The Power of Play: Exploring Bend Interaction as a Design Affordance in Co-Design Process Via Utilizing Theatrical Improvisation (RePlay) with Young Makers

Layda Gongoa
Computing Department, Lancaster University
Lancaster, UK
email address

Euan Fraser Tait
Psychology Department, Carleton University
Ottawa, Canada
email address

ABSTRACT
In this paper we describe a study that was part of an academic/industrial collaboration exploring bend interaction as a design affordance for conducting Co-design process with young makers. Co-designing is a progressive design strategy that involves designing with the users as design partners in the creation process. The results reflect activities and themes which the young makers explored when engaged in tinkering with electronics and arts and craft materials. It also explores utilizing physical externalizations via the *RePlay* framework. This research contributes to understanding the value of maker inspired learning including, the value of physical externalization *(RePlay)* as a tool for facilitating the design and learning process of young makers. It also engages in exploratory design research regarding the implementation of bend transformation as part of developing an electronic learning toy.

Author Keywords
RePlay, Bend Interaction, Maker Inspired Learning, Tangible Interaction, Design Research Methods

ACM Classification Keywords
Design Research, Technology and Education

INTRODUCTION
The team of bright minds assembles, each a designer in their own right. A dense mix of wide eyes and sheepish gazes as the children gaze at the craft tables overflowing with some familiar and some new materials such as mesh, wires, lights and buzzers. Parents curiously peer back as they file out of the room. After an energetic session of focused improvisational play utilizing the *RePlay* framework, the young designers are set loose, grabbing armfuls of materials. The smell of hot glue and faint metallic tang wafts around the room. The quick snips of wire cutters snipping pipe cleaners and insulated wire can be heard at every table. The room is filled with the chatter of collaboration. Many sentences beginning with "I know, I'll…" "Maybe If I…" and "Am I allowed to…?" can be heard bouncing around the room, with each child working through their process in their own unique way. This is a study exploring how some of our youngest minds are an invaluable to the design process when there is both guidance and creative freedom in equal measures.

Background
This paper reflects upon an industrial /academic collaboration and the exploration of bendable interaction as a design affordance via maker inspired learning workshops. Our industrial partner uses "Maker" inspired workshops to facilitate children learning about technology by combining traditional arts and crafts materials with electronic components. "Maker" inspired projects help kids learn about technology by combining traditional materials with electronic components and alternative conductive materials such as conductive paint and conductive thread. Through workshops at schools, libraries and community centers our industrial partner encourages young people to engage in "tinkering". Tinkering, is a mindset, a playful approach to solve problems through direct experience, and experimentation.

Building upon technical research on display deformation via OUI's (Organic User Interfaces), we worked with children to Co-Design low fidelity prototypes as a way to explore design requirements, form factors, contexts and activities for an electronic toy that utilized bend interaction as an affordance. [1,2,3,4,5]. Our research goal was to explore utilizing deformations as a unique design affordance paired with circuit building. In contrast to the commonly used interaction style of taps and swipes to interact with apps or touch screen interfaces such as iPads, a deformable interface offers a tactile interaction with the technology where the feedback is experiential and physical. A bendable interface presents a novel approach for Tangible Human Computer Interaction research. This technology offers a particular opportunity for designing with children in mind, as it compliments their natural desire to explore their environment through tactile manipulation. Bendable interfaces present a well suited tool to facilitate and as well as for designing unique contexts of engagement, learning, and play with technology. The inspiration for this project comes from related technology and education research regarding maker inspired learning, and market research [6,7,8,9,10]. This project also draws from the experience of technology and education researchers. Leading education researcher Kylie Peppler conducted a forum in 2015 at the NY Maker Faire with educators who remarked that the "Maker movement in education was unlike anything ever seen, and in particular, that teachers were the driving force behind the change." (Foreword) [11]. Peppler describes research in this highly interdisciplinary field as "Makeology" meaning the study of making which is the titile of her recent book on the subject[11].

RESEARCH METHODOLOGY

The project involved a Co-Design process where by an adult design team collaborated with young makers in an informal maker context. The unique quality of this design process is that the children were not simply passive participants but held key roles as active members of the design team. Co-designing is a progressive design strategy that involves designing with the users as design partners in the creation process. For this project we were inspired by the *Blue Bells* method as well as the *RePlay* framework and applied these strategies within an informal making workshop. [12,13,14,15,16,17]. Blue Bells is a method developed by researcher Janet Read at the Child Computer Interaction Group at the University of Central Lancashire and used in HCI (human computer interaction) to co-design technological artifacts with children [Utilizing *Blue Bells,* children as not treated just users, but equal members of a design team [12].

RePlay

We emloyed the *RePlay* framework to conduct exploratory research. It provided the researchers with an entry point for Co-designing prototypes that included bend interaction as a key design affordance. In this study, *RePlay* was used as a body storming technique. When conducted as part of a group activity *RePlay* and some of its' techniques tap into the concept of group mind or flow by guiding the group to collaboratively engage in enactive perception, performing what one of the author's describes as "creativity in action". Creativity in Action encourages awareness through reflection during the creative process by drawing attention to physical aspects of creative process. Via *RePlay* important themes to innovation process are explored for example reflection, flow, improvisational creativity, enactive perception and bodily externalizations [16] The RePlay techniques used for this study are described below:

Design Machines

As can be seen in Figure 1.0, this game involves players using their connected bodies to create a living, breathing "machine". One player begins by performing a motion or sound continuously. More and more players are then incorporated as part of the design machine, each with their own unique action. One of the conditions of this game is that one part of each of the player's bodies' must be touching another player. Participants need to pay attention to the other player's movements and choose their own physical expression in response. Optimally, the creative component is expressed to its fullest when the players engage in minimal verbal communication, and instead focus on the other player's movements and how they can contribute to the "design machine". The facilitator then selects one of the

Figure 1.0 Design Machines exercise in action.

players and asks them to step out and describe the design machine based on what the players have collectively created. [16].

Trigger Objects

Trigger objects are open-ended props that represent metaphors for tangible interfaces. In the context of this study the trigger objects were incorporated within the design machine activity to organically introduce the potential of bend affordance to the children we were working with. There were 3 trigger objects and each incorporated bend interaction as well as the use of circuits. One had a vibration motor, the second had an LED and the third has a buzzer. As illustrated in Figure 2.0, when the trigger objects were bent and connected end to end, they would trigger the circuit to buzz, vibrate or make a sound [16].

Traces

The Traces method is a technique to map out a creative process, usually through drawings, interviews and journal entries. In addition to the information shared by the creative,

Figure 2.0 Maker #11 interacting with trigger object.

the researcher collects their own set of observations concerning the designers research process, typically through video or photographs also sometimes in some cases the researcher's own visual interpretations. In our first workshop we collected drawings the children created a part of planning their design process. In the second workshop, we collected videotaped physical externalizations as we prompted the young makers to use their bodies to reflect on the design process. The Traces technique allowed us to individually analyze each child's creative process and observe and record emerging themes[16].

Research Question

How does conducting *RePlay* impact children's design processes and how is bend deformation incorporated into their final outcome(s)?

Research Hypothesis

We expected insights about designing a deformable prototype with children in terms of technical requirements, knowledge regarding our target audience's needs and expectations, as well as data including videotaped physical externalizations, photos, low fi prototypes, interviews and drawings. The low-fi prototypes which the children created are the basis for conducting further development. As part of this exploratory research project we expected to identify new research challenges and areas of potential research opportunities. Based on our prototypes and user studies we expected a set of requirements for designing toys which utilized display deformation as part of their design.

WORKSHOP STRUCTURE

Our research involved low-Fi prototyping/Co-designing sessions with a mixed team of interaction designers, facilitators, educators, and children. For this study, the core requirement was that the project needed to include bending as a key facet of the design. Via utilizing *RePlay*, collecting *Traces*, and think aloud methods we investigated how much the bends were informing the activity and whether utilizing *RePlay* facilitated the children's creative process and later reflection on *'making'*. The first part of the workshop consisted of utilizing the *RePlay* framework. What is unique about the *RePlay* framework is that it meshes together design research with improvisational games to encourage design thinking and collaboration. The session began with some traditional Improv Theatre warm up exercises including passing around an invisible object. As the object was passed around participants would transform it by giving it properties such as "heavy" or "fuzzy". In the second workshop, a constraint was introduced that the children had to incorporate at least 2 bends and 2 trigger objects in their project. After the constraint was explained the children were lead through a *RePlay* whereby we organically introduced the *Trigger objects* and gave children opportunities to interact with them during the *Design machines* exercise. At the end of each making session the children worked in pairs with a researcher and were instructed to explain their inventions to each other. Researchers asked exploratory questions concerning the child's design process to encourage reflection. Initially, the children were prompted to create drawings as well as verbal explanations. In the second workshop the children were prompted to use physical externalizations in conjunction with their verbal explanations. These videotaped feedback sessions facilitated the children's reflections on making. After each workshop, the adult design researchers discussed the workshop, the results, as well as what could be improved for the next session. The debriefing sessions were also videotaped for future reference. The adult design team outside of the workshops with the children explored different materials, form factors and expanded upon the prototypes developed in the studies with the young makers. This work was informed by existing research, their own prototypes, as well their skill sets in interaction design, engineering, psychology, computing, deformable interfaces and technical validation.

Participants

We worked with 2 groups of 6-10 children between the ages of 7-9 yrs. All the participants had previous experience attending a previous workshop or event. The workshop team consisted of 2 facilitators and 3 research assistants tasked with taking notes, drawings, and photographs of the children's projects. Another research assistant was exclusively tasked with videotaping the design process. Once the making part of the workshop was over the researchers also conducted interviews with the children regarding their inventions and creative process. As part of debriefing and discussing the results, the research assistants and facilitators discussed what worked and what could have been improved regarding the workshop.

Materials

Arts and Crafts materials such as pipe cleaners, pom-poms, foam and mesh along with circuit building materials that enabled vibrating, spinning, lighting up, and movement in straight lines and circles were used. Examples of circuit building materials were; conductive paint, wire, DC motors, vibration motors, buzzers, LEDS, and bend sensors.

RESULTS

Given this research was exploratory we were prepared for a wide variety of results and an organic workshop structure. We have framed our results of the Co-design process applying a similar structure to the *Blue Bells* method by defining the three phases of; before play, during play and after play. The most significant results occurred "during play" which was when we conducted the workshops with the young makers. We hypothesized how the children might respond to the use of *RePlay* but we were not really sure what to expect. After conducting workshop#1, we worked on developing the workshop structure in a direction which would allow for more reflection and constraints regarding the use of bend deformation this was due to observations made by the researchers as well as the facilitators during the debriefing session after workshop#1.

Child ID worksop 1	Invention outcome	Child ID worksop 2	Invention Outcome
1, Male	-Aesthetic Bending Ranndom craft materials taped together	7, Male	-Functional Bending Light up game required the bending of wires to function
2, Male	-Absence of Bending Alien craft model	8, Female	-Functional Bending Copied trigger object from RePlay
3, Female	-Aesthetic Bending Model of a cat, bent pipe cleaners to create whiskers	9, Male	-Functional Bending Conceptual ink sprayer used bending to direct ink hose
4, Male	-Absence of Bending Decorated Pen Holder	10, Male	-Functional Bending Wires were positioned so they could be bent to complete the circuit to power his lamp
5, Male	-Absence of Bending Robot model, using toy cars as wheels	11, Female	-Functional Bending Complex use of lights and circuitry to modify a toy car Included a rudimentary impact sensor that relied on deforming a bumper made of wire
6, Female	Functional Bending Complex light up alien model with posable head	12, Female	-Functional Bending Electronic belt, bending was necessary to wear and activate the belts sound and light functions

Table 1.0 Summary of makers' inventions from workshop#1 and #2.

Before Play

We conducted a great deal of material research and best practices research of existing electronic toys (18,19,20). Given the connections between various components was an important design requirement for this age group, we researched traditional toys with this quality and how the material design was executed. In terms of our research design we also used *RePlay* games that we thought would be relevant to facilitating the design process as well as fostering reflection about making.

During Play

In workshop #1 the children struggled with trying to incorporate bend interaction as part of their inventions. In some cases, it was dropped as a functional component and instead became a characteristic rather than an interaction. Table 1.0 summarizes the various inventions children in the workshop created and Figure 3.0 is a sampling of projects from both workshops. In Table 1.0 each invention has been given a designation depending on its relationship with bending. Aesthetic bending is defined as being merely an accessory part of the design process with no functional qualities. After the creation phase of the workshop was completed we questioned the children about their design process and use of bending. In workshop#1 the young maker, would pick a part of their invention that was malleable and declare that it was a bendable part. The challenge we found with this, particularly in workshop #1, was bending was never fully conceptualized as an interaction style. We suspected that the children would create their projects without bending in mind and later try to justify that aspects of it were bendable to satisfy the researchers. In workshop#2, as previously mentioned, we decided to introduce constraints by stating that the children had to incorporate at least 2 trigger objects and 2 bends as part of their inventions. This change in workshop structure influenced the types of results from night to day. For example, instead of creating numerous superficial examples of bend interaction the children's projects became much more elaborate and instead of exploring a set of loosely connected ideas each of the inventions suddenly became much more focused and tangible as is evidenced in Table 1.0 The children in workshop #2 displayed a much stronger grasp of bend as an interaction style incorporating bending as an invaluable functional aspect. Although Figure 3.0 represents only a few projects from each workshop, the image is fairly representative of the quality and complexity of the projects the children were working on in each workshop. Workshop #1 was characterized by a set of similar looking inventions that mostly consisted of one or two pre-made objects glued or taped together as can be seen in Figure 3.0. In workshop #2 after the introduction of the trigger objects to demonstrate the potential of the material available and with minor guidance in the form of constraints the children's projects became far more complex. At first glance the second from the top on the right hand side of Figure 3.0 may appear to be a strange set of craft materials cobbled together, however its design and construction is deceptively complex. This belt constructed in the workshop #2 buzzes and lights up after the user wraps it around their waist. Seeing these images side by side is a clear indicator that children are capable of complex design processes when given inspiration and a framework to

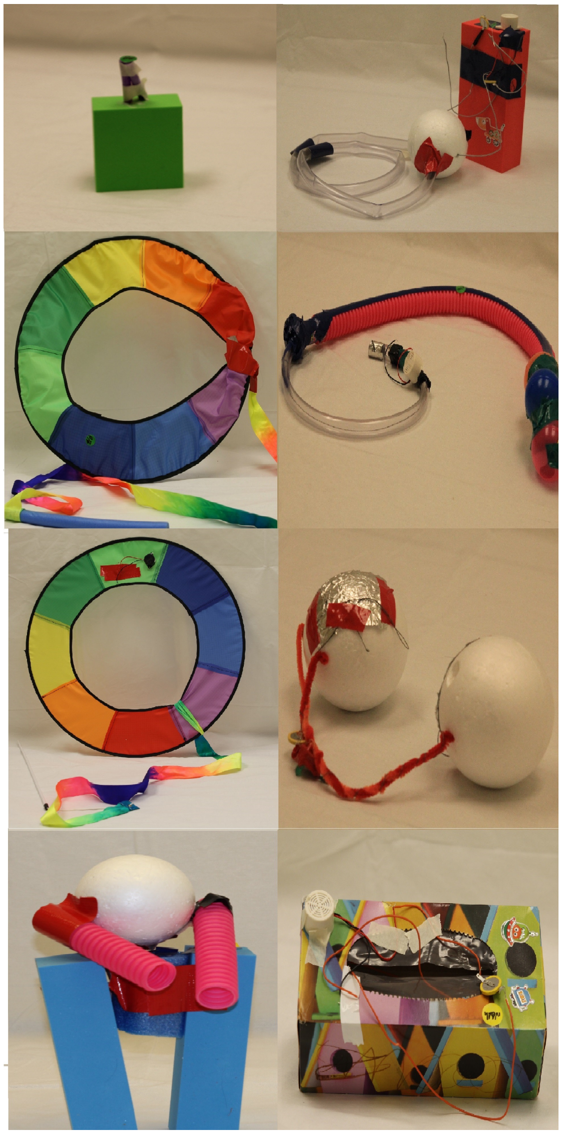

Figure 3.0 Sample projects, images on the left are taken from workshop 1, images in the right are from workshop# 2.

build their ideas around. The trigger objects were successful in that they served to give the children a concrete starting point for their projects as well as an example of how to apply the circuit building materials. This was in contrast to workshop #1 where we presented the children with a mass of materials and little guidance. This lead to in some cases numerous but unfortunately under elaborated prototypes which did not adhere to the requirement of exploring bend deformation.

One of the goals of the research was to get an idea of the types of activities which children engage in during the making process. We found that robots were a huge theme, expanded on by several different children. Other popular themes included wearables, small animals, wheeled objects and flying objects such as frisbees. There were also a number of decorative boxes as well as objects which were highly interactive and exploring some of the fundamental concepts of interaction design in that when I do X this trigger Y. There were some projects which were much more process oriented or conceptual in nature whereby the young maker was really curious about exploring the materials and less concerned about the final outcome. Some children had concrete plans from the start and other developed their ideas as they worked with materials. For some children there was a concrete idea such as "gravity" and for others it was based more on personal use or perhaps an improvement to their lives. The variation in design process for example the importance given to planning for some of the makers compared to others echoes observations of expert designers and how each person's process is unique. [17]. Another example of a unique work style can be seen in Maker #1, who participated in the *RePlay* but did not display overt enthusiasm. His design process was individualistic and he opted to sit on the floor away from his table-mate. He ended up creating aesthetic toys "just for me" that were based around and exploration of the properties of the materials such as the mesh tubing. This is in contrast to Maker #11 who from the very start had a clear planning process. Maker #1's project in Figure 4.0 is on the left and Maker #11's project appears on the right.

Even amongst twins there was clear differences in their design process. For example, twins Maker #9 and Maker #10 displayed enormous enthusiasm for all stages of the workshop. They eagerly grabbed handfuls of material and showed a constant stream of work, occasionally punctuated by the occasional pinching or grabbing of the other twin. Maker #9 reported that he had been inspired to make his ink sprayer after seeing one of the researchers wave their arms during the design machines exercise. He reported that it looked like an octopus, which gave him the idea for his ink sprayer. Conversely his twin brother reported that he had not been inspired by the design machines activity but had become fascinated with the light up trigger object, prompting him to create a secret reading lamp (to be used after his mum had put him to bed) that used the deformation of wires to turn the light on and off. Other children had differing reports where they informed researchers that the *RePlay* exercise had "been fun" and "helped wake me up" but did not inform their design process. The idea of fostering awareness within

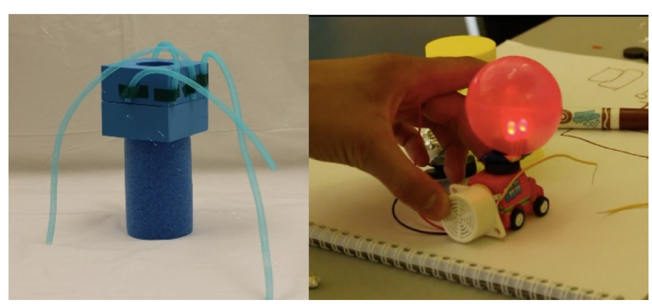

Figure 4.0 Aesthetic objects taped together (left), impact sensing car (right).

creative process is a previously documented observation of one the benefits of conducting *RePlay* as part of *'creativity in action"*. [15,16] Child #12 for example stated that she relied entirely on a stream of ideas that started as soon as she began to assemble materials and speaking aloud. The variety of design and ideas displayed by the young makers in both workshops was remarkable. A concern one of the facilitator's expressed was that on several occasions she had observed a "viral" effect amongst the young Makers where one project drew the attention of many of the other children and resulted in multiple copycat projects. Our study controlled for this phenomenon by splitting children up into groups seated at different tables, however in some cases there was a small copycat effect, as can be seen in the two middle images on the left side of Figure 3.0. Both of the projects were constructed by different children at opposite ends of the room and yet they look almost identical. Other than a few copycats the majority of designs were based around unique concepts inspired by the child's own personal experience. For instance, Maker #3 designed a model cat, because her parents would not allow her to get one in real life. During the *RePlay* exercises she was extremely shy. In Figure 1.0 she can be seen clinging to a researcher's leg. However during the course of the workshop she opened up considerably as soon as she started applying her idea and bringing it to life.

After Play

Given the themes and activities the children were interested in we decided upon the idea of a building a kit in order to facilitate activities such as building, animals, masks, jewelry, and cars. One aspect which we explored in more detail was how the circuits might be embedded inside building blocks. As a result, we did some material exploration via 3D printing of the connections. Given that each of the members in the adult design team came from different backgrounds such as engineering, computer science, and design we employed the use of squishy circuits as a communication tool and as a tactile way to explore aspects of the prototype [21,22]. From a technical standpoint we explored using fibre optic cable as a bend sensor which via attenuation would sense light levels. This change via bending the fibre optic optic cable could then be utilized as information to trigger an interaction. We came across this application of fibre optic cable based on previous research implementing its use in the design of a flexible stylus pen [23].

DISCUSSION: Maker Centred Learning

As society moves from a jobs to culture to a culture of technological literacy Blikstein and Worsley remark that the materials which children use robotics kits, and electronic kits should be designed specifically with children in mind. Platforms such as Arduino and others are not appropriate, as they introduce a plethora of technical information foreign to original learning goal and end up frustrating children before they are able to accomplish even the simplest projects. [24]. Designing learning tools with this specific demographic in mind fosters youth-oriented accessibility. Traditional childhood developmental theorists such as Piaget, Montessori, and Vygotsky have suggested that hands on experiential learning is extremely valuable in terms of shaping an educational process [25,26,27]. Making is a way of bringing engineering to young learners. These concrete experiences provide a meaningful context for understanding abstract science and math concepts Constructivism, a term coined by the founder of the maker movement Seymour Papert, encourages children through facilitated projects with technology to independently program projects while at the same time work within a supportive framework[28].

DISCUSSION: Teaching Fundamentals of Human Computer Interaction

One unique and unexpected outcome was how the *RePlay* framework was utilized to teach fundamentals of human computer interaction. Through having the children conduct the *design machines* exercise they began to understand the basic principle of "cause and effect" and how to translate this as part of design requirements for their inventions (prototypes). This is evidenced in the final projects which the children made but also how *design machines* and the *trigger objects* provided a physical analogy for guiding and supporting the young makers' design thinking.

DISCUSSION: Utilizing Replay as Part of Co-Design Process to Facilitate Body Storming and Reflection on Making Practice

After implementing the trigger objects and constraints as part of conducting RePlay in workshop#2, a clear shift in outcomes were observed. Many of the children in workshop#1 seemed to be confused as to the instructions of incorporating bending into their projects and instead opted to create superficial models based on familiar objects or copy other children: see left-side Figure 3.0. In workshop#1 makers often were perplexed as to how to use the electronic objects, despite the researcher's explanations. However when we introduced the trigger objects in workshop#2 they were much more integrated in the makers projects. *RePlay* was not only a good way to facilitate the initial brainstorming process but also worked as an effective tool for explaining the constraints of bend interaction as one of the design requirements via the use of design machines combined with the trigger objects. In workshop#2 the use of *RePlay,* to introduce bend interaction resulted in more highly elaborated projects which incorporated bend interaction as opposed to bend as a functional characteristic. This is evidenced during the reflection part of the design process when researchers asked children about their design process. The answers we received were much more concrete. The children clearly articulated their train of thought as can be seen in the YouTube video "the power of play" [29]. Table 1.0 illustrates how the concept of bend interaction is much more integrated into the final designs in workshop#2, as an

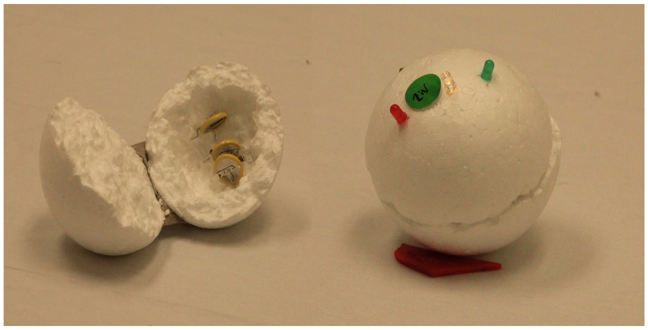

Figure 5.0 Maker #7's light up guessing game. Left image interior, right image features light up exterior.

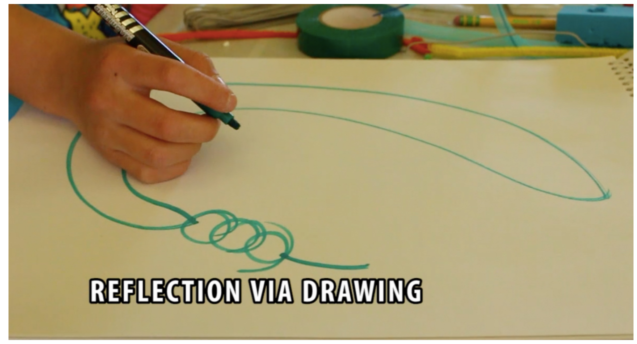

Figure 6.0 Image of Maker #12 drawing her electric belt she'd created earlier in the workshop.

essential component of their projects rather than a superfluous add on. A clear example of integrated functional bending that came about was Maker #7's light up guessing game in workshop# 2, featured in Figure 5.0 The premise of the game of chance was that you had to guess which light amongst three would be illuminated after bending a wire to complete the circuit. A simple but distinct difference in the usage of bending compared to for instance in workshop#1 where by, Maker #1's object Figure 4.0 on the left, incorporated bending but only in such a way that it was a functional trait of the material he utilized. According to these results, it is clear that when designing with children *RePlay* can sometimes be an effective tool.

DISCUSSION: The Value of Physical Externalization to Facilitate Reflection on Making

An important aspect of the makers' design process is how the children responded to being asked to conduct physical externalizations and how this translated in differing ways in their design process. For example, twins Maker #9 and Maker #10 based their design process and ideas on conversations they had with each other, reporting to have gained no creative input from the *RePlay* exercises. In comparison, Maker #9 reported that during the invisible ball exercise he had been inspired to think about ink and octopuses, jumpstarting his design for an ink sprayer, featuring a hose (or tentacle) that would spray ink in concept. Other children responded well to the design machines exercise, such as Maker #11 who reported that seeing one of the researchers bend his arms reminded her of a car, which prompted her idea of using a toy car as the basis for her circuitry project.

Another key observations was how that only a few of the children utilized drawing as part of their creative process. This was an interesting observation as design research suggests drawing is used sometimes as a tool for reflection and sometimes as a tool for planning during the creative process [17]. This can be seen in Figure 6.0, where Maker #12 can be seen drawing her electric belt invention. In the first workshop, we had the children perform an exercise in pairs in which one child would describe to the other child their invention via drawing. We however found this task to be daunting for most of the children. One of the workshop facilitators who has a great deal of experience with working with this age group within a making context summarized that drawing for this age group can sometimes be very challenging as at this age some the children may still be struggling with things like manual dexterity and familiarity and confidence with drawing materials. Children at this age are also very eager to please and therefore might not yet feel they possess the skill set to communicate their ideas affectively. We therefore sought to incorporate physical externalizations as part of the reflection part of the workshop not only in the early body storming via *RePlay* but also later and instead of drawing. In the second workshop we did this by instructing the children to physically act out their inventions to their partner, while being asked exploratory questions by the research assistants. We found this process to be much more effective as a tool for reflection compared to drawing, as well as for collecting information about the

Figure 7.0 Maker #12 utilizing body storming to reflect on her design.

children's making process. In Figure 7.0, this process can be seen put into action after a researcher prompted Maker #12 to show us what her invention looked like by acting it out, allowing her to incorporate physical expression into her reflection process.

DISCUSSION: Technology Product Development

Our primary focus of this research was the design process, rather than the development of technological breakthroughs. However, given part of the research had to do with exploring the bendable interaction aspect of our prototype it seems relevant to mention it. We had valuable recommendations in terms of the various technology we could implement in terms of achieving bend interaction. For the purpose of this exploratory research we decided to explore a method which utilizes fibre optic solid core material as a bend sensor. This was achieved through the effect of attenuation[23].

CONCLUSION

As our society moves towards a ubiquitous adaption of technology as a natural extension of our moment to moment activities, we are also transforming the nature of play. Traditionally speaking, imaginative role-play is often an opportunity to practice adult activities such as tasks around the home. However, with the use of technology as a creative tool, children can make functional inventions and adaptions which reflect their unique needs and requirements. This in fact changes the nature of play and the agency children now have to impact their surroundings. This type of hands on engagement with technology presents an opportunity for children to engage with technology via tinkering and maker inspired learning. Educators, parents and education researchers therefore have a vested interest in developing our current curriculum to incorporate the principles of the maker movement into the classroom.

FUTUREWORK

It would be interesting to conduct another study where by the reflection component was further embedded as part of the design machines game. This would mean that *RePlay* would be used as a framework for body storming as well as reflection via conducting the design machine game, and introducing constraints via the trigger objects. Once the making session was complete design machines would be played once again as a tool for reflection regarding the making process and where the young maker may have struggled with materials or made particular breakthroughs. The children would repeat the *design machines* games by collectively creating each-others' inventions with their bodies. At the same time players would narrate the functions and how they achieved their outputs with making. The researchers would also ask questions regarding their process, and use of materials in order to facilitate reflection about making.

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