Engaging 'At-Risk' Students through Maker Culture Activities

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ABSTRACT
This paper presents a set of lessons learnt from introducing maker culture and DIY paradigms to 'at-risk' students (age 12-14). Our goal is to engage 'at-risk' students through maker culture activities. While improved technology literacy is one of the outcomes we also wanted the learners to use technology to realize concepts and ideas, and to gain freedom of thinking similar to creators, artists and designers. We present our study and a set of high level suggestions to enable thinking about how maker culture activities can facilitate engagement and creative use of technology by 1) thinking about creativity in task, 2) facilitating different entry points, 3) the importance of personal relevance, and 4) relevance to education.

Author Keywords
DIY; maker culture; education; young learners; 'at-risk' students.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Learning with tangible interfaces is said to have a range of benefits and more so for young learners, people with learning disabilities or novices [20, 38]. The assumption is that tangible user interfaces (TUI) leverage a sense of familiarity when interacting with something concrete and physical thus, lowering the threshold for participation [20]. Specific to education, TUI research has received great interest [26]. While the focus has been on designing novel interfaces for education (e.g. [2, 38]) there have been fewer empirical studies that question aspects of introducing such interfaces, their impact on learning, and relevance to groups of learners who may be less inclined - young learners with learning disabilities or limited by other life circumstances that form barriers to their learning [20].

"Maker culture has become a way to express creative and communal drive" encouraging invention [12]. For education it is said to be "a natural extension of a long-standing emphasis on learning-by-doing in art and science" [12]. Following this mindset, several makerspaces have been setup across a range of instructional environments (including libraries, museums and K12 schools) to allow makers to experiment, invent and practice hands on learning using technology tools [12]. Technologies being developed for these spaces focus on "expanding and democratizing the range of human expression and creativity" [2] and span across a wide range, including high-end technologies (e.g. 3D printers, CNC machines) to small scale, relatively low-cost tools (e.g. microncontrollers and sensors) [17, 35]. Encouraged by the maker movement possibilities, we explored strategies to introduce a group of 'at-risk' young learners in Ontario, Canada, to maker culture activities using a small subset of makerspace tools (electronics and common art supply materials, Figure 1).

Some at-risk students face various kinds of life circumstances (e.g. abuse and trauma), which create barriers to their education and healthy personality development [21]. Such youth are often in high danger of dropping out of school due to academic failure, impacting their future economic self-sufficiency. Our goal is to present maker culture activities as a way to engage them. We want to elevate the learning task beyond as an embodied activity and motivate the students to engage with the technology, not necessarily for technology's sake but as a means to an end in the creative process. While engagement with the makerspace tools embeds learning technical skills (programming and circuitry), our goal is not to measure improved technical competency, but rather to explore strategies to position them as creative designers with agency. We would like to point out that it is not an ability gap that separates these learners from others, but the lack of student-centered educational opportunities. Based on this, we expect similar subjective benefits with this specific group - such as, creative expression and improved self-confidence. What we have observed while working with these students is that situational traits that hinder participation in the maker movement, for example, tendencies to quickly give-up, unwillingness to experiment and communicate, less engagement and lack of motivation, are more noticeable, allowing us to explore how one should introduce such technologies.

Makerspace tools have been previously introduced to young learners (e.g. [3, 18, 15]). In this area, our research contribution includes the following: 1) we explore the relationship between hands-on maker culture activities and engagement

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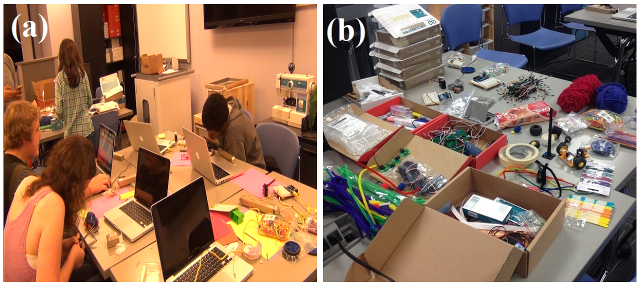

Figure 1. Study environment: (a) Students building their projects and (b) Design materials provided.

and 2) present a set of high-level lessons learnt from running small-scale maker culture studies with 'at-risk' students. We borrow from TUI education research [20], education research (e.g. [19, 31]) and maker culture paradigms (e.g. [3, 18, 15]) to guide our strategies, and understand their impact on creative learning.

RESEARCH MOTIVATION

Maple (pseudonym) is an alternative school in Ontario, Canada, that provides educational programming for students from government approved Care, Treatment, Custody and Correctional facilities. The students typically live in foster care or group home facilities. The primary purpose of this alternative program (in progress for the past two years) is to provide students with effective instruction that leads to the re-integration of students into community schools, post-secondary institutions or employment. The students are identified with a variety of cognitive, behavioural, emotional and developmental exceptionalities, which include anxiety, oppositional defiant disorder and various learning disabilities. These conditions can be significant barriers to their education or learning. Our overarching goal in working with this particular group of students is to explore the impact of digital technologies on student engagement in the learning process and in the development of their traditional and digital literacy skills.

Based on some existing research [3, 7, 5, 15, 18, 24] we felt that introducing maker culture activities with this group was fitting. Students could continue to develop their interpersonal skills through the collaboration necessary in the makerspace learning environment and also develop their computational and analytical thinking skills through the coding and circuit activities. Furthermore, the creativity and engagement that has been witnessed [3, 5, 15, 18, 24], motivated us to introduce the students to makerspace tools like the LilyPads and Arduinos in order to position them as not only programmers but designers with unique creative vision and agency.

RELATED WORK

The contribution of maker culture to learning in science and engineering has been explored by Blikstein and Krannich [1]. The authors have identified a set of actionable items for future work highlighting the need for developing more tools, evaluating the tools, and making sense of the observations. Kuznetsov et al. [18] and Stager [33] have explored the maker movement in the context of 'at-risk' youth. We attempt to expand this body of work by contributing in the following ways: 1) we explore a larger set of makerspace tools as platforms for introducing hands-on creative making; 2) While some of our lessons learned re-iterate findings discussed by Kuznetsov et al. [18] and Stager [33] i.e. unfinished projects leading to frustration, bottom-up teaching style as a useful tool for increasing participation and benefits of casual collaboration, we found (differently) that how something is introduced makes a difference. For example, unlike the positive acceptance of Lilypad's noted by Kuznetsov et al. [18] for mentoring and therapy of 'at-risk' children, our participants were less inclined or in some cases unwilling to engage in e-textile activities; Lastly, 3) our strategies also shed light on other aspects such as activity design, suggestions for considering possible entry points and suggestions to make the process personally and educationally relevant.

Constructive TUI's [37] or those that support building interactive systems have been previously introduced. There are several examples that fall under this category such as physical widgets [11] or Phidgets, which assist in development of physical interfaces using various sensors and actuators; LilyPad Arduino [2], a sewable and programmable electronic module designed for building soft interactive textiles and .NET Gadgeteer [13], a prototyping platform that supports plugging together modules with varied functionality. Specific to introducing physical and digital making skills, tools have been introduced to young learners and adults for purposes such as building crafts [5, 24], for introducing interactive electronic textile education [2, 15, 18], as a medium for therapy and mentoring of 'at-risk' students [18], and for personal digital fabrication [22, 23]. Specific to computer science education, LilyPad Arduino's have been discussed by a number of researchers [2, 4, 9]. To support prototyping, TeeBoard [25] and EduWear [16] have been presented as platforms for introducing interactive textile education to children. Our research is inspired by several of these researchers and expands this body of work by exploring how physical making and building skills can be introduced to 'at-risk' students who have fewer educational opportunities and whose circumstances tend to promote disengagement with educational activities.

PHASE 1: EXPLORING EXISTING STARTER KIT ACTIVITIES TO INTRODUCE MAKER CULTURE ACTIVITIES

Study Methodology

In phase 1 we introduced eight Maple students (3 girls and 5 boys, ages 12-14) to circuitry and coding using the LilyPads, Makey-Makey kits, and Arduino Starter Kits. Our goal was to provide participants with a theoretical and practical understanding of basic circuitry and coding and to help them develop computational thinking and problem-solving skills. We took an inquiry and constructionist approach [19] to teaching both circuitry and coding, where the students were positioned as active learners, collaborating with peers to construct knowledge and understanding of the various theoretical concepts and practical skills associated with creating circuits and computer programming. The lessons were scaffolded to encourage student engagement. The students came to the university lab once per week for a two hour "maker" session and were allowed to work independently or with a partner. The workshops were led by the lab manager, a research assistant and a volunteer pre-service teacher candidate (with a background in mathematics and computer science). Data sources included field notes, photos, videos and informal conversations with the students, teacher and support worker. Data was collected before and after each unit for posterior qualitative analysis [34].

Activities

LilyPad activities: Students were first introduced to circuits with the LED bookmark activity in the LilyPad kits [27] (3 classes). We provided the participants with a brief overview of circuits and an online walkthrough of how to build a circuit using the LilyPad materials. The students were encouraged to look to their peers and online (Sew Electric website) for assistance in setting up the circuits and/or sewing. They were free to search on the Internet for inspiration and discuss their projects with peers. Sewing was observed to be a time intensive activity and debugging sewed circuits was found to be quite challenging. Most students were easily frustrated, "*...Lilypads were just so boring making them... I don't want to spend that much time on them again. I had to keep sewing at the same spot cause I messed up and sew again.*" [P1].

Makey-Makey activities: We then introduced the students to the Makey-Makey kits [6] (3 classes). The students were first required to figure out the basic circuitry with the Makey-Makey tools and to use some conductive object(s) in the circuits. They then used the sprite-animation and backdrop design features of Scratch [29] to create a simple game or animation that they would eventually connect to the Makey-Makeys (with or without additional novel objects in the circuits) to use as controllers for the games. One particularly keen student had rushed through and willingly explored the Makey-Makey kit on his own (had previously not completed the LilyPad activity). For the remainder of this activity, he and another student took on the role of a "teacher" and guided their classmates using various online tutorials. The level of engagement and interest for all of the students was markedly higher during this activity than with the LilyPad's ("*...just plugging the chords in you can just see how everything reacts almost instantly"* [P2]). We were not sure if it was because the students now had a basic understanding of circuits, were able to create/code their own games using Scratch, the novelty factor that came from using items like bananas and cherry tomatoes, or all of the aforementioned.

Arduino activities: The final portion of this unit involved the introduction of the Arduino starter kits (4 classes). The students were given a variety of projects from the Arduino starter kit book, for example, crystal ball, zoetrope and spaceship interface. To prep the students for the more advanced coding and circuitry, we used CodeCombat website to introduce students to "writing code". We also did a kinaesthetic activity with them called the Electron Run-Around. This had the students acting out the path electrons go through in various circuit scenarios. When it came time for the students to start their work with the Arduinos - coding and building basic circuits, students appeared less comfortable and less prepared to apply the knowledge gained from the previous activities. Students were frustrated as they spent long time building circuits and programming and did not observe desired results or were caught in the loop of debugging circuits and code ("*I think the most difficult part was when I looked in the books and I'd see a project that I wanted to make and then I built all of it but some way through all that something went wrong so I had to re-do everything and it was kind of repetitive.*" [P2]). Many who were not already interested in technology in general shut down (staring blankly at the components or computer screen) or chose to be engaged in other activities such as chatting with friends or surfing YouTube.

Results

At the end of phase 1 five students had attempted all of the above listed activities. However, in terms of actually completing a project, only two students were successful. One of the most important takeaways from working with the Arduinos is that the students need to understand not only how to use them but why this knowledge is relevant to other areas of their lives. For example, the students need to be able to see that the knowledge they are constructing by learning the Arduinos can help them better understand their digital world and how to 'hack' it in order to have an impact on it or manipulate it for their own desires and uses. Without the ability to contextualize the work and the purpose for it the students found it difficult to maintain a level of interest necessary to work through the many challenges that are part of working with the makerspace tools. Lack of thorough understanding of the functionality behind the Arduinos and the language used in the coding is also an obvious barrier to preventing project completion.

In terms of the tools, we quickly realized that tools had to be selected carefully based on the learning goals. For example, Arduino starter kits were not as "low-floor" as we had considered. They required fairly proficient understanding of circuitry and programming. However, Arduinos have "high-ceiling" as they can provide several possibilities for taking things further. On the other hand, Makey-Makey were simplistic, but are limited to tasks that turn everyday objects into touch interfaces. In terms of tool design, this observation highlights the need for considering balance whereby the tool enables engagement with minimal knowledge, but with gradual increase in learner's technical competence, the tool or mechanism of learning should be extensible to explore more complex concepts

PHASE 2: EXPLORING DESIGN-BASED APPROACH TO INTRODUCE MAKER CULTURE ACTIVITIES

Study Methodology

Phase 1 and 2 had different study goals. While phase 1 focused on introducing the maker mindset using the starter kit activities, phase 2 focused on exploring open-ended, student-centered design-based approach for engaging the students. To investigate the question of how design activities can be presented, and in an attempt to improve engagement, we looked

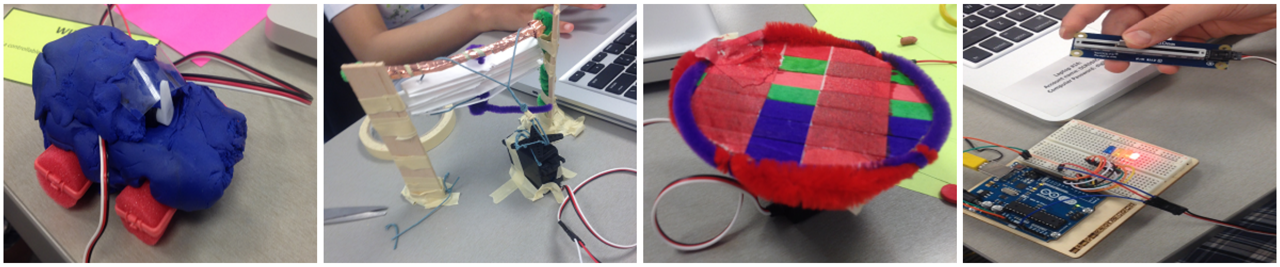

Figure 2. Examples of projects built (left to right): (a). Windshield wiper, (b) Sun blinds, (c) Angular speed and (d) Direction controller.

into literature of tangible user interfaces. Inspired by activity types suggested by Marshall [20] and manipulatives classification suggested by Zuckerman et al. [38], we propose a two category classification for maker culture activities - ***real world building tasks*** and ***abstract concept building tasks***.

To encourage development of so-called soft skills (i.e. collaboration, peer involvement, developing independence, choice making and self-determination) we decided to simulate an experience similar to design studios [32], wherein the practitioner undertakes a project based 'learning by doing' approach. The designer is often given a brief or a set of requirements, following which they are expected to conceptualize and realize the final artifacts. Design studio approach encourages the designer to gain and synthesize knowledge from stages of thinking, designing, collaborating and finally creating. It is said to be enjoyable and an effective framework for critical learning [32].

To introduce this approach, the students were cast in the role of a creator and designer and asked to build projects in small scale prototype forms using any material (at least one computational component) of their choice. The students were provided with project cards with brief descriptions. We provided the participants with code templates and a variety of computational and physical materials (i.e. switches, push buttons, LEDs, sliders, temperature sensors, mini speakers, clay, polymorph, Lego, wool, pipe cleaners, popsickle sticks etc.), placed in a common space for free access (Figure 1). The actuators and sensors were a mix of phidgets [11] and Arduino components. The electronic components were chosen such that their complexity level was relatively low for circuit connections. All the sensors had three or less pins (ground, power, analog or digital) for circuit connection. They were free to search on the Internet for inspiration and discuss with peers or researchers organizing the workshop.

The workshop was run over 3 days for 8 hours and was led by two research assistants and the lab manager. Six out of eight students attended on all days. Two students attended two days of the workshop. Similar to phase 1, we collected photos, videos (with the exception of two students who were audio recorded), responses to questionnaires, semi-structured interviews and informal conversations from the students, class teacher and support worker, for posterior qualitative analysis [34]. We also encouraged the participants to document their design process using notes and sketches.

Activity Design

We designed a set of sixteen project cards to function as 'triggers' or 'scenarios' for the design brief [32]. The students' interpretations of these cards were recorded in the form of their final projects. The sixteen project cards were classified under two broad categories: *real-world building tasks* and *abstract concept building tasks*. *Real world building tasks* as the name suggests involved building an object that the participants would have seen or known about from their surrounding environment. Our eight real-world cards included the following: windshield wiper, sushi table, elevator, sun blinds, swing, thermostat, bed light and robot (e.g. Figures 2a and 2b). *Abstract concept building tasks* involved building a representation to demonstrate an abstract concept. Our eight *abstract concept task* cards included the following: mechanics, safety, angular speed, direction control, pendulum, brightness controller, natural light regulator and boiling point (e.g. Figures 2c and 2d). The descriptions for each card made explicit that the objects had to be controllable in some way and the scale of the prototype should work for tiny Lego people models. For example, 1) Build a controllable swing for tiny Lego people and 2) Build a controllable system that demonstrates how uniform surfaces can be cleaned.

Results

Five participants built one *real world project* and one *abstract concept project*. Two others built one *real world project* each and the remaining participant built an *abstract concept project* (some examples of projects built by the students are as shown in Figure 2). Our observations can be summarized as below:

The way of presenting the building tasks (*real world* and *abstract concept*) influenced the design process. Table 1 describes the main differences observed between the two categories of project types. In the case of *real world projects* it was observed that integration of technology was mostly the last step and was not the primary focus of the maker (technology was at the background of the building activity). Usually the *real world projects* started with a sketch, followed by gathering of materials to build the project. For example, in the windshield wiper project (Figure 2a), the participant spent significant time modeling the toy car using clay, rollers and tape. The choice of integrating a servomotor to function as the wiper followed much after. Even at this point, the focus was on design and aesthetics for hiding the motor box of the servo. The participant was reluctant to modify servo template code to make sure her clay model was not disturbed.

Category	Real world task	Abstract concept task
# Electronics	Less	More
# Physical materials	More	Less
Starting point	Usually started with sketches and common art supply materials.	Usually started with the electronics functionality.
Inclination	Generally observed to more be enthusiastic about these projects as they felt it had more design creativity. Implementation came later in the process.	Observed to be less inclined because they found 'how to' implement an abstract concept more challenging.
Challenges	Said to be easy because: the starting point is usually more common materials, and because they have a mental image of how the object looks and functions.	Said to be more complex because: focus on functionality and high barrier to entry for computational aspects (circuitry and programming) led to frustration.

Table 1. Observed differences between the project types.

Thus, aspects of aesthetics, object design and modeling was at the foreground of the building activity. Modeling *real world projects* was also said to be relatively easier and interesting. One participant mentioned that the *real world project* was easier for him, *"because I knew what I was making" [P8].*

In contrast, *abstract concept projects* had computational materials at the forefront. Often the starting point was understanding how components function and how they can be used. For example, in the case of direction controller project (Figure 2d), the starting point involved choosing components to enable the functionality of direction control. Although this project was an exception, but as seen in Figure 2d, this project used only computational materials. *Abstract concept projects* were also said to be slightly more complex and often saw participants spending more time building circuits and programming their components. These projects were also found to be difficult to accomplish due to programming challenges (*"I just didn't like it because I could not do any of it [programming] almost" [P1]*). One student however, explicitly mentioned liking the complexity involved in the *abstract concept project* (*"I enjoyed it more. I liked the more complex projects" [P6]*).

Three out of 5 participants rated liking their *real world projects* more compared to the *abstract concept projects*. One participant rated liking the *real world project* just as much as the *abstract concept project*. Of the three participants who built one project each, one liked the abstract project he was working on (natural light regulator), one was neutral about liking his *real world project* (elevator) and one did not like her real-world robot project (had in the start of the project mentioned robot to be the "coolest" project). We do acknowledge that it is hard to generalize this result with a sample size of five students exposed to building both types of projects.

In terms of creativity, irrespective of activity type, we gathered that working with Arduino's this time around was more creative: *"We had to be creative, my entire class had to be. I had to build a swing and I had to think, what am I going to use. I used pipe cleaners and servo" [P2].*

The experience was said to be creative because:

" I liked that there was no boundaries, you could do whatever you want" [P3].

"...instead of using the materials the book said, I could use whatever I felt like." [P3]

One participant mentioned that he found it was *"fun"*, but also a *"little bit the same as last time though."*. The difference he stated was, *"we had to actually do more than programming to just make lights to blink" [P1].*

A more obvious takeaway was the benefit of employing partnered learning. It stood out as a good pedagogical tool to reduce anxiety and generate knowledge and ideas. We observed that employing this approach better prepped the students to be able to contextualize and understand the theory behind circuits as well as contextualize and understand the code they were looking at and being asked to manipulate. Think-alouds when it comes to problem-solving/trouble-shooting seemed to be helpful for the students to vocalize and locate the problem and then to work through it systematically to solve it. Thinking aloud may have not only kept them accountable to the task at hand but also may have helped them better organize their thoughts and/or see the issue from a new perspective: *"I relied on my peers for input, for example, maybe you should do this...That's really good. I helped one of my classmate a lot, because she kept asking me how do the resistors work and I said I don't know..."*. (The participant later mentioned having learnt about how resistors work.) [P2]

Table 2 shows the pre- and post-workshop responses for participants' self-assessed experiences for circuitry and programming. Columns two and three represent the number of participants who agreed (strongly agree or agree) to the asked statements. While the number of participants who felt comfortable with programming and circuitry increased after the workshop, most participants had to be helped with programming and circuit building.

LESSONS LEARNT

We set out to use maker culture activities to engage 'at-risk' students. Based on our findings we propose a set of strategies for introducing maker culture as a means of supporting and augmenting academic and emotional education for 'at-risk' students and similar youth groups.

Statement	Agree before	Agree after
I feel comfortable programming computers on my own	2	4
I feel comfortable building electronics on my own	4	6
I enjoy programming computers	3	5
I enjoy building electronics	5	6

Table 2. Participant self-assessments.

Creativity:
Creativity demonstrated (again) its capability to become an important motivating factor when introducing hands-on maker culture and DIY practices [10, 17, 35]. We saw this being emphasized with our group due to the students wish to have a sense of control over the creative learning experience (explicitly mentioned by one student), a feeling which lacks in other aspects of their lives, which are heavily monitored, regulated and surveilled. Creativity as a process defined by Csikszentmihalyi et al. [8], consists of five stages: preparation, incubation, insight, evaluation and elaboration. From our experience we learnt that the strategies to introduce maker culture activities should enable the five stages of creativity for improving engagement and interest. In terms of activity design, the task should focus on identifying projects that will allow participants to be immersed in a problem that is interesting to them and will arouse curiosity. Instead of having something procedural, the activities should provide more freedom for participants to think, realize how the project can be accomplished, and provide access to resources that will allow implementation (as discussed in results section). Discussions with the class teacher also validated this view of creativity, wherein she explained, *"...when we did it the first time, we followed the book, and we followed the procedure laid out in the book to complete something. This time they were given a task and they were the ones who had to creatively come up with a way to program it and put it together and achieve the end result. And I think they really liked that aspect."*

Task Classification:
The students' responses indicated task classification had implications on what was emphasized in the learning process - creativity in design or focus on technical aspects. In *real world building tasks* creativity in design was more emphasized. As discussed in the results section, starting with common art supply materials as opposed to intimidating electronics, and familiarity with the real-world object (having a mental image of how it looks and functions), can promote creativity in prototyping of existing structures, followed by procedurally implementing a standard functionality. For example, the design of sunblinds can take many forms, but the function of opening and closing the blinds is somewhat standardized. This reflection is consistent with suggestions provided by Marshall [20] for exploratory learning activity (where the learner explores an existing representation or model of a topic/*real world building task*) which enable cognitive growth and reorganization of existing concepts. On the other hand employing *abstract concepts tasks* can help place more focus on improving technical skills. For example, to prototype a controllable pendulum, the maker has to explore how to implement concepts such as force, restoring force and gravity. Since pendulums have somewhat standard design, the creativity lies in the implementation of the functionality, and in incorporating the electronics. This insight is similar to Marshall's implications for expressive learning activity, stating that learners create an external representation of a domain using their own ideas and understanding/*abstract concept task* which ultimately enables deeper reflection on the concepts [20].

Entry point:
Learning to program and build circuits is challenging and especially for novice learners [3, 30]. In our study methodology, students were shown videos of projects online as inspiration for what can be achieved using the provided makerspace tools. Sometimes this helped, but at other times this external reflection was less successful, for example, in the case of the LilyPad video: *"...I put up the link to LilyPad, we started going through the other projects, some of the girls were a little more excited about doing it, but all the rest of them were done..."*[Class Teacher].

Beyond early prepping through the use of inspirational videos, access to a wide variety of tools was observed to be another possible entry point. Based on students' comfort level with computation, they may choose to start with more common art supply materials (i.e. clay, pipe cleaners, popsicle sticks etc.) as opposed to electronic materials (i.e. servomotors, sliders, touch sensor etc.). For example, a student who was frustrated with e-textile projects (starting point: circuit stitching), found building electronics enjoyable during the windshield wiper project. The starting point in this case was modeling the clay car (an activity she enjoyed), followed by incorporating the servomotor to serve as the wiper. Thus, computation was a means to an end in her creative process. In contrast, a student who was working on building a system that can clean horizontal surfaces, was observed to be more enthusiastic about starting to program a servomotor. Once the servomotor was functioning as per his requirements, he attached a pipe cleaner on top of the servomotor to function as a broom.

Unlike traditional TUI's, which generally have a concrete physical interface and abstract digital representations, maker culture activities have less clear distinction in terms of what becomes the concrete and abstract representation. For example, programming was the more concrete task in the case of *abstract concept projects*, as opposed to *real world projects* where the physical art supply materials were the more concrete entities. From our experience, this decision is designer driven and therefore more reflective and creative. Our suggestion is to present participants' with a continuum providing a wide variety of entry points that embody different mixtures between the bits and bytes of programming and physical manipulatives representations reflecting on the final concept.

Personal Relevance:
As observed in phase 1 of our exploration, the most important takeaway from introducing makerspace tools was that it

was not enough for the students to simply become technology literates. From our informal discussions with the participants we learnt that students valued the possibility of doing something that was relevant to them (whether in terms of creative skills, problem solving skills or improving programming skills) much more than being introduced to the concept of "how-to".

While it can be challenging to cater to every child's needs, aspects of likability (*"yes, I like my project"*), choice making (*"...instead of using the materials the book said, I could use whatever I felt like" [P3]*), potential to further improve a particular skill set (*"I think it will be cooler to do it at school - practice more programming and manipulating code..."[P7]*) and envisioning future possibilities (*"building stuff, like more electronically controlled objects" [P6]*) were few factors we observed to be relevant to the students' experiences.

Allowing students to discover the possibilities (as noted in phase 2) as opposed to following a procedure from a starter-kit book was more appealing to the students. It is surprising that although projects like LED bookmarks are equally creative and functionally relevant, students found it less engaging and useful. From our observations, we note that the process of creating can be more engaging and personally relevant if the makers are given more discoverable options - the individual tangible objects had to be presented as embodied learning materials (i.e. how can I use clay for this?; can I use servo to solve this problem? etc.) in contrast to presenting the final artifact (LED bookmark) as the embodied learning object.

Relevance to Education:

Our work has a constructionist orientation and is based on the notion that learning is most effective when learners are active in making tangible objects in the real world and draw their own conclusions through experimentation with various media, where learners construct new relationships with knowledge in the process [14]. As such, unlike more traditional instructionist approaches to learning (where the knowledge to be received by students is already embedded in objects delivered by teachers), constructionist learning encourages the learners to create new knowledge based on their active engagement with raw materials.

Overall, the vision of maker culture lends itself to constructionist learning. In our study the participants' demonstrated that students need to be given practical design challenges through the making of tangible, real-world artifacts. We were also reminded that focusing on the affordances of digital technology alone, or even how the learner interacts with the technology tends to reinscribe the traditional grammar of schooling. Instead, we need to examine entire ecologies, including the practices, material contexts, and social contexts of the students. Rather than focus on explication and step-by-step scaffolding [28], our study suggest that learners should be given opportunities to begin in complexity, to discover, to explore, and to enact their own course of learning "by engaging in idiosyncratic challenges, by figuring things out, and by co-producing multimodal artefacts" ([36], p. 7). Maker culture pedagogies engage learners in the "activity of production, enabling actors to deconstruct and reconstruct, interpret and refigure, and to make both meanings and things within the context of appreciably meaningful cultural/aesthetic interventions" ([36], pp. 13). Our findings suggest that the introduction of maker culture to education can encourage students to become designers and producers of materials and resources, and enable them to apply their experiences within various educational contexts.

CONCLUSION AND FUTURE WORK

In this paper we explored a range of possibilities to introduce maker culture activities to at-risk students. Our goal was to engage students with technology to not only to improve their technical literacy skills, but also to create an environment that can support healthy personality development (through the development of skills such as collaboration, peer involvement, developing independence, choice making and self-determination). In an attempt to explore this space, we took a two stage approach, investigating aspects of engagement and task design. Based on our observations and experiences with the students, we presented a set of strategies to inform future research in this space. Our strategies suggested the following: 1) thinking about creativity in task, 2) possible entry points, 3) importance of personal relevance and 4) relevance to education.

Introduction of maker culture activities to communities with limited technology literacy (less access and exposure to technology) is a challenging space to continue exploring. While we explored the role of materials and open-endedness to serve as entry points, the perspective of technology re-design is yet to be explored. As next steps, we would like to explore designing assistive software platforms for promoting wider participation in creative hands-on design activities.

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