



Computer as Chalk: Supporting Youth as Designers of Tangible User Interfaces

Amon Millner, amonmillner@acm.org

Franklin W. Olin College of Engineering and MIT Media Lab

Abstract

This report covers an effort to develop engaging technological tools and activities that promote learning and creative expression. It argues that the ways in which people use chalk can serve as an inspiration for rethinking how people can harness the expressive power of computational technologies. The report introduces the Hook-ups System, a set of technologies and activities designed to enable young people to create interactive experiences by programming connections between physical and digital media. With it, young people integrate sensors with various materials to create tangible interfaces for controlling images and sounds in computer programs. Research questions explored in an evolving design experiment probed how attributes of the Hook-ups System enabled youth from two after-school technology centers to engage in building personally meaningful projects, express themselves, and transform how they approached design.

Keywords

Scratch, sensor board, informal learning environment, physical computing, tangible interface

Introduction

The ways in which people use chalk (e.g., drawing hopscotch grids) can serve as an inspiration for rethinking how people can harness the expressive power of computational technologies. Today's computing devices have the potential to enhance expressive activities for diverse groups in similar ways that chalk does, but that potential has yet to be realized. This paper introduces a system designed to help young people explore chalk-like properties of computing technology. Now, more than ever, computers (and related embedded devices) need to fulfill their role of being machines that offer many avenues for dynamically creating artifacts.

Chalk has become a mainstay for far-reaching realms of work and play. In the form of sidewalk chalk, it allows children to lay a foundation for playing on any open asphalt or concrete surface (e.g., hopscotch and foursquare grids are often drawn in chalk). In the form of tailor chalk, it enables fashion-focused professionals and hobbyists to mark designs on a variety of materials that will be cut to create custom clothing. Sculptors even shape lumps of chalk into artistic pieces. Chalk can be the cornerstone for many creative activities for people with a variety of interests.

Too many citizens and children do not conceive of computers as being integral tools for the activities they engage in based upon their interests. It is common for computers that schools or technology centers make available to children to have software like adult-centered productivity tools, edutainment applications, and games. Applications that support creative expression are less common. Computers have made their way into many modern classrooms, but are typically used as a supplement to a typical classroom's information transmission culture. Chalk activities are established among a diversity of children as being more than a means of transmitting information from teachers to students. Seeing chalk peppering city sidewalks should serve as reminders of



how children use the medium creatively and also serve as a challenge to creators of computational tools to strive toward making computers as much a part of children’s creative culture as chalk is today.

This report provides insights into how children learn as they design using the Hook-ups System. The Hook-ups System is an attempt to transform computers into a new kind of tool for helping novices make interactive experiences – ones that encourage youth to learn in new ways through creating their own tangible user interfaces. The Hook-ups System is a set of technologies and activities designed to enable young people to program connections between physical and digital media, specifically by integrating sensors with various materials to create tangible interfaces for controlling images and sounds in computer programs that they themselves create. For example, a 10-year-old created a paper-plate-based flying saucer, added a sensor, then wrote a program to control an animated flying saucer image on the computer screen.

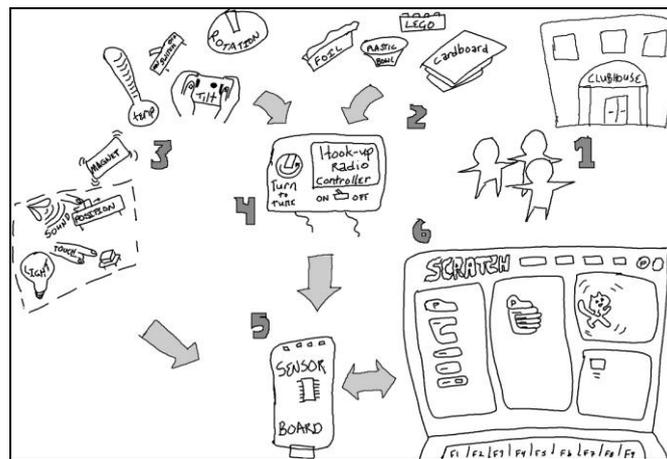


Figure 1. Elements of the Hook-ups System

Youth currently use Hook-ups tools for a range of activities that relate to their varied interests. It enables youth to act as “physical computing” designers – creating interactive experiences using the process sketched in Figure 1, which serves as an overview of how the elements that comprise the Hook-ups System work together. People usually over the age of seven [Figure 1-1] combine physical materials [Figure 1-2] with hand-made or manufactured components that react to changes in the physical environment (sensors) such as sound or light levels [Figure 1-3] to make a creation called a “Hook-up” [Figure 1-4]. People connect sensors (e.g., knobs or switches) on Hook-ups to the core technology of the Hook-ups System - Scratch Sensor Boards (Millner, 2007) [Figure 1-5]. This board plugs into a computer running a programming environment called Scratch (Resnick et. al, 2009) [Figure 1-6]. Scratch controls digital media according to how a person writes a computer program to behave when a Scratch Sensor Board notifies Scratch that part of the physical world that it is sensing has changed. The process of creating a Hook-up varies from person to person based on interests, experience, and materials available. Technical information about the Scratch Sensor Board (SSB) can be found at (Millner, 2007). Most of the 10,000+ sensor boards currently in circulation cost learners and educators \$50 United States dollars to purchase (for the physical parts from sparkfun.com – additional shipping and handling costs varied).



Background

Constructionism is the cornerstone approach to learning upon which Hook-ups research is built. The approach suggests that young people learn best through the process of constructing artifacts that are meaningful to themselves or others in their communities. Papert argued that people learn particularly well while actively engaging in constructing artifacts to share with and be critiqued by others (Papert, 1980). Hook-ups work involves young people designing and sharing artifacts in community settings. Rogoff's idea of a community of learners (1994) suggested that learning comes as people participate in shared endeavors – transforming roles they play and understandings they have along the way. Creating Hook-ups in group settings typically involves transforming participation. Creators are idea generators at one point and collaborative problem solvers at others. Constructionist and community of learners paradigms both promote children having responsibility and autonomy as they relate to information as it is used in practices that are relevant to their community.

The progeny of the Logo programming language (McNerney, 2004) developed over the last 30 years serve as a foundation for the Hook-ups System. The trajectory of physical computing toolkits focused on making “tangible interfaces” to graphical programs running on computers are also foundational. Toolkits described in an IEEE summary paper (Cottam & Wray, 2009) vary in intended use and audience, from MIDI-based toolkits for digital music enthusiasts to the BASIC Stamp for roboticists. Notably, the authors mention that essentially none of the toolkits in the tangible user interface space are designed to appeal to young learners. The Hook-ups System addresses that void in the up-and-coming physical computing field. It does so by providing an example youth-friendly system that features: a programming languages that is more visual than text-based; an interface board that reports sensor readings to a computer that is running programs that respond to interface board communications.

Other projects that relate closely to the chalk inspiration of the Hook-ups System are ones that situate computing within artistic contexts. Researchers are increasingly recognizing that establishing connections between computing and communities of other practitioners who construct physical artifacts has value for broadening who participates in computing. A growing number of designers of computational toolkits who believe that creative makers who work with traditional media such as paint can learn a lot from and change the thinking of fellow creative makers who work mostly with computation. For example, Graham's *Hackers vs. Painters* (2004) delineates ways in which painters and computer-savvy makers can benefit from adopting processes associated with learning both practices. Graham noted “I've found the best sources of ideas are not the other fields that have ‘computer’ in their names, but the other fields inhabited by makers. Painting has been a much richer source of ideas than the theory of computation.”

Methods

The design experiment framework has guided Hook-ups research. Design experiments can be characterized as research projects that seek to achieve some practical change through iteratively re-designing educational spaces and to assess the successes and failures of the efforts on an ongoing basis (Brown, 1992). They provide a framework for engineering, re-engineering, and adapting to local conditions of innovative learning environments. These studies are oftentimes situated within complex learning environments. Using the framework helped highlight ways in which Hook-ups technologies and activities influenced the participants learning in two informal environments. Insights from the first case study below helped improve the tools and learning



environment of the second case study.

Research questions focused on how the Hook-ups System exhibited attributes that enabled young people to create in ways that gave them experiences similar to those that people have when using chalk – engaging, expressive, and transformative experiences. The engaging attributes of chalk experiences help engage groups of young people who vary in culture, interests, and extracurricular activities. (E.g., chalk can mark up sidewalks for hopscotch). The expressive attributes support youth in creating and sharing projects that express parts of their personalities, passions or positions on social issues. (E.g., chalk can be sculpted into artistic expressions.) The transformative attributes transform how youth approach design – enabling them to explore design strategies and engineering ideas. (E.g., iteration is easy with chalk.) The questions asked:

In what ways does the Hook-ups System:

- Q1) engage groups of young people who vary in culture, interests, and extracurricular activities within an informal learning environment;
- Q2) support youth in creating and sharing projects that express parts of their personalities, passions or positions on social issues; and
- Q3) transform how young people approach design – enabling them to explore design strategies and engineering ideas?

This study’s research questions examined the extent to which the Hook-ups System has been designed and deployed in two informal learning environments in ways that made it embody the attributes of chalk by being: adept at *engaging* a diversity of youth interests in creative processes, capable of evoking *self-expression* during creative processes, and instrumental to activities that helped children *transform* their approaches to design.

The Hook-ups design experiment structured how data were collected and analysed about how the people in the learning environments adopted the System. Multiple data streams from a set of visits to one site would inform the plans for future visits to that site and the other research site. The data also guided iterative refinements to the Hook-ups System. Data included field notes, project artifacts, video recordings, and surveys. Primary findings are presented as case studies.

The Hook-ups System: Case Studies & Analysis

Two cases are presented to show Hook-ups in action: Stuffed Bears and Hot Potatoes. Each case presents the accounts of events, artifacts, and experiences that indicated that the Hook-ups System enabled learners to have experiences that were engaging, expressive, and transformative.

Stuffed Bears

A group of teens taught two stuffed bears how to “talk” at the South End Technology Center (SETC). SETC is situated within a set of housing developments. Its population is comprised of mixed-generation learners - people from the ages of four to “no-longer-counting.” The Center offers: free computer access to youth of all ages; computer-controlled fabrication devices such as laser cutters; craft materials; a soldering/circuit-making workbench; and a program called Learn 2 Teach, Teach 2 Learn (L2TT2L).

L2TT2L mobilizes teens in their out-of-school time to gain knowledge in emerging technical domains, to create their own ways to share knowledge with their younger peers, and to contribute to the leading edge of technological innovation. It is an evolving multi-part program that provides an opportunity for youth (aged eight and up) to engage in projects related to science, technology, engineering, and math as they might in some college environments. Once teens are hired into the



program, they are paid a salary to be teachers of their peers. During a summer phase of the L2TT2L program, participants use part of their time working on group projects (when they are not teaching younger learners community centers). One participant of the 2007 summer session, Shawn, discussed his experience creating the Stuffed Bears Hook-up in response to a survey question asking him to explain his three-month long summer group project.

Shawn: The first year of my L2TT2L journey, I was grouped with about 6 or 7 young people. Our community-based project was to create a robot that struck out to gang violence or whatever violence struck in our community. So my project was a talking bear [...] We took a regular bear that kids probably 7 or 6 play with and we inserted sensors in the bear - in the hands, the feet, the stomach, and I think we had some in the ears too. We recorded sounds into the sensors so if one of the kids pressed the palm of the bear, it would either say a phrase or teach [...] The songs would be either teaching the kids how to recite their ABC's, their 123's, or just have positive messages. In our communities, there's a lot of gang violence so we wanted to start by creating a project that would affect the kids younger than us so they wouldn't have to live through the same.

The idea for Shawn's project came when one of his six project group members brought an old electronic stuffed bear toy to SETC. The toy, named Talking Bubba Bear, was dressed up in overalls and a flannel shirt – an outfit inspired by farmers. It said things with a southern U.S. accent when someone squeezed its paw. For example, one squeeze would play one of the 200 phrases it had in its memory such as "hey, will you fluff up my hair? Come on, wiggle my head and fluff up my hair." When a person wiggled its head, it would then respond by laughing. That bear became the base upon which Shawn's group built its summer project: Thugaboo and Proper Bear (Figure 2). The project group members realized that toy companies used technology to make caricatures of certain dialects, such as southern U.S. accents. Why shouldn't they try making their own caricature toy? No one in the group knew of any toys that spoke like some of the thugs in their neighborhoods. They figured that they should make their own – or at least, modify the existing toy to say things that they wanted it to. They called their first modified bear Thugaboo.



Figure 2. The Proper Bear and Thugaboo Hook-ups

Shawn's group was looking to learn about how the existing electronics worked inside of the talking bear so that they could know where to modify it. The group also sought help from the three adult L2TT2L staff members as they attempted to understand how the toy's sensors were connected. Group members explained their attempts to understand the bear's sensors to staff. Instead of guiding the group to use multimeters to measure signals, staff helped group members probe the bear's wires by having the participants touch wires with alligator clip-heads that measure resistance from one of four ports on a Scratch Sensor Board. The group put clip-heads on two wires and watched the Scratch screen as they squeezed different parts of the bear. On the screen, they had a read-out showing the status of whether sensor-A was connected. It would toggle from "FALSE" to "TRUE" when a person squeezed the part of the bear that contained the sensor to which the Scratch Sensor Board alligator clip-heads were attached. The group labelled the wires to keep track of sensor mappings so that they could write programs specific for each.



Shawn's group played around with messages from the Thugaboo bear that sounded like they were coming from a seasoned neighborhood thug. For example, one recording urged kids to "learn your ABCs" instead of "getting A's and K's." The latter was referring to something that kids might do if they involved themselves in the gun-violence-ridden world associated with becoming a thug. The "A" and the "K" alluded to the first letters of infamous AK47 assault rifles. Thugaboo spoke using a vocabulary with which Shawn's group felt their target audience would be familiar enough to understand and find funny.

The group used what it learned from converting Bubba Bear into a Hook-up to design a second bear that also delivered stay-in-school messages. They made this bear, which they called Proper Bear, use a vocabulary that they did not associate with thugs. Instead, they recorded phrases in what they called "proper" English. They started with a stuffed bear that came with no built-in sensors. They instrumented it with switches that were small enough for them to maneuver through the stuffing into the bear's extremities. They mapped some of the recordings in a Scratch project to the sensors in Proper Bear. They dedicated four alligator clip-heads of a Scratch Sensor Board to Thugaboo and another four to Proper Bear for a demonstration at the 2007 L2TT2L final project exhibition (that was open to the public). They used one Scratch program that had a drawing of a bear on the screen to show users where the bears' squeezable sensors were. The program included multiple recordings for each bear and would play different quotes at different times. The idea was that all types of people (and toys in this case) could speak to children about the importance of educating themselves. The bigger idea was that promoting education would deter young people from making decisions that lead to gun violence.

Hot Potatoes

The Hot Potatoes Hook-up resulted from three weeks of work in the Charlestown Computer Clubhouse. Computer Clubhouses (Kafai, Peppler, & Chapman) are centers that offer low-income communities an array of computer technology outfitted with a professional suite of design software. Most of the roughly 100 Clubhouses distributed across 20 countries are over 1,000 square feet spaces that incorporate a large community table, clusters of computers, and studios for music recording and video recording/editing areas. The Charlestown Computer Clubhouse is located in a Boys and Girls Club facility, where the Clubhouse is one of many activities club members have to choose from during after-school hours (up to 8:00 PM). Any member of the Boys and Girls Club was welcome to join Hook-ups drop-in activities that took place from the hours of 4 – 7PM once a week during the winter months of 2010. The participants in this case used an improved Scratch Sensor Board released after the concluding the sessions in which the Stuffed Bears were created. The Hot Potatoes creators could get started on their work earlier in the workshop because the improved Scratch Sensor Board's USB port and auto-detecting software required less configuration to get up and running than the Stuffed Bears team had to do each session.

The Hot Potatoes project started when a small group of five Clubhouse members (aged 13-16) came together to learn how to make interactive experiences that called for full-body interactions, similar to Nintendo Wii games. They wanted to know how a Scratch Sensor Board could be used to make Scratch projects that involved movements like a person swatting a fly. The group thought of fun interactions that involve people's hands and the idea of hot potato came up. Hot potato is a game that emerges when a group of people start throwing any small object from one person to another - each one trying to throw the object to someone else as fast as possible, like a hot potato that will burn him or her if it is held for too long. After figuring out that hot potato was a game that constantly called for an object going from a well-lit area (such as open air) to a dark area



(such as inside of a pair of hands), one member of the group draped a brown paper bag over the Scratch Sensor Board to make it look like a potato. Another member made sure to cut a hole in the bag where the Board's built-in light sensor was positioned so that they could use light feedback from that sensor in a Scratch program.

The initial Hot Potatoes project involved a drawing of a hand on the Scratch screen holding a potato when a person was holding the physical "potato." It worked, but the group wanted a game that was more playable than carefully tossing around a tethered "potato." They realized that it would not be a good idea to perform a high arching throw as doing so might disconnect the Scratch Sensor Board or worse – make the laptop fall. The group had to make a potato that they could throw around freely in a way that Scratch could keep track of it.

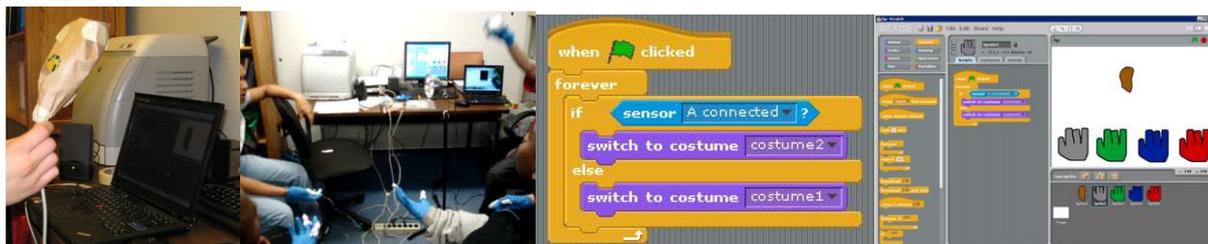


Figure 3. The Hot Potatoes Hook-up

The group covered a tennis ball with foil. Group members made gloves that connected their thumbs to one alligator clip-head on a Scratch Sensor Board and their index fingers to the other clip-head. One person's hand was wired to a Scratch Sensor Board's "A" jack. Other people's hands were connected to jacks B,C and D. The group made the project (in Figure 3) show which player was holding the potato by drawing two costumes/images for each of four hands – one holding a potato, and one without. The group tested the code that determined which hand on the screen should show that it was holding the potato – according to who actually held the "potato" at the time. While four people wearing hot potato Hook-up gloves tossed the "potato" to test the code, the fifth person sat at the computer and drove the programming.

Although the initial code functioned, it did not account for a representation for the potato when it was in the air – and not in a person's hand. To make a potato image appear in the air at the right time, a member named Kendi had to be very specific as he described the condition in which he wanted the on-screen potato to appear in the virtual air. Kendi thought out loud about how he could get past what he perceived to be a bug in the program. One of his colleagues, suggested that Kendi make several scripts to handle each case – one to announce when the potato was not in player A's hand and similar scripts for players B,C, and D. Instead, Kendi opted to make his own script. He figured out that he could make one command block test multiple conditions: if the potato was in player A's hand OR player B's hand OR player C's hand OR player D's hand. If any of those conditions became true when his program ran, the script would make the image of the flying potato hide. After his peers tested his code, Kendi was elated when he looked back to the computer screen to see that the flying potato image appeared when the physical potato was in flight. He raised both hands and exclaimed, "I'm a genius!"

The group had to debug/solve additional issues that arose both in the physical and virtual worlds. For example, they had to fix short circuits that would happen when players moved their bodies too much and caused the wires that connected a glove to the Scratch Sensor Board to cross. The group had been using wire that had no plastic coating to prevent two wires from completing a circuit when they came into contact with one another. Having no other wires available, the group continued to play, but discovered that their jeans were good insulators – so they kept wires on



each side of their legs.

Analyzing elements of Hook-ups System experiences across cases

The Hook-ups System helped the Stuffed Bears and Hot Potatoes creators gain experience in designing interactive systems and learning engineering design practices in a group setting.

Supports for engaging experiences

A key quality that made engaging experiences possible was the Hook-ups System's ability to connect with participants' personally meaningful activities. The Thugaboo and Proper Bear Hook-ups engaged the six-person group (and peers around them) who shared an interest in making up voices to caricature certain lifestyles (thugs or over-articulate people). This case highlights that Hook-ups helps give teens new experiences that leverage interests they had as young children – pretend play with stuffed animals – and adds new dimensions for exploration.

Hot potato is the kind of game invites people of all ages to join in. The Hook-ups System helped turn a competitive (yet friendly) activity into a collaborative building experience. Basing a Hook-up on hot potato tapped into the kind of quick and fun group interaction which the participants found engaging in Wii games they played. One technical feature of the Hook-ups System that helped the group make Hot Potato was the four external sensor jacks. In the case of Hot Potatoes, one switch on each jack could represent a separate player. Four jacks enabled four players to engage in tossing a potato around comfortably. The group managed informal turn-taking as they balanced playing, iterating their game's design, and debugging.

Supports for expressive experiences

A key quality that made expressive experiences possible was the System's ability to connect to participants' personally meaningful materials. The Thugaboo Hook-up represented an especially expressive project. One of its creators sparked the project idea by bringing an old toy to work. The Scratch Sensor Board's ability to connect to the existing sensors in his toy – a talking stuffed bear - made the project very personal. The playing-card size of the Scratch Sensor Board was conducive to embedding it inside of the bear so that people were interacting with the bear instead of the Board. The bear Hook-ups were also expressions of multiple issues that the creators sought to address. The Hook-ups System helped them find their own way to promote education as a way to mitigate the growing problem of gun violence in their communities. The content of what the group programmed the two bears to say was in and of itself expressing a lot. Both bears were giving stay-in-school messages using different delivery styles. The creators were expressing that positive messages are received differently when delivered by someone people are familiar with.

The Hot Potatoes Hook-up creators used the project to playfully express how they felt about one another. One of the participants wanted to project how different he was from his peers by making an unusual art request for the hand graphic on the screen that mapped to his glove. He told his friend who was drawing the on-screen images to draw a square-shaped potato in *his* hand instead of the oval potato that the artist was drawing for the other players. That is, the requester wished to stand out by having a square potato graphic appear in his hand every time he caught the actual potato. His friend who was drawing the graphic granted his request for individual expression.

Supports for transformative experiences

A key quality that made transformative experiences possible was the System's ability to encourage and support iterative design processes. Before Shawn's group could create Thugaboo, they had to figure out how to repurpose Talkin' Bubba Bear. Group members were each taking a



new approach to design – breaking down something old to make something new. To break down Bubba Bear in a way that preserved parts they needed, the group had to test whether components inside the original toy were trash or treasure for them. As they disassembled the toy, they were able to think about which of the sensors in various body parts they wanted to take over. For example, when they noticed that Bubba Bear reacted to stomach squeezes, they thought about more statements that Thugaboo could say – realizing that they weren't limited to sensors in his extremities.

The Hot Potatoes Hook-up represented an especially transformative project. Its creators changed both the scripts that governed their game and the physical components of the Hot Potatoes interaction while their peers were playing. Doing so allowed the participants to constantly have live feedback for the changes they were making and enabled them to try new project directions quickly and iteratively. When transforming an approach to design, the style with which one builds and the attitude taken while doing so evolves. The Hot Potatoes group took the approach of learning on-the-fly as they extended their prototype rapidly and dealing with interaction issues as they arose. In the spirit of getting a Hot Potatoes prototype running quickly, no one in the group noticed that the hands of each participant were wired using exposed-metal wire instead of plastic-covered/shielded wires. This oversight helped the group learn about electrical conductivity. As the group debugged the short-circuit issue, they discovered ways in which wires in an electrical circuit could be connected or interrupted.

Conclusions and Contributions

The Hook-ups work was successful across the different workshop settings that each case represented. The Stuffed Bears case was opt-in work as a part of a three-month program. The Hot Potatoes case was a drop-in effort over the course of three weeks. Nevertheless, both showed that the Hook-ups System was adept at *engaging* a diversity of youth interests in creative processes, capable of evoking *self-expression* during creative processes, and instrumental to activities that helped children *transform* their approaches to design.

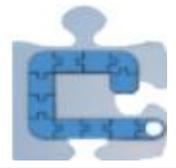
This Hook-ups research contributed technological tools that promote learning and creative expression. Using chalk as an inspiration while designing the Hook-ups System contributed to youth becoming engaged in building tangible interfaces and helped people rethink how they can harness the expressive power of computational technologies. This work can serve as an example for designers interested in making new platforms for enabling young creators to extend activities they're involved with, incorporate a multitude of materials around them into projects, and evolve their design skills as they iteratively improve projects.

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