCESS (Kouroupetroglou and Pino, 2001), and the OATSoft open-source software repository (Judge *et al.*, 2006). Open-source assistive technology hardware is also becoming more common. For instance, recently the specialised "Hackcess" user forum was created within the Makey Makey discussion board (an open-source hardware board), with a stated focus on the use of this specialised electronic component in assistive technology applications (www.makeymakey.com/forums). Tecla (http://gettecla.com/), a commercial hardware and software tool that provides touch-free access to smartphones and tablets, is also developed using an open-source software and hardware model. Hurst and Tobias (2011) presented two case studies of projects that involved DIY assistive technology hardware development. The first project involved instructors of an adaptive art class who wanted to find a means for their students to paint without using their hands. After unsatisfactory experiences with expensive consumer solutions, they decided to make their own customized drawing tools. By combining parts from solutions bought online and a face shield, they were able to come up with a more stable and comfortable solution than was otherwise available. The second case study documented the approach adopted by a member of the maker community with a focus on assistive technology. This individual, who is a retired finance professional with an engineering degree, has been independently adapting, designing and building assistive technology and disseminating the results via a website (workshopsolutions.com). The website currently contains more than 170 designs (both of his own and submitted by community members). His practice is a concrete instantiation of the belief that the sharing of ideas online is important and allows for people to connect with the technologies they need.

Forming interdisciplinary teams to address specific problems faced by people with disabilities and to customize or develop new technology is becoming more common. These teams bring together diverse experiences and knowledge bases – for instance, subject domain knowledge (e.g. engineering and computer science, speech language pathology, occupational therapy, special education teaching), and life experiences (e.g. as an assistive technology user, as an individual living with a disability, as a frequent interaction partner with individuals who has disabilities). For example, CanAssist (www.canassist.ca/) which is an organization (non-academic unit) at the University of Victoria, BC, employs a diverse group comprising of individuals with disabilities, co-op and graduate students, and volunteers (consisting of retired engineers and other professionals), in addition to engineers, software developers, and project managers. CanAssist develops technological solution for community – identified problems, oftentimes by customizing and modifying existing computer hardware and software. Another organization in the UK, REMAP (www.remap.org.uk), uses a similar approach by recruiting skilled volunteers to customize or make assistive technology when suitable choices do not exist. Similarly, the MERU charity organization (http://meru.org.uk) designs and fabricates customized devices for children with disabilities. In North America, the Tetra Society (www.tetrasociety.org/) is a non-profit organization that recruits retired engineers and engineering students to modify and develop customized assistive technology devices.

In the next section, we present the design and evaluation of two open-source, customizable communication board prototypes developed using maker methods and by an interdisciplinary team. Next, we provide a discussion of the affordances of the design and the implications of this method for future DIY digital assistive technology development. We end with a conclusion and discussion of future directions.

2. A DIY open-source, customizable communication board case study

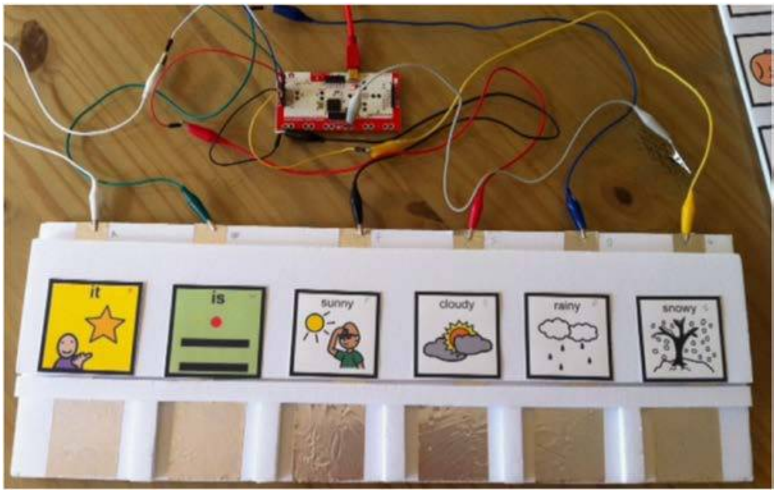
We present a case study that demonstrates the application of the DIY methodology to the creation of an open-source, customizable speech generating device (SGD), which we have coined as "TalkBox". TalkBox is intended to be an affordable and more-easily obtainable alternative to commercial SGDs. Two prototypes were developed: prototype 1 made use of a Makey Makey board for input actions, whereas prototype 2 used a more sophisticated system configuration using capacitive touch sensors and a Raspberry Pi computer. A collaborative design methodology was utilized, and our interdisciplinary team consists of the "citizen designer" and special education specialist, and students and faculty from a computer research lab. Throughout our process, special education domain expertise, hacking, and programming skills were combined.

2.1 Prototype 1

Prototype 1 made use of the Makey Makey human interface device (HID) (JoyLabz, Santa Cruz, CA), which is a circuit board that has 18 input ports that can be connected, via alligator clips, to any conductive object (e.g. aluminium foil, metal objects, even fruit and vegetables!) (Collective and Shaw, 2012). When the conductive object is touched by the user, a closed circuit is formed, which, in turn, dispatches an signal to the output USB port that is emulates either a keyboard key press or a mouse click. The closed circuit is completely safe for users, easy, since the levels of electrical potential are well below harm thresholds. The HID allows essentially any conductive object to serve as an alternative to a keyboard key or mouse button. Makey Makey can be connected to any computer through USB and thus, only the most basic level of computer literacy is needed to make use this component.

The prototype 1 communication board (Plate 1) consisted of a chassis made out of polystyrene foam and cut into a rectangular shape. Arrayed along one edge of the chassis is a series of "switches" (currently, six are used). Any layout or configuration of the switches is possible. The switches are formed from self-adhesive aluminium duct tape, which is cut with scissors and fastened to the foam chassis to separate them from one another by (non-conductive) foam channels. Each of the switches is connected to the Makey Makey by alligator clips via a contact

Plate 1 Prototype 1 consists of a computer (not shown) and a Makey Makey board connected to a hand-made foam board fitted with aluminium foil touch-switches and labelled with replaceable printed symbols



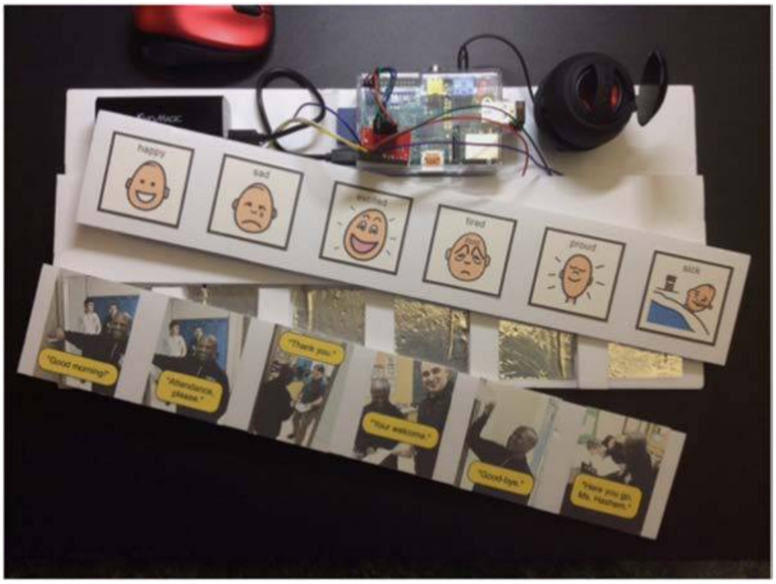
assembly, made from aluminium strips running from the switch to the clip flange. Additional rectangular foam boards are then cut, to form the seats for the switch labels, which are colour printed and affixed by regular craft glue. These switch labels are drawn from a symbol set that is in common use among the students. The communication board was then connected a consumer off-the-shelf (COTS) computer, via USB, that was running the SoundPlant (http://soundplant.org) software, which is a shareware tool that allows the keys on the keyboard to be mapped to sound files. Through this mapping, each switch activation triggered the playback of the associated sound file, implementing, in effect, a basic SGD.

The design work on prototype 1 was conducted by one of the co-authors who is a special education teacher and maker. He has worked for many years as a special education teacher in the Greater Toronto Area, working with students with various and often multiple disabilities. In recent years, he has become interested in using maker tools and methodologies to develop custom assistive devices for his students. His interest and motivation led him to experiment with electronic prototyping tools. For prototype 1, he used a network of family and friends to bring together expertise, combined with the user of online resources, to resolve technical issues.

2.2 TalkBox

The other co-authors of this paper, during a visit to the 2013 Toronto MakerFaire (http://makerfairetoronto.com) saw prototype 1 on display there. Following this initial contact, possibilities for collaboration were explored and eventually a team was formed to work on a second version of the communication board, Prototype 2 (which was then dubbed "TalkBox"; shown in Plate 2). There were several issues with prototype 1. First, the Makey Makey required the user to be grounded when touching the pads. Although this was not an insurmountable obstacle (e.g. it had been shown to be possible to train users to press two pads simultaneously, where one was connected to ground, or to use a wristband connected to ground), it presented a non-trivial inconvenience. Second, Makey Makey needs to be connected to a computer via USB. The computer that was used in the prototype was relatively large and inconvenient (for instance, it could not be placed on the user's wheelchair tray, nor could it be moved around too much, nor was the connective USB cable convenient in a busy classroom setting). Third, the cost of components (the Makey Makey, combined with the cost of the COTS computer) was expected to be a problem, given for the budgetary constraints of the school board.

Plate 2 Prototype 2, TalkBox, consists of a Raspberry Pi connected to a capacitive touch sensor, speakers and a hand-made foam board with aluminium foil touch-switches



To address these issues, the design shifted to the use of the Raspberry Pi single-board computer (www.raspberrypi.org/) rather than a COTS computer. The SoundPlant software is not available for the Raspberry Pi's OS (Linux), so the Scratch programming language (pre-loaded on the Raspberry Pi) was used instead to map the leads from the Makey Makey to specific sound files. Last, we explored the possibility of an alternative to the Makey Makey, using the MPR121 sensor controller (Freescale, Austin, TX), which was less expensive (£5 compared to £40, approximate costs).

The Raspberry Pi computer is a low-cost single-board computer developed in 2012 by the Raspberry Pi Foundation (www.raspberrypi.org/) in the UK to promote programming and computer science education in the classroom. Despite its recent appearance, Raspberry Pi has received a lot of attention and a vibrant community is already formed around its use (Bridgewater, 2012). Although small (credit-card sized), Raspberry Pi is a full-fledged computer with processing power sufficient to perform speech synthesis and even high-definition video processing. Because of its size and small power consumption, it is used extensively for embedded and physical computing projects.

The MPR121 sensor controller provides a capacitor touch sensor that accepts human body capacitance as input and is activated when a hand or finger touches a pad connected to it. The capacitor touch sensor does not require a simultaneous connection to a ground wire. The Raspberry Pi and touch sensor combination is small enough to be connected to a wheelchair, blackboard, or even clothing and can be powered with batteries; the combination of Raspberry Pi and touch sensor costs significantly less than a computer connected to the Makey Makey. In order to capitalize on these advantages, we needed to develop a software interface to connect the touch sensor and the Raspberry Pi; further software was developed to actually implement the mapping from input event to communication board behaviours. Last, an additional software module was developed to provide the capability to configure this mapping (e.g. the ability to define multiple mappings between different input actions and sound files, and defining the trigger to switch among multiple mappings). This work unfolded over six weeks, with weekly design meetings, and iterative design methodology, and frequent modifications. A GitHub project was created (http://hrairhlessil.github.io/TalkBox/), which provided software versioning, issue tracking, and open-source deployment.

TalkBox (prototype 2) is shown in Plate 1 (top left). TalkBox consists of a Raspberry Pi board connected to a MPR121 capacitive touch sensor, an inexpensive battery power source for the Raspberry Pi, a battery-powered USB speaker and a wireless mouse. The setup is connected to a polystyrene foam chassis similar to the one used by prototype 1, but with smaller aluminium tape switches and shorter wires for connecting the switches to the MPR121 pin sensor connections. Initial experiments showed that the use of alligator clips and large touchpads did not work well with the capacitive touch sensors (many false positive and false negative activations registered). The core software runs as a daemon, which initializes by loading the required sound files. TalkBox uses six pads, each of which is mapped to a sound file (and is signified by an image placed above the pad). Whenever a pad is touched, the corresponding sound file is played back on the attached speaker. Thus, TalkBox, in effect, implements an open-source SGD. In the current version, both six and 12 switch variants were developed (12 pins are available in the MPR121 sensor). The six-pad variant keeps the interface relatively compact.

To expand the repertoire of words and phrases, a scheme was used whereby they are arranged into categories, and the user can switch among different categories. The software module is used to configure the set of categories, the words and phrases in each category, and the sound files that each word or phrase is mapped to. The user can switch between categories by pressing the mouse button (each button press selects the next category in the category sequence). This method of category switching was chosen because currently the teacher makes the change. Each category also has a corresponding foam-core strip that has the images affixed for each word or phrase in the category, which can be placed on the chassis of the interface by the teacher when each category is changed. It is possible that the user could change the category as he or she wants (by assigning the “change category” function to one of the pads), although some further modification would be needed (e.g. some sort of digital display so that the image label for the switches could be dynamically updated, or a scheme whereby the switch labels are left out).

The current words were selected specifically for the user for whom TalkBox is being designed and is customizable for each user and case scenario. The set includes some common words for use in the classroom setting, as well as words and phrases (i.e. the ones in an “Greetings/Attendance collection” category) for an activity done in the specific context (i.e. school and special education class) in which the prototype is going to be used. The TalkBox is thus serving as both the script and a visual checklist for that activity. It assists both in communication and in helping to focus on, and better understand the task at hand. For each of the identified words and phrases, two variants of the digitized speech files were recorded (one male and one female adolescent voice), so that even this early version of TalkBox could offer that degree of user tailoring.

2.3 Preliminary evaluations

Prototype 1 was originally developed for a set of specific users (students) in an educational setting. The users were either non-verbal or used verbal communication rarely, and used various commercial AAC systems with a variety of access solutions that had been provided through the available social services. For multiple and different reasons, many of the AAC system configurations had shortcomings. For instance, with the systems that employed touch screens, there were input errors caused by the user resting the side of their palm on the board while trying to touch a target with their finger and by the student’s inaccuracy in targeting and calibrating pressure of touch actions (since the screens required pressure to be applied straight on or in a well-aimed swipe). With the systems that employed physical switches, the amount of pressure required for activation was too great, at least relative to the user’s physical capabilities (and the force thresholds could not be calibrated). Also, the sizes of the switch were not optimally tailored to the users and could not be adjusted (some users require larger switches because of lack of hand movement precision, whereas others could have used smaller-sized switches, which would have afforded a larger number of switches and thus more selection options). For the joystick-based access solutions, the amount of hand-eye coordination required for use also presented barriers. These students, to various degrees, benefited from the assistive technology services that were formally available (from the school board and the government), but, for various reasons, were matched with technologies were not satisfactory and were either abandoned or were at risk of abandonment. Alternative technologies were needed, but could not be obtained for multiple reasons (e.g. long waiting times for re-assessment, limitations in the repertoire of the off-the-shelf technologies that are approved to be prescribed, and high cost of buying alternative systems without the aid of socialized services that subsidize assistive technologies).

Preliminary evaluations of the two prototypes were conducted with two non-verbal users. Both users are students at the special education school that the inventor of the system teaches at.

The first user, who has multiple disabilities, including cerebral palsy, scoliosis, spina bifida, and who is non-verbal, had been matched with a variety of commercially available AAC solution, including DynaVox, but they did not work well for her. Specifically, she had difficulty with providing the pressure and precision needed to activate the switches. She was able to successfully use both prototypes to engage in multiple communication exchanges (Plate 3).

The second user has autism and is also non-verbal. A task he has been learning in the school is collecting attendance. We modified TalkBox such that a set of phrases that include specific greetings and requests for attendance are added as a category to the software. The student has successfully used TalkBox to conduct the task.

The preliminary evaluations have been successful with both prototypes. However, we are planning more user evaluations to compare TalkBox with other devices and with more users.

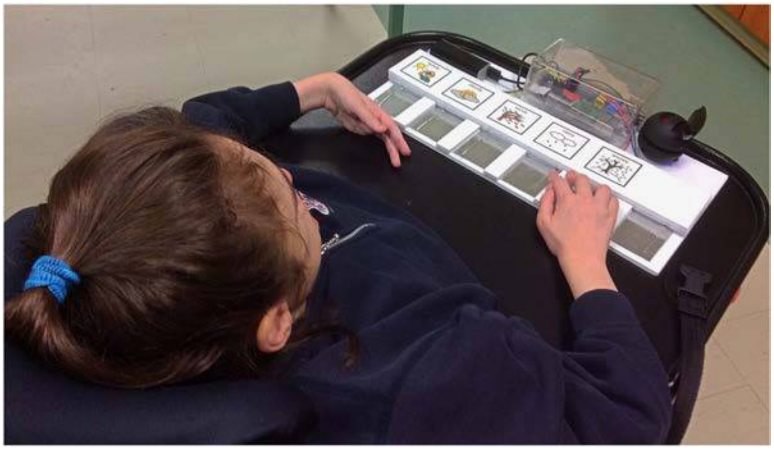
3. Disscusion

3.1 Design features of TalkBox

The two prototype open-source communication board designs offer several benefits that make them competitive to existing alternatives:

- Ease of deployment: from the very beginning, a great motivation was to share the design in such a way that other people can recreate it themselves. To this end, documentation and instructions on how a version could be made were posted online (Feraday and MacNeil, 2013). For prototype 2, TalkBox, schematics of the electronic components, the developed software code, instructions on how to assemble the hardware and load the software, as well as, small libraries of original voice samples that can be used free of charge for the speech synthesizer are posted on the GitHub repository (http://hrairhlessil.github.io/TalkBox/).
- Customizability: both the size and number of switches are customizable within constraints. For prototype 1, the size of the pads is quite flexible, and provided a conductive material is used, touch activations are reliably detected. For TalkBox, if the pads get larger than the size currently specified, touch detection becomes less consistent. We are currently exploring the range of sizes with which the interface works reliably. For both prototypes, we have implemented six pads but many more pads can be used in the future (up to 18 for prototype 1 and up to12 for each sensor connected to TalkBox). On the software side,

Plate 3 TalkBox in use



for prototype 1, any software programme that uses the keyboard as input can be used. For TalkBox, we are currently developing a software interface that allows it to be used to interact with any software programme that uses the keyboard as an option.

- Design visibility: with technologies becoming more complicated, it is common to hide the functionality of new devices. One of the appeals of this design is that the interface's underlying mechanism is easily visible and understandable. In the future, we aim to capitalize on this aspect of the design by using the device as an educational tool and to explore the possibility of using it to teach digital design to students with disabilities.
- Ease of repair: some students do not have good control over the pressure they exert on the communication board, resulting in heavy use. Although many commercial AAC boards are made sturdy and durable, switch failure due to heavy use does occur and swapping out hardware components can be difficult and expensive. It is easy and inexpensive to replace any of the components of TalkBox (e.g. foam board chassis, aluminium foil switches, connector assemblies). Moreover, other types of materials can easily be substituted, as the situation warrants.
- Cost: compared to the cost of a conventional communication board, which currently run from £70 to 99 for simple modules[2], the cost of the open-source communication board is small (~£40, not including labour). For prototype 1, the costs include the Makey Makey board (~£40), plus the cost of the computer (to which the Makey Makey is connected, via USB). The other parts and materials cost less than £5. For TalkBox, the costs include a Raspberry Pi (£20), a capacitive touch sensor (~£5), the power supply, a speaker, and other materials. Depending on the use scenario and context, various components (such as a monitor or Wi-Fi module) can be added to Raspberry Pi for additional functionality.

3.2 DIY assistive technologies: a promising future

The current project is an example of a DIY grassroots solution to the immediate need for assistive technology to facilitate communication and self-expression in a classroom setting. This project is based on collaboration between academia and community. The benefits of this mode of research have been discussed at length in the knowledge mobilization community (van deVen and Johnson, 2006), and have been noted in prior work (Gómez *et al.*, 2012; Hamidi *et al.*, 2010). Through our experiences, we have come to believe that bringing together community partners, researchers, students, and users has great potential for the development of relevant projects that incorporate key insights rooted in concrete domain expertise. We believe an important aspect of this project is that it brought together community partners, student researchers and faculty in a collaborative team whose activities were beneficial to all parties. For the students, this project was an excellent learning experience and an example of how one can craft one's education by working on projects one deems as meaningful. For the community partner, the collaboration provides sustainable and stable access to complementary programming and analysis skills, as well as a point of interface to the so-called scholarly community. For the academic researchers, the collaboration provided valuable contact with the community and a meaningful design domain. Needless to say, for all parties involved, many of these motivations coincided. More importantly, for all the parties, this was a volunteer-based self-motivated endeavour (the project, as of yet, is unfunded), and the real reward was in conducting the project itself: exercising creativity and problem-solving skills in a collaborative atmosphere towards the higher goal of helping people with disabilities communicate through technology.

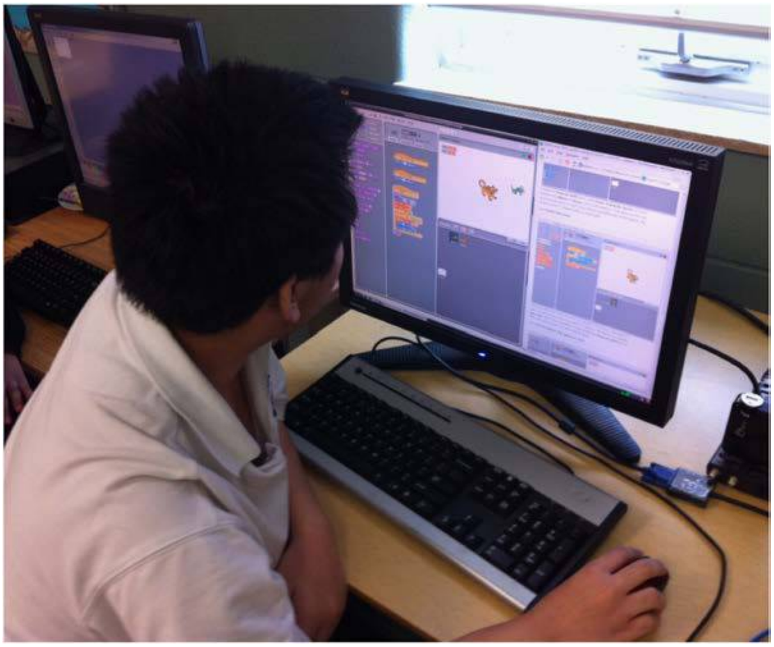
The emphasis of the Maker and of the DIY Movements is on hands-on creation activities. We believe it is important to balance the aspect of novelty with reflection and direction. We believe academia does have a role in the Maker Movement, for instance, through analysis and exploration of the underlying theoretical frameworks and to increase awareness and critical reflection on the hidden assumptions, ideologies, values, and potentialities of underlying technology design. This blend can be found in the current project. We recruited the maker methods of combining low-tech prototyping with open-source hardware, but we also developed clear user scenarios and recognized the values embedded in the design.

Another one of our goals is to create new ways for people with disabilities to come up with ideas, and to design and to make the technologies they themselves and other people with disabilities would use. Our conjecture is that the TalkBox system can be assembled by youth with mild cognitive disabilities, and we plan to investigate the fabrication process as a potential opportunity for paid employment. In addition, we see the Scratch programming language, which is already built into the TalkBox device, as playing a role in the teaching of programming to students who are presently not offered that learning opportunity. The original idea behind developing the Raspberry Pi computers was to incorporate programming into the school curriculum. The second student who used TalkBox to perform school tasks successfully has also shown interest and potential in learning programming using the Scratch programming language on the Raspberry Pi computer (Plate 4).

We believe TalkBox's design characteristics (i.e. ease of deployment, customizability, and low cost) make it an ideal bridging device, a device that can easily and affordably be built and used in the absence of more robust alternatives and until such alternatives are identified and acquired. It has potential not only in the special education classroom, where it was developed, but also in other contexts where an intuitive and low-cost communication device might be helpful to communicate basic information with people who might temporarily not have their communication devices with them. Finally, the low cost and availability of material makes this an ideal assistive device for deployment in developing countries and communities where access to more expensive alternatives is not prevalent.

Our approach to assistive technology has another aim, as well, and that is making assistive technology solutions available to international communities. Due to their low-cost and open-source designs (and thus reproducibility), new revolutionary design ideas that use low-tech DIY and open-source hardware are already appearing around the world (e.g. the freely available Disabled Village Children (Werner, 1988) and the Robohand project, http://robohand.net). Our vision is to expand these possibilities by making digital assistive technology designs available to more people in developing countries, through online publishing of open-source hardware ideas. This will also provide a space for innovator in these countries to share their ideas and vision, and will dialogue between interested stakeholders to create mutually beneficial relationships.

Plate 4 Building a game using the Scratch programming language being run on a Raspberry Pi computer



4. Conclusion and future work

New “citizen designer” tools and methods provide great potential for the development and deployment of novel, low-cost assistive technologies. We have presented two prototypes of an open-source communication board that was developed using these methods. The board is provided as an alternative to commercial proprietary design components that are often hard to modify. An important goal for this design is its availability to other potential “citizen designers”, who can then build and modify it in whatever way they feel would benefit the end user. We have also discussed ways to foster similar projects by linking in-the-field special education teachers and caregivers with novel ideas for assistive technology with students: an exchange potentially beneficial to both parties, as well as, more importantly, to users with disabilities. Finally, we believe we have taken a step towards developing accessible interfaces to making tools, such as the Raspberry Pi and Arduino that are deemed important components of future education.

In our approach, we brought together community partners, students and researchers in our lab. Community partners provided relevant design scenarios informed by their experience working with clients with disabilities. Their ideas were supported by technical work provided by undergraduate and graduate students and supervised by faculty. In this way, the students gained valuable hands-on experience and community partners gained access to technical expertise. In addition, we also used open-source hardware and software that can be replicated by other developers and made use of maker methods, such as 3D printing and rapid prototyping, to customize our designs further. The development of the open-source communication board is an instance of using this approach.

The first step in our future plan is to evaluate the interface with more users with disabilities. This will provide us with insights into the potentials and shortcomings of the design and help us refine it in future iterations. While the current interface was informed by many years of experience working with people with disabilities and by taking into account first hand information on the needs of specific users with disabilities, having a working prototype allows us to communicate and explore design alternatives more effectively with the users of our system and follow a participatory design methodology to refine and extend the interface, a method that has been found to be effective in previous research (Dawe, 2007). We plan to make another version of TalkBox that is not limited to synthesizing sound and where touching the pads correspond to general input actions that can control a variety of applications and programs on the Raspberry Pi. This will allow us to have an accessible interface to the Raspberry Pi, a possible step towards helping students with disabilities exercise the learning potential of the Raspberry Pi. Finally, although we have detailed instructions and code on the project website, we want to come up with a process to assemble and customize the system that is accessible to students with disabilities. Currently, we are examining ways to present TalkBox and other variations through an affordable, easy-to-assemble and customizable kit (possibly with some 3D printed components).

Notes

1. The term “citizen designer” has been used before, for example, by Heller and Vienne (2003), to denote socially responsible designers that take into account social and human values. Here, we use the term in a different sense to refer to people who are not professional designers (i.e. do not have formal training in design and do not earn their living through design work) but similar to “citizen scientists” adopt design methods and use them in a grassroots fashion to come up with solutions to real world problems.
2. Price estimates are based on the price of QuickTalker and GoTalk9+ systems as offered by Ability World (www.ability-world.com), a UK assistive technology supplier (checked on March 2015). More complex systems, such as DynaVox Express and Lightwriter SL40, cost upwards of £2,500 (as offered by Toby-Churchill.com, checked on March 2015).

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Further reading

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