---DRAFT of my chapter from---

THE COMPUTER CLUBHOUSE

Constructionism and Creativity
in Youth Communities

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CHAPTER 5

Interface Design with Hook-Ups

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Schools, homes, and Computer Clubhouses have become places in which children express themselves using crafts and computers. This chapter explores how Clubhouse members bring craft materials and computers together in new ways—by designing physical computer interfaces called *Hook-ups*. For example, a Clubhouse member constructed a physical flying saucer capable of controlling an interactive Scratch project displayed on a computer screen.

This chapter begins with a brief description of the flying saucer example to, help explain how Hook-ups work. The motivation for the Hook-ups research project was to promote engagement and learning through digital actions with physical objects that can provide a natural foray into scientific concepts, design, and invention. Case studies highlight the Hook-up creations of three Clubhouse members and show how they each followed their own interests through the design of digital and physical realms. The chapter ends with a discussion of the ways in which Hook-ups unlock paths for learning across boundaries in Clubhouses and beyond.

HOW HOOK-UPS WORK

Nia, a 10-year-old Clubhouse member, designed and built a Hook-up that controlled an animated flying saucer in Scratch simply using two paper plates stapled together. Nia drew decorative lights around the outside of the plates and secured a pushbutton to the top plate (see Figure 5.1). She then extended her saucer into the digital realm by using Scratch to animate an abduction beam every time she pressed the pushbutton.

Figure 5.1: Nia's UFO Hook-up and Scratch program

To make her interface, Nia used the core tool of any Hook-ups project: the *Scratch Sensor Board.* This board is a printed circuit board that contains and connects a set of electronic components that detect changes to certain properties of its physical environment. The board reports digital information concerning changes in the physical environment to Scratch through a cable that connects the board to a computer's USB port.

The Scratch Sensor Board supports a variety of sensors—objects that react to environmental conditions by changing their own electrical properties. The boards use the computer to which they connect as a power source, supplying electric current to conductive paths throughout the board. Eight of those paths pass through sensors. Four paths run through built-in sensors that change current flow according to light intensity, sound levels, a sliding shaft's position, and a pushbutton's position, respectively. Another four paths run through (alligator) clip cables to which sensors connect and disconnect. Clipped-on sensors range in application from measuring temperature to detecting a board's degree of tilt. Young people have utilized a variety of sensors to detect diverse aspects of their environments, but the scope of this chapter includes interfaces using the type of sensor most prevalent in Clubhouse member-made Hook-ups: switches.

Switches are mechanical devices, like Nia's pushbutton, that connect or break parts of conductive paths in an electric circuit. The Scratch Sensor Boards measure current along paths containing sensors. When a switch's mechanical state is such that its contacts are apart, a Scratch Sensor Board notices an "open" circuit. When a board detects an open circuit, it changes the value of a block in Scratch labeled "sensor connected?" If a circuit is open, when a Scratch program encounters this block in a script, the block inquiring about the status of a sensor or switch receives "false" or "not connected." When a switch's contacts touch, a "closed" circuit results, and the "sensor-connected" block becomes "true" until the contacts separate.

Nia's script repeated continually as it moved a graphical saucer to a new screen location and checked if the pushbutton atop her physical saucer had been pressed. When the "if" block in her script received a "true" value from her sensor board via the "sensor-connected" block, a set of command blocks generated an abduction beam graphic. When "sensor-connected" was false, the script would bypass the blocks responsible for generating the abduction beam.

THE HOOK-UPS PROJECT MOTIVATION

The Hook-ups Project is motivated by questions concerning design, engagement, and learning: How can we design technological tools to enable a range of activities that combine physical and digital design processes? What kinds of connections to personal interests help novices become engaged in Hook-ups design? As youth engage in various styles of design, what concepts related to computing and physical design do they learn?

Building upon physical design experiences that dovetail with computational design provides new opportunities for youth to think and construct creatively. Having more creative opportunities prepares youth to thrive in a society in which the reach of computation is expanding in our working and learning environments, yet we still value rich learning through our physical senses. An increasing number of scientific fields, such as astronomy and earth and environmental sciences, are recognizing creative approaches to computing that influence their practices (Anthes, 2008). Youth will be at the helm of these budding fields involving computing. American inventor George Washington Carver argued that "new developments are the products of a creative mind, so we must therefore stimulate and encourage that type of mind in every way possible" (quoted in Kremer, 1991).

More recently, Richard Florida and Daniel Pink have led a growing number of authors urging that we extend the development of the creative mind into contemporary contexts (Florida, 2002), bringing attention to the "seismic—though as yet undetected—shift now underway in much of the advanced world" that will place "artists, inventors, designers and the like in a position to reap society's richest rewards and share its greatest joys" (Pink, 2006, p. 1). Hook-ups projects can foster young people's inventive and creative states of mind, building upon Papert's "objects-to-think-with" constructionist philosophy, as well as Pestalozzi's assertion that people learn best through the activation of their physical senses and physical activity (Pestalozzi, 1894).

The Hook-ups Project serves as an entry point for youth/novices to invent and design interactions between physical objects and computer programs. Eisenberg (2003) argues that projects with such a focus should become a larger part of the learning research landscape. Integrated introductions to design allow youth to develop design skills, explore design strategies, and learn scientific concepts through multiple pathways.

PHYSICAL AND DIGITAL DESIGN OPPORTUNITIES AT CLUBHOUSES

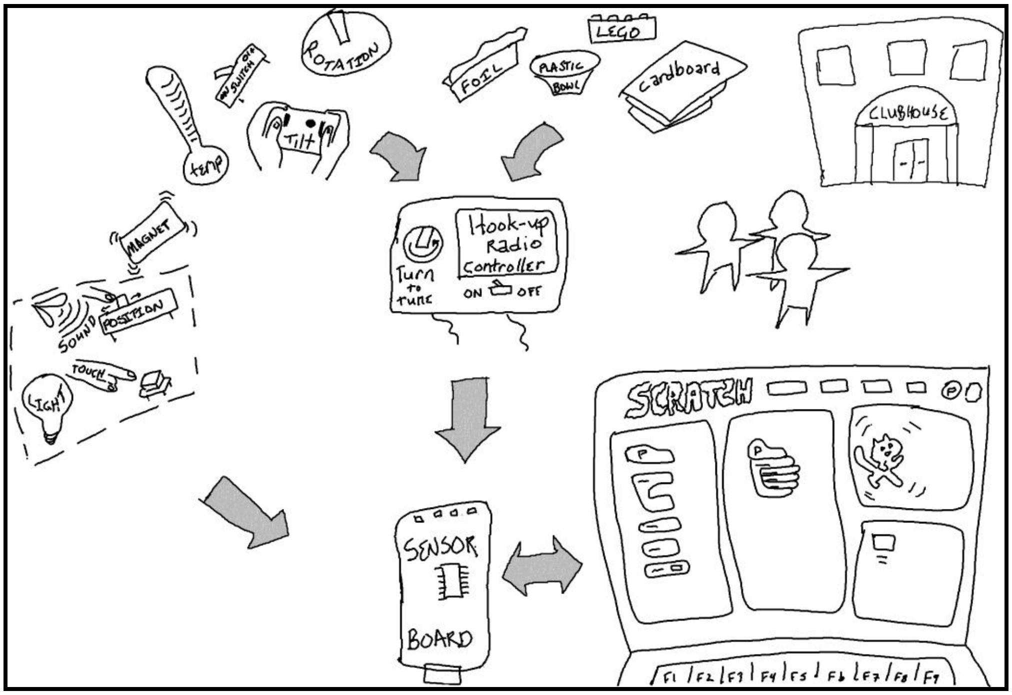
The informal learning environment in Clubhouses is conducive for youth to explore ideas through designing and inventing using both physical and digital media. Members have combined physical and digital realms in projects using LEGO Mindstorms kits to enable physical objects to run computer programs that allow creations to dynamically interact with the physical world. The Hook-ups Project builds upon the research that led to Mindstorms, and differs by enabling youth to use physical objects to make interfaces to a computer's on-screen world. Another distinction is that the Mindstorms kit lends itself to LEGO brick-based projects using primarily LEGO-made sensors. Hook-ups are designed to connect with a wider variety of materials and sensors, providing members with multiple paths to learning.

CLUBHOUSE MEMBERS CREATING HOOK-UPS

In creating her flying saucer Hook-up, Nia made decisions that all Hook-ups creators face. Each interface creator chooses different sensors, materials, and programs from many possible options to build his or her desired interaction. Figure 5.2 illustrates the landscape of options for building a sample Hook-up: a radio interface. The Clubhouse youth (top right) choose to combine physical materials (top) with a combination of hand-made or manufactured sensors (top left). The sample radio Hook-up (middle) reflects their choice to use a cardboard box as a form that features their artistic elements, a rotating knob sensor, and a toggle switch. Youth connect the radio's sensors to the Scratch Sensor Board (bottom) tethered to the laptop running Scratch (bottom right). They program Scratch to make a cat move when the switch position changes and a person rotates the knob.

The materials from which members select to form sensors and interface housings come from a supply of materials that already exist at a Clubhouse or supplies found elsewhere. On occasion, the materials and sensor types available inspire the Hook-up. In other cases, a project idea calls for a member to find specific materials.

Figure 5.2: Hook-ups system elements



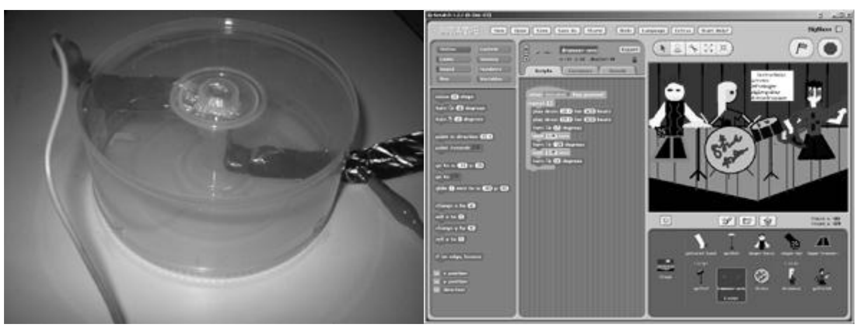
The following three cases illustrate how Clubhouse members navigated the design space depicted in Figure 5.2. Each covers projects that used switches as sensors in unique interfaces and led to different outcomes. The first describes a Hook-up inspired by a drum. A slingshot influenced the second. The third features a clay-covered magnet capable of moving objects on a screen similarly to how a computer mouse works. The data collected for each of the cases consist of field notes that documented design activities and interactions between Charlestown Computer Clubhouse members and mentors, saved Scratch programs, and Hook-up artifacts created by members.

Ray's Drum

In this Computer Clubhouse Ray is an ever-smiling 12-year-old rock-star-in-the-making who worked on a music project using unexpected materials to learn how switches could generate synthesized musical notes. Ray liked working with music at the Clubhouse and wanted to enhance an interactive band project he wrote in Scratch. He envisioned letting a user hit a physical drum mock-up to start animated drumming sequences and sounds. (His idea predated the popular drum- and guitar-driven Rock Band video game that influenced later Hook-ups.) Craft drawers at the Clubhouse supplied an assortment of traditional materials, such as Popsicle sticks, pipe cleaners, and packing peanuts, yet none of the materials looked suitable for making an instrument. While Ray did not discover what would become his drum in the craft drawer/area, he found a drumlike object, a CD spindle case, on the computer supply shelf. By turning office supplies into material for construction, Ray did what many designers do: He embraced the unexpected. Soon he discovered that the points at which the CD spindle case's base and top met could be transformed into a switch.

Ray experimented with adding foil to the CD case cover and base so that when people hit the cover, the two parts would meet, causing the metallic foil strips to meet. This contact would signal to the sensor board that the circuit was closed (and thus conducting current). In order for Scratch to detect that he was closing a circuit, Ray had to attach one sensor board clip head to the CD case's base-side foil strip and the other to the cover's foil strip, using wire to extend the cable's reach (see Figure 5.3). Ray watched the reading on the "sensor-connected" monitor in his Scratch project change between values of "true (0% current resisted) when the cover was pressed and "false" (100% current resisted) when the cover was at rest above the base's foil. In order for Ray to make his switch's foil contact strips touch each other when a person struck his drum, he placed the strips in a location that would signal a circuit closing with a reasonable amount of reliability only when an actual strike occurred. Switch placement for reliability became an important design consideration.

Figure 5.3: Ray's spindle drum Hook-up and Scratch program



Ray's strikes triggered Scratch scripts to make sounds that satisfied him. He then upgraded his Scratch band project to trigger digitally synthesized musical notes via physical drum strikes as opposed to the keyboard strokes that his project previously relied upon. His new script featured command blocks that only played sounds if the preceding conditional block detected "sensor-connected" to be true. His program played drum sounds and at the same time triggered an on-screen drummer to move his arms. Ray explored manipulating a switch to control current flowing through an open or closed circuit before ever learning about the concepts in a class. Ray worked with a mix of music, computation, and physical materials to make his first Hook-up.

Martin's Slingshot

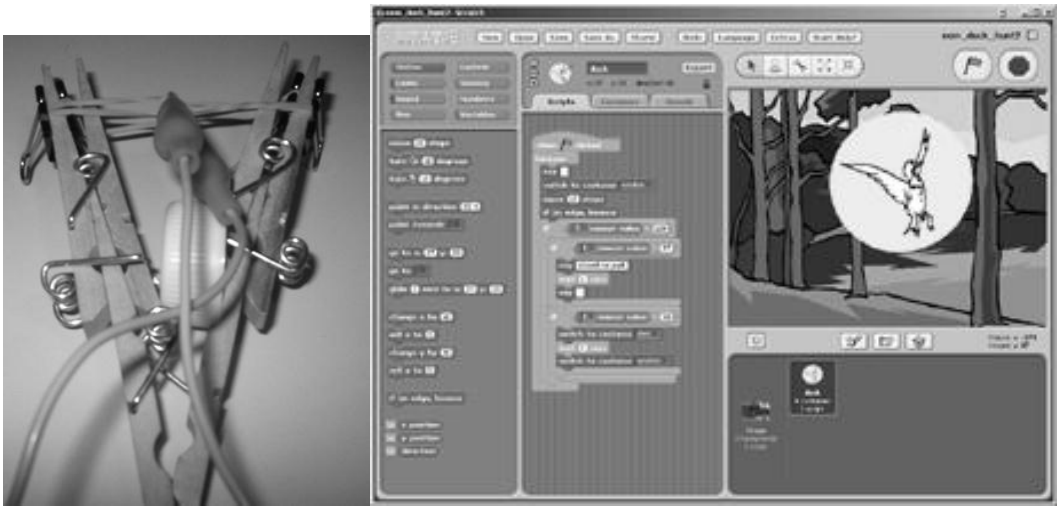
Martin, a 13-year-old member who enjoyed stirring up activity in the Clubhouse, had fun flinging things. However, before he was introduced to Hook-ups, he couldn't do so without the risk of putting others in danger. He overcame several challenges as he built a complex slingshot Hook-up from simple parts and tweaked its tensile strength to have it control an interactive game.

Similarly to how Ray considered ways to integrate a handmade switch into an existing product's casing, Martin found after several tries an existing product that he could repurpose to serve as the base for his slingshot switch. Martin had to find his own parts. He looked around the Charlestown Clubhouse for ways to make a slingshot. Though he ran into difficulties, he ultimately gleaned an understanding of the design strategy of building complex things from simple parts.

Children looking to make a traditional slingshot are usually able to find a sturdy Y-shaped stick with two branches to stretch a rubber band across. The cold of Boston's winter made searching for an appropriate tree branch difficult for Martin. Instead, he searched around the Clubhouse. A clothespin he found seemed sturdy, yet he could not spread the wooden prongs far enough apart to make a convincing slingshot interface. Having access to multiple clothespins, he embarked on the mission to build a larger slingshot—one that would fit in his hand.

Martin clipped three clothespins together and added a bottle cap to spread them into a Y shape. He was surprised by how fast the multiclothespin structure fell apart when he pulled the rubber band he placed across its top. Onlookers were surprised to see clothespins flying and some offered their ideas for fixing the design (while a few others made fun of the mess). In Clubhouses these are the kinds of disruptions that create opportunities for mutual help and new ideas. A small group of members helped Martin reorient the clothespins several times. As is the case with many designs, iteration proved fruitful. The slingshot wasn't able to withstand a rubber band pull until the group removed the springs on each clothespin and re-inserted them into a new location on the prongs. Martin placed springs in a way that secured two clothespins together. In a clothespin's normal use, the spring applies force to the wooden prong tips to provide enough tension to keep clothes on a clothesline. For a slingshot, clothespins didn't need tension to keep prongs closed; rather, they needed tension to keep three clothespins connected. Martin rearranged the springs, explored leverage points while repositioning springs, and ultimately added a switch to the slingshot rubber band so that he could (digitally) fling things at Scratch objects.

Figure 5.4: Martin's clothespin slingshot Hook-up and Scratch program



Martin clamped a pair of sensor board clip heads to the front and rear sides of the rubber band (see Figure 5.4). When the rear side of the rubber band was pulled back and released, the exposed metallic parts of the clip heads came into contact and closed a circuit. Martin wrote a Scratch program that recognized when the switch was closed and propelled a digital object across the computer screen toward a digital duck—an adaptation of an interactive program written by his peers for a different Hook-up.

Kerry's Clay Mouse Emulator

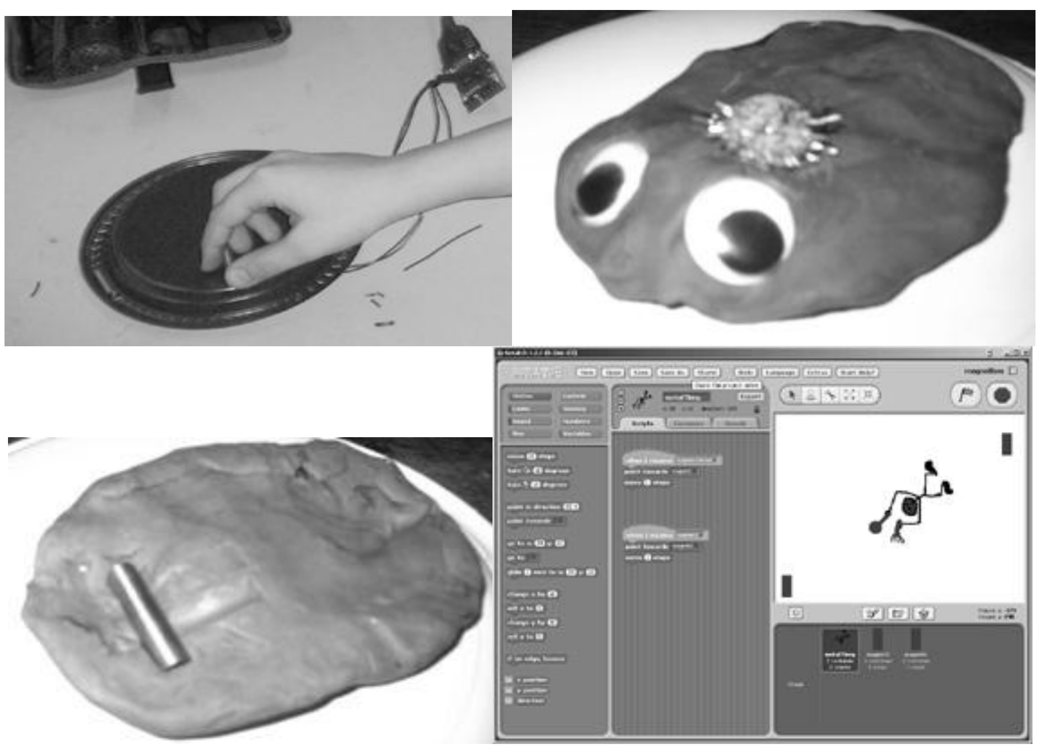
Kerry, a reserved 13-year-old, turned an interest in clay and magnets into a way of understanding how some computer programs coordinate events. The Clubhouse setting gave him freedom to explore a project with no particular end in sight. As he adopted a bricoleur approach (Turkle & Papert, 1990 to designing his clay mouse emulator, Kerry was free to dynamically change project directions. His project benefited from clay, magnets, and computers - each being in close proximity to one another.

Kerry realized that magnets and reed switches were parts of the material that Hook-up researchers/mentors brought to Charlestown (among other materials and sensors to augment a Clubhouse's collection of crafts and sensors). We explained how these switches worked in a context with which Kerry was familiar. A reed switch is commonly found on door and window frames lying adjacent to a magnet affixed to the closed door or window. When a typical building alarm is armed, the system senses when a door or window is opened by noticing that the magnet is no longer keeping the frame's reed switch closed (i.e., the two objects have separated).

Before doing any project planning, Kerry experimented with distances at which magnet pairs would attract and repel. The distance gave him an idea of how far apart he had to place reed switches so that two did not simultaneously close due to one magnet. He used his measurement to arrange four reed switches under a plate so that no single magnet could close more than one switch. Kerry connected the switches to clip heads on a Scratch Sensor Board. He modified a Scratch program he saw a peer using to make a character on the screen move in different directions when one of the hidden reed switches closed due to a nearby magnet.

Kerry realized that his Hook-up worked similarly to a computer mouse—it could fluidly move objects on the screen. He became enamored with designing something quickly that worked somewhat like an item he could buy (a mouse) yet wanted to give it personality. He found it difficult to mimic the curvy shape of the mouse on the computer nearest to him using paper. A plastic bowl was too bulky. He discovered that he could mold a lump of sculpting clay into the mouse shape he desired. He wedged a magnet into the bottom of his mold and added decorative eyes to the top to serve as fake mouse buttons. What he created was not only a piece of art, but a means for him to explore magnetism and computation (see Figure 5.5).

Figure 5.5: Kerry's magnet-carrying mice Hook-up and Scratch program



Just as a magnet can influence multiple objects around it, a Scratch block can broadcast information to influence other objects. Each object can choose to react to the information or ignore it. Kerry attempted to use his understanding of magnetism to understand broadcasting. He envisioned Scratch objects communicating with each other similarly to how he imagined magnets communicate. He could imagine magnets broadcasting messages to other magnets. One end of a magnet could broadcast a message, "come to me," while the end of a nearby magnet is always listening for that message. When the second magnet's end hears the message, it responds with an action, moving toward the broadcaster. Kerry drew a character that was holding what appeared to be metal silverware. He programmed the character to respond to "magnet-on" and "magnet-off" broadcasts. Kerry had the freedom to explore how magnetic fields could influence physical and digital objects and to experience how digital objects passed information to each other.

HOOK-UPS POSSIBILITIES IN CLUBHOUSES AND BEYOND

In combining craft materials and computers to make interfaces, Nia, Ray, Martin, and Kerry followed their interests through diverse project trajectories. The rest of this chapter considers how they became exposed to concepts in design, physics, engineering, and computer science, and shows how such interdisciplinary projects transform spaces (in Clubhouses and beyond) into resources for creating projects and developing creative minds.

Ray's interest in music shaped his Hook-ups experience. He had already created several Scratch projects, so he eagerly seized the opportunity to extend a music-based project into the physical world. In brainstorming plans for his drum Hook-up, he initially sought to make a multiple-drum set. Helping members like Ray, who wish to start a project that mirrors or simulates a nontrivial activity, is challenging. Activities such as Ray's drumming have multiple components that make the actual experience of playing them rich. It is difficult to determine which components of activities are conducive to designing a tractable initial Hook-up.

Balancing tractability and challenge, while at the same time promoting authentic interaction, is an elusive yet valuable goal for those facilitating Clubhouse activities. Facilitating an appropriate first step opens the door for further steps. As soon as Martin finished his slingshot he began working with a group on a related Hook-up. Should a member continue to work on a project beyond a simplified initial interface, he or she will be calling upon understandings of the Hook-ups toolkit gleaned while building the initial interface. Exploring how switches work and/or creating a custom switch served as an appropriate starting step in the Hook-ups cases discussed here.

Ray did not consider it a complex activity to place foil at strategic locations within a discarded CD case to create a switch. An experienced designer would consider Ray's switch to be simple. By contrast, parts of Martin's project called for him to exercise the design strategy of building complex behaviors from simple parts. Martin's slingshotlike Hook-up only came together when he built a structure larger and stronger than a single clothespin by combining three of them.

Building Martin's Hook-up exposed him to concepts relating to multiple fields. Like the project paths of the other Hook-up creators discussed, Martin's involved controlling electric current through a switch. Additionally, he worked with his hands to explore the tension and tensile strength of his construction materials—squeezing and tweaking them to find potential breaking points. These topics from mechanical engineering and physics, coupled with the computer programming topics he encountered, allowed him to explore all-too-often disparate disciplines.

Ray's path to creating his Hook-up included musical, electrical, and computational components. Kerry's combined sculpting, magnetism, and computation. Kerry explored magnetic fields with sensors and digital animations. His project was more distinctive than the common classroom activity of using magnets to move iron shavings around. The latter helps people visualize the effects of a magnetic field. In Kerry's case, Scratch offered a dynamic way to visualize how magnets influence objects.

Our Hook-ups creators' diverse paths arrived at computing through physical design paths based on different interests. The computing concepts they explored also differed. While sensor-based projects typically call for their creators to work with conditional statements (such as, if "sensor-connected," do this—a fundamental computing concept), the members confronted other computer science topics as well.

Martin learned about conditional statements by reusing Scratch scripts that he saw his friends create. In adapting the script he inherited, he had to familiarize himself with the concept of *code reuse.* He examined the workings of his peers' interactive game to adapt it to his needs. A common practice among programmers is to build complex computer applications by working with less complex chunks of code, often coming from other people. The vast libraries of code available for established programming languages, such as Python, are a testament to the popularity of the code reuse concept.

Martin's efforts to create a new interface for a project built on his peer's prior work demonstrate the utility of a project-sharing community. Clubhouses often keep members' files in a shared space where everyone can access art, music, and programs. In a classroom setting, borrowing a peer's work to start a project is less prevalent.

Starting from a blank Scratch screen (rather than a friend's sample), Kerry explored passing information between objects in his Scratch program in a way that made sense to him: a conversation between magnets. Two magnets talking would not likely be an illustrative example for the part of a computer science course syllabus concerning interobject communication.

It seems unlikely that Nia's, Ray's, Martin's, and Kerry's schools could support projects that involved students combining computers and physical materials. K–12 schools and colleges alike are asked to arrange their resources to educate large groups of diverse students. Traditional teachers in these formal settings are charged with ensuring that their students become acquainted with core concepts of a course. In contrast, a Clubhouse coordinator focuses on helping members to explore their particular interests in projects of their own choosing.

Clubhouse coordinators should play a distinct role in supporting members' interests and approaches, and yet at times coordinators have facilitated activities in ways that were not conducive to Hook-ups work. For example, coordinators who question their ability to understand the intersection of computing and craft have sometimes shied away from providing support to members who take on such activities—even in nontechnical regards, such as encouragement or access to materials. In certain cases, coordinators have remedied lackluster support for projects fusing computers and crafts by increasing their comfort with new Clubhouse activities or sharing facilitating duties with assistants, available mentors, and advanced members. When these groups provide flexible support, members have more guides for interdisciplinary explorations like the cases represented in this chapter.

Current United States policies for funding schools in low-income communities make it difficult for teachers to purchase and manage materials, given subpar facilities and pressure to meet controversial academic benchmarks (Kozol, 1991; Sampson, 2007). The projects illustrated in this chapter demonstrate how youth can find suitable craft and recycled materials in unusual places, thus reducing the material procurement hurdle for schools interested in adopting Hook-ups activities. With any materials that art studios, physics labs, or cafeterias provide, more Hook-ups activities become possible either during or after school.Inviting youth to integrate recycled objects, digital media, and items from their homes into projects encourages them to view the space around computers in new ways. They begin to merge sensors with (or make sensors from) everyday materials that they would not normally associate with computers. Creating associations between computers and physical objects with which children have existing relationships changes their relationship to computing. Projects like Hook-ups that link computing with items that a child considers familiar are a step toward making the world of computing more widely familiar.

In a study that Margolis and Fisher (2003) conducted to examine why women (and underrepresented groups in general) represent only a small percentage of college students studying computer science, they note factors such as lack of experience. Because males and females of both struggling and affluent backgrounds generally gain experience constructing objects from crafts and found materials at early ages, using such materials to make interfaces for computers ensures that a range of children have a familiar starting point in the activity. A factor that helps mitigate the experience gap in Hook-ups activities is the novelty of controlling digital worlds with as many physical objects as one can find. Creating objects that control computers is an activity to which children are unlikely to have been exposed.

Establishing personal connections between youth who are underrepresented in traditional computer science and new fields stemming from computing is critical. Researchers and organizations like Computer Clubhouses must play an important role in preparing youth to advance the growing number of fields that computing influences. Doing so would heed Carver's call to action about developing creative minds early.

This chapter explored how children at Computer Clubhouses are designing and building their own physical computer interfaces called Hook-ups and discussed several initial outcomes of the Hook-ups research project in Computer Clubhouse settings. Three case studies (and an extended example) illustrated how members created physical interfaces to digital projects and, by doing so, connected themselves to computing, scientific concepts, design, and inventing. The kinds of explorations at the intersection of computing, broad interest, and everyday materials that the Hook-ups project helped introduce to Clubhouses are steps toward preparing today's youth to fully participate in the creative society that authors Florida and Pink have projected for the future.

NOTES

Information about building or ordering sensor boards that communicate with Scratch is available at the Scratch Web site (http://scratch.mit.edu). Click on the "forums" or "support" links and then click on the phrase "sensor boards." The names of the Hook-ups creators in this chapter are pseudonyms.

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***Note that several references listed here were made in prior chapters of this book rather than in this draft. They are included here for readers who are interested in the Computer Clubhouse or the Scratch programming environemnt.**