Computer as Chalk
Cultivating and Sustaining Communities of Youth as Designers of Tangible User Interfaces

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Abstract

My research efforts focus primarily on two areas: (1) developing engaging technological tools that promote learning and creative expression and (2) designing supportive environments that invite broad participation with these technologies. In this dissertation, I argue that 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.

At the core of my research is 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 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.

A framework called the Constellation of Connected Creators emerged from my work with the Hook-ups System. It provides facilitators with strategies for introducing technological tools and activities to communities of learners. It identifies several roles that both facilitators and participants adopt over time to sustain youth engagement in technology-rich learning activities: creator, co-learner, collaborator, coach, and colleague.

This dissertation reports on my investigation that took place in two after-school technology centers over a five-year period. Two sets of questions guided my inquiry. The first set probed how attributes of the Hook-ups System enabled diverse audiences to engage in building personally meaningful projects, express themselves, and transform how they approached design. The second set examined which strategies were successful for using the Constellation of Connected Creators to establish a culture in which facilitators engaged groups of newcomers, cultivated future facilitators and supported their successors.

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1 Introduction

New developments are the products of a creative mind, so we must therefore stimulate and encourage that type of mind in every way possible.
-George Washington Carver

My research efforts focus primarily on two areas: (1) developing engaging technological tools that promote learning and creative expression and (2) designing supportive environments that invite broad participation with these technologies. In this dissertation, I argue that 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 chapter begins with societal issues that motivate my work. It then discusses the two main contributions of my dissertation work. It concludes with a roadmap of the document – providing a brief description of each chapter.

1.1 Ideas and motivation

George Washington Carver understood that established creators must play a role in developing the next generations of creators. Carver, known mostly for his scientific contributions (and to a lesser extent for his painting prowess), charges adults with a call to action that remains relevant today: "New developments are the products of a creative mind, so we must therefore stimulate and encourage that type of mind in every way possible " (Kremer, 1991). To respond to Carver's call, I have created a system and framework that help cultivate communities of expressive designers.

George Washington Carver's call to encourage creative minds undoubtedly included the minds of children from a diversity of backgrounds and walks of life. The encouragement he argued for was not limited for some people in particular domains. Today, it might seem like a given that "developing creative minds" covers all children, yet at times in the past it was illegal to teach some Americans to read, let alone to pursue scientific study. Today, we are still seeing the effects of that history, especially when examining the numbers of underserved minorities and women working in scientific fields (May & Chubin, 2003). An account from an African American student who attended my high

school in Portland, OR, circa 1950 recounts one kind of situation that contributed to keeping scientific fields from benefiting from more creative minds:

> "I remember when I was a sophomore at Lincoln High School we had a white teacher there, an English teacher by the name of Mrs. Watson - I'll never forget that name. We studied George Washington Carver, who was a scientist (a great scientist, a black scientist). In the course of the study, in the book we had to read, she got up one day and made it very clear to the class that Carver was a very rare exception for a black person (a Negro) and that we could not look to see this happening any time soon - a black person with a scientific mind excelling like that. I'll never forget she said this: 'for the most part, Negroes are good at dancing and athletics. That is where they excel.' And she looked right at me as if to say 'now that is what you ought to go after, either be an athlete or a dancer.' I was the only black person in the class. She'll never know what that did to me on the inside because every kid in the class turned around and looked at me. I actually think that she thought she was doing a service for me. I felt like she thought she was saying to me something that would help me: 'don't waste your time trying to be an author, a writer, a scientist, a teacher, a professor, or a banker, or a business man. You do well in athletics. You have rhythm. You can dance and this is where your people excel.'… That wasn't the only event like that, but was the most crushing."

By today's standards, the account above is reprehensible, but not so far from contemporary messages as it should be. Examples of how children who are underrepresented in computing still receive such messages (albeit usually more subtly) are captured in the work of Jane Margolis and others. Margolis' books *Unlocking the Clubhouse* (Margolis & Fisher, 2003) and *Stuck in the Shallow End* (Margolis, Estrella, Goode, Holme, & Nao, 2008) present too many accounts like parents putting a computer in a son's room but not a daughter's and guidance counselors in public schools tracking students of color away from AP courses such as computer science (unconsciously or otherwise). My work aims to mitigate as many of those factors as possible. I designed the Hook-ups System and the Constellation of Connected Creators to help a broad group of youth see themselves as creators who can wield the power of computing to scratch creative itches and solve community problems.

Chalk lets almost any child create. 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 alone cannot give us the kind of creators we need for tomorrow's society. If children do not identify with being capable creators who use computing, we run the risk of missing out on technological developments that could improve society. If computing and countless related fields are to have the kind of diverse

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thinking that they need to thrive, they cannot afford to miss opportunities to attract creative thinkers.

1.2   Contributions

I intend for this research to spark the imaginations and expand the mindsets of after-school technology center members and academics alike. Ideas in this dissertation are meant to contribute to multiple research areas related to designing technologies for youth. For designers and developers, my research offers a system for transforming computers into a new kind of tool for helping novices make interactive experiences. It offers a set of guidelines for cultivating and sustaining creative communities by introducing new practices, programming languages, and physical computing toolkits. It presents my insights and guidelines to serve as catalysts for future designers to develop systems that will enable youth to learn in new ways through creating their own tangible user interfaces. For educators, this document provides insights into how children learn as they design using the Hook-ups System. I offer the insights I developed from working in informal settings to advance the body of work that is challenging what types of activities should take place in the more formal educational spaces that our children inhabit. In carrying out my Hook-ups work, I also developed a framework for cultivating and sustaining creative communities called the Constellation of Connected Creators. Together, the work this document reflects contributes to bringing us closer to fulfilling Carver's vision of cultivating creative minds.

A brief introduction to the Hook-ups System

At the core of my research is 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 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.

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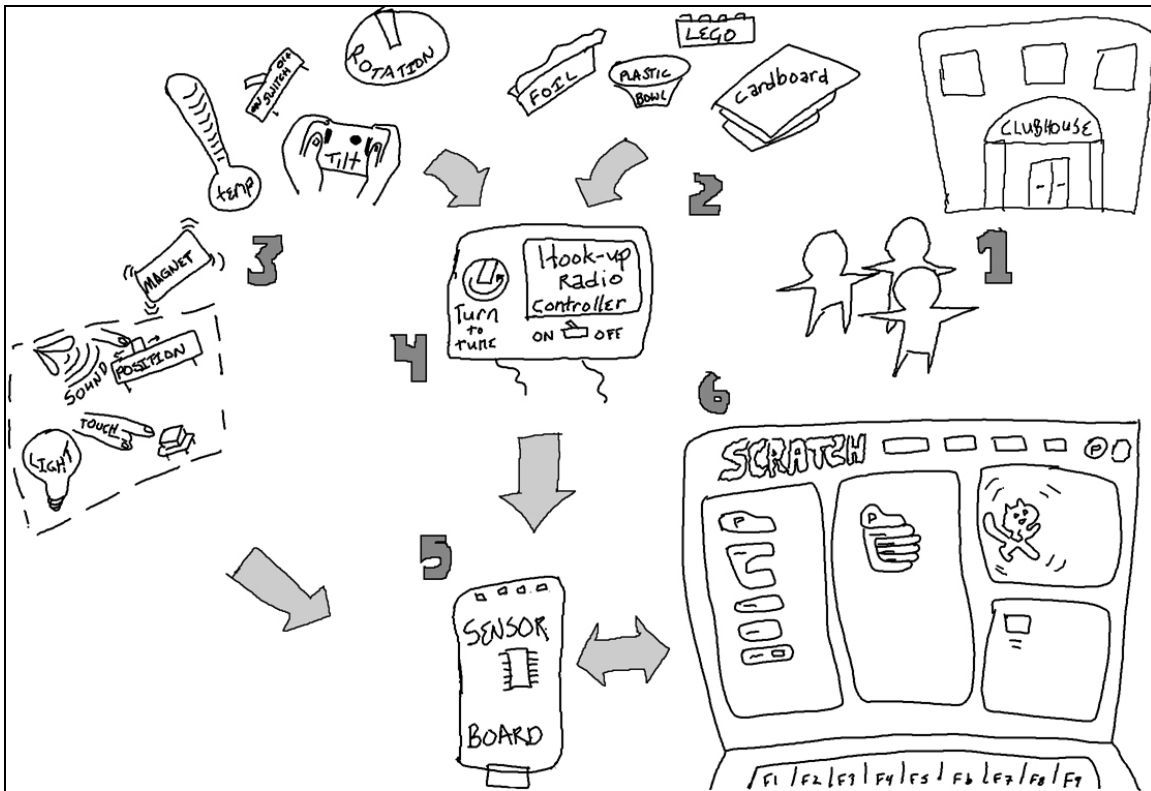
Figure 1 elements of the Hook-ups System

Youth currently use Hook-ups tools for a range of activities that relate to their varied interests. It is a system that enables youth to act as "physical computing" designers – creators of interactive experiences capable of programming connections between digital and physical media. Figure 1 serves as an overview of how the elements that comprise the Hook-ups System (detailed in chapter 4) 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]. (The faux-radio controller depicted to be a cardboard box form featuring hand drawings, a rotating knob sensor, and a toggle switch is a Hook-up.) People connect sensors (e.g., the faux-radio's knobs/switches) on Hook-ups to the core technology of the Hook-ups System - Scratch Sensor Boards [Figure 1-5]. This board plugs into a computer running a programming environment called Scratch [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.

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I deployed the Hook-ups System in two after-school technology centers over a five-year period. Two sets of questions guided my inquiry. The first set probed how attributes of the Hook-ups System enabled diverse audiences to engage in building personally meaningful projects, express themselves, and learn through adopting new approaches to design.

The second set of questions examined what strategies were successful for establishing a Constellation of Connected Creators. In the process of cultivating a sustaining Hook-ups culture using the Constellation framework, I asked questions related to how facilitators prepared participants to explore their interests, learn and create in groups, and take on facilitation duties themselves.

A brief introduction to the Constellation of Connected Creators

The Constellation of Connected Creators is a framework that supports facilitators as they introduce technological tools and activities to communities of learners. It identifies several roles that both facilitators and participants adopt over time to sustain youth engagement in technology-rich learning activities. These roles are: creator, co-learner, collaborator, coach, and colleague. Participants' activities, roles and relationships to peers shift over time through each stage of the Constellation of Connected Creators framework: Engaging Newcomers, Cultivating Facilitators, and Supporting Successors. Figure 2 presents an overview of the cyclical nature of the framework.
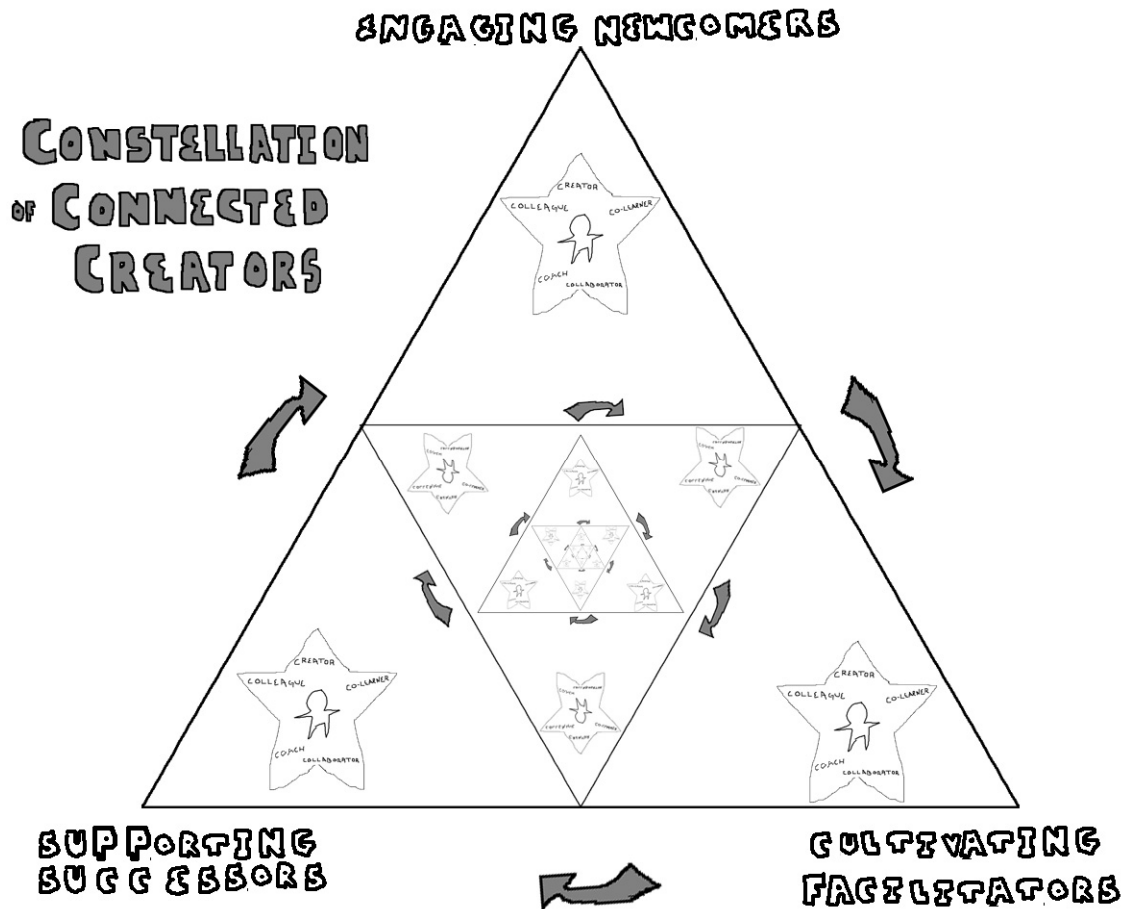
Figure 2 the Constellation of Connected Creators framework at-a-glance

In Figure 2, the three stages of the Constellation of Connected Creators begin with Engaging Newcomers. In this stage, the initial facilitator plays each role to the degree he or she deems necessary to engage the early participants. Once the facilitator has engaged participants, the facilitator's focus shifts to stage 2 – Cultivating (future) Facilitators. In this stage, the facilitator plays the five roles described above in ways that focus special efforts on communicating, modeling, and allowing participants to try strategies that help keep participants engaged in their learning environment. The Supporting Successors stage begins when the future facilitators demonstrate that they're responsible and willing to run the environment with autonomy. They can then steer the environment where they believe it should go. In this stage, the initial facilitator's focus becomes supporting his or her successors as they begin to reframe and lead the activities in the evolving learning environment.

1.3   Dissertation roadmap

Chapter 1 Introduction: situates my motivation for pursuing this dissertation work. It presents one of the major motivation threads: broadening participation in computing. It provides a quick summary of the key components of the system and framework I've designed as a part of this work. This chapter concludes with details of the overall dissertation chapter structure.

Chapter 2 Background: describes the theoretical frameworks upon which my work builds. It highlights two threads in particular – constructionism and communities of learners. This chapter highlights the characteristics of the foundations my work draws upon.

Chapter 3 Research Design: presents the major research questions my work explored. It discusses the approaches I undertook in designing the Hook-ups System. It introduces the research sites in which I conducted Hook-ups work. It describes the design experiment method I drew upon heavily as I carried out my dissertation study and covers how I managed the study's data.

Chapter 4 The Hook-ups System: introduces the notion of chalk as a key design criteria for computational tools. It details how chalk inspired the design goals of the Hook-ups System. It describes the System's architecture and illustrates the types of Hook-up artifacts people create. It highlights the design styles and practices that the Hook-ups System helps youth explore. It defines what physical computing toolkits are and compares related work to the Hook-ups System.

Chapter 5 Case Studies of the Hook-ups System: presents three case studies of Hook-ups work in three distinct settings. The first case focuses on a pair of creators' experiences in a workshop that spanned three consecutive days. The second highlights a Hook-up that came into existence over a three-week period. The last case describes a pair of Hook-ups that creators brought to life over a three month period (in a summer program). Analyses of how each case demonstrates the ways in which the Hook-ups System exhibited chalk-inspired attributes are included. It shows the ways in which the constructionist notions played out in the research sites. This chapter includes analyses of similarities and differences between the Hook-ups work carried out in all of the cases.

It highlights how I facilitated activities in different ways to ensure that Hook-ups-style learning became possible in the diverse workshop settings.

Chapter 6 The Constellation of Connected Creators Framework: offers the notion of a Constellation of Connected Creators as a means of establishing and sustaining a creative community. It describes the roles that facilitators and participants play in three stages of this framework. The chapter presents the framework's connections to the communities of learners' theoretical foundations.

Chapter 7 Extended Case Study of the Constellation of Connected Creators: covers three years of two participants' experiences that illustrate the Constellation of Connected Creators' three stages in action. The chapter introduces challenges I faced while facilitating learning in an evolving environment and suggests strategies for overcoming them.

Chapter 8 Conclusions and Contributions: recaps the contributions that my dissertation work makes to academia and society. It presents lessons learned from designing and deploying the Hook-ups System and the Constellation of Connected Creators framework.

2 Background

This chapter covers theoretical frameworks that I find useful for thinking about how learners in community settings interact with technology and each other. The first section focuses on constructionism. The second section discusses the communities of learners paradigm.

2.1 Constructionism

Papert's constructionist theory is a cornerstone upon which Hook-ups research, and many of the research projects it draws lessons from, is built. It suggests that young people learn best through the process of constructing artifacts that are meaningful to themselves or others in their communities. Constructionist learning centers on the idea of learning through design experiences. 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.

Papert was struck by how members of a Brazilian Samba School learned together and became engaged in expressive activities while preparing for a carnival parade. He saw the Samba School communities as places where the young, old, rich, poor, related, and new acquaintances could learn together around singing, dancing, teaching, and costume-making. That perception led him to believe that Samba School communities could serve as valuable models for other learning communities. He urged that aspects from the schools should be replicated in technology-rich learning environments. Resnick, Rusk, and Cooke helped bring into existence a network of after-school learning centers called Computer Clubhouses (Resnick & Rusk, 1996) loosely inspired by Papert's idea of a technological Samba School.

2.2 The Communities of Learners paradigm

Rogoff advanced the idea of a community of learners (1994). Her theory suggested that learning comes as people participate in shared endeavors. Her work argues that learning is a process of transformation of participation itself – that how people develop is a function of their transforming roles and understanding in the activities in which they participate.

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The paradigm promotes children having responsibility and autonomy as they relate to information as it is used in practices that are relevant to their community. Rogoff examined the ways learners take in subject matter that is regarded as important within their communities. She posited that mature members of the community typically facilitate the learners' discovering the subject matter through participating in various practices. The experiences Rogoff drew heavily from reflect work she conducted at a school with a structure that included parents at the core of the community of educators. That shaped her approach - suggesting that adults should not run every aspect of the environment, nor should a child be expected to be the primary acquirer of his or her knowledge. In a community of learners, the student learners should have autonomy and responsibility. They should have experiences that are relevant to a practice and learn ways to synthesize what is important about those experiences so that they can share those understandings with others in their community.

Through the "design experiment" work (introduced more thoroughly in the chapter 3), Brown sets out on a task with aims shared by my efforts - to "attempt to engineer innovative educational environments and simultaneously conduct experimental studies of those innovations" (Brown, 1992; Collins, 1992). In Brown's design experiment work in fostering communities of learners (FCL) schools, she highlighted the roles of learners, and also of technology in the environment.

In my work, roles of adults, teens, adolescents, and different technologies are all key components in fostering a creative environment. Brown was a leader in the FCL movement – grounding how she worked in notions of Rogoff's communities of learners and the Vygotsky social constructivist traditions (Wertsch & Stone, 1985). (Brown credits Collins for coining the design experiment term, however, she is often credited for helping the approach become used widely.)

The type of experimental studies Brown referred to were not formal/traditional lab experiments (such as those a psychologist would carry out to determine if a subject's reaction could be attributed to a certain stimulus). Rather, she would experiment with an approach to introducing a subject matter and adjust along the way in an attempt to ensure the class was learning (and helping each other learn).

3 Research Design

In this chapter, I describe research frameworks I found useful for framing and carrying out my dissertation study. One method I have drawn from heavily is called "design experiments." It influenced the structure of how I introduced the Hook-ups System to learning environments, collected and analyzed how the people in the environments adopted the System, iteratively refined the Hook-ups System based on my analyses, and (re)introduced the Hook-ups System to similar settings. As a part of my iterative and reflective practice, I continuously researched how the Hook-ups System exhibited attributes that enabled young people to create in ways that gave them experiences similar to those people have when using chalk – engaging, expressive, and transformative experiences. The engaging attributes are the ones that help engage groups of young people who vary in culture, interests, and extracurricular activities. The expressive attributes are the ones that support youth in creating and sharing projects that express parts of their personalities, passions or positions on social issues. The transformative attributes are the ones that transform how young people approach design – enabling them to explore design strategies and engineering ideas.

I asked two sets of research questions. To explore those questions, I visited two after-school centers weekly to facilitate Hook-ups activities. I designed these activities to evolve both the learning environment and the Hook-ups System in positive ways. This chapter articulates my research questions, explains the research traditions upon which I base my approach, covers my research site selections, and details my methods of collecting appropriate data for examining my questions.

3.1 Questions

My research questions examined the extent to which I have designed and deployed a Hook-ups System in innovative learning environments in ways that made its tools and activities 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.

Two sets of questions guided my inquiry. The first set probed how attributes of the Hook-ups System enabled diverse groups to engage in building personally meaningful

projects, express themselves, and learn through adopting new approaches to design. Specifically, these questions asked:

In what ways does the Hook-ups System…

A1) engage groups of young people who vary in culture, interests, and extracurricular activities within an informal learning environment;

A2) support youth in creating and sharing projects that express parts of their personalities, passions or positions on social issues; and

A3) transform how young people approach design – enabling them to explore design strategies and engineering ideas?

The second set examined what strategies were successful for establishing a Constellation of Connected Creators. In the process of cultivating a sustaining Hook-ups culture using the Constellation framework, I asked questions related to how facilitators prepared participants to explore their interests, learn and create in groups, and take on facilitation duties themselves. Specifically, these questions probed:

What strategies help facilitators…

B1) engage diverse newcomers in physical and digital design;

B2) contribute to cultivating future facilitators; and

B3) support a facilitator's successors in an evolving learning environment?

3.2 Approach

An ongoing cycle of experimenting with an educational intervention and evaluating it provides opportunities for researchers to refine the interventions based on insights about how the intervention is influencing the learning and practices in that particular environment. I drew my research framework primarily from a design experiment (DE) model that focuses on such cycles. I utilized qualitative methods to develop case-studies, workshop facilitator guidelines, and a framework for cultivating and sustaining creative learning environments as my primary research findings. DEs 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; Collins, 1992). They provide a framework for engineering, re-engineering, and adapting to local conditions of innovative learning environments. That framework guides a process of conducting studies situated within

complex learning environments in ways that highlight how technologies and practice innovations influence the participants.

In both of my research sites, youth who had been creating for an extended period of time influenced the learning environments. In one site that had programming to keep youth involved for multiple years, the youth with extended experience typically took on roles that involved facilitating activities for others. In those roles, they captured and synthesized for peers design strategies they found useful. When the first wave of youth facilitators moved on (after aging out of a center's youth programs), their successors had chances to become facilitators and mold the learning environment to their taste. This constant and cyclical revision of educational environments ensured that the informal learning environments stayed conducive to providing engaging, expressive, and transformative experiences for new waves of participants.

I selected research sites that already operated in cycles that were well-suited for design experiments. In those DE-conducive environments, I collaborated with participants and staff to agree upon the ways we would implement social structures, evolve practices, and introduce technological tools. This evolution deliberately yielded considerable control to the youth for how activities evolved.

My design differed from the kind of classroom-based design experiments the model evolved from. In classrooms, the participant pool is likely to stay constant. In my informal environments, youth opted in or out at their discretion. My dissertation work included developing strategies for applying the DE model in less-formal learning environments that feature up-to-date (and some bleeding-edge) technologies.

To illustrate how the Hook-ups research efforts evolved, Figure 3 depicts the timeframe within which I conducted seven design experiment Hook-ups iterations in the two research sites.
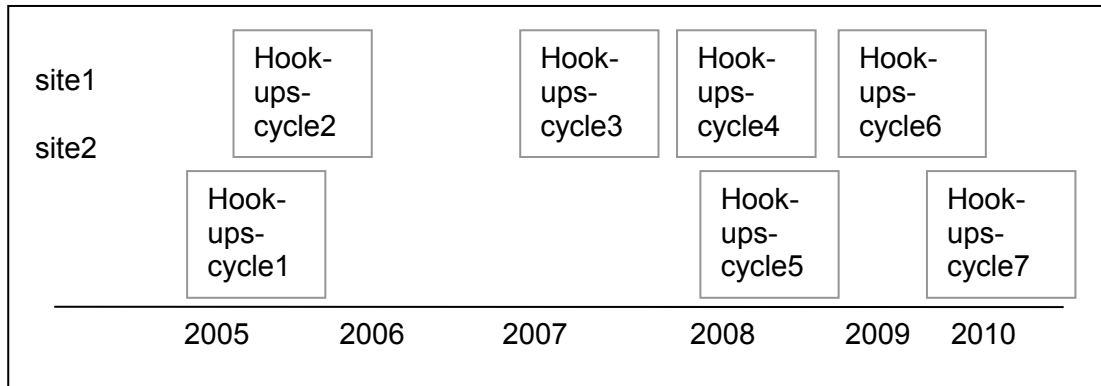
Figure 3 Hook-ups design experiment timeline of research cycles

3.3   Sites

I have been at the core of research efforts involving two worldwide networks of community technology centers: Fab Labs and Computer Clubhouses. Fab Labs are community-based laboratories that make personal fabrication (Gershenfeld, 2005; Mikhak, Lyon, & Gorton, 2002) within reach to makers of all ages in roughly 30 locations across 10 countries. The Computer Clubhouses (Kafai, Peppler, & Chapman) 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 incorporating a large community table, clusters of computers, and studios for music recording and video recording/editing areas.

Research I conducted leading up to my dissertation study involved introducing Hook-ups activities to several research sites within these networks. Below, I describe the primary research sites for Hook-ups work in each network. I selected them after conducting workshops at multiple sites within each network. The dozens of workshops helped me understand factors that made sites conducive for youth to invent interactive experiences. For example, workshops that I helped facilitate for an after-school program based on an apprenticeship model featured a culture that tended toward over-structured interactions between adult facilitators and youth to the point where young people could not explore their interests through Hook-ups. I selected the following research sites because they exhibited: an ability to sustain mentor support, a staff that was open to exploration, reconfigurable workspaces, safe places to house Hook-ups artifacts, centralized storage for digital media, and broadband internet access.

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The Charlestown Computer Clubhouse site

The Charlestown Computer Clubhouse is located in a Boys and Girls Club facility. The Computer Clubhouse is one of many activities youth have to choose from during after-school hours (up to 8:00 PM). During periods of the day, youth of certain age groups are allotted time slots for certain activities in the Charlestown Boys and Girls Club. The Charlestown Computer Clubhouse offers:

- a free access policy for youth aged 6-18,
- over a dozen Windows-based PCs featuring several professional design applications,
- an area where craft materials can be found, and
- a large table where the community can congregate.

The South End Technology Center / Fab Lab site

The South End Technology Center (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." This center has the following features that offered me opportunities to explore different aspects of the Hook-ups System:

- a free access policy to youth of all ages,
- computer-controlled fabrication devices such as laser cutters and a large router,
- craft materials, and
- a soldering/circuit-making workbench.

Hook-ups work in the Clubhouse site has taken the form of afternoon drop-ins or short-term special workshops or projects that Clubhouse members build on their own schedules. In SETC, a program called the Learn 2 Teach, Teach 2 Learn (L2TT2L) integrates the Hook-ups System as a core component. 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 initially conceptualized by Mel King and David Cavallo that has been expanded and carried out by a growing community. The program 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. The pedagogical design of L2TT2L draws on the same pedagogical approaches I described in chapter 2.

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Once in the program, participants are paid a small salary to learn and teach. Participants who are in their first year are called first-year youth teachers. Participants who have served as a youth teacher for one or more of the previous years are called returning youth teachers. Staff who are in college are called college mentors (they are former returning youth teachers when possible). (See the Appendices for more information on L2TT2L.)

3.4 Methods

This section describes the methods I used to investigate my research questions at each research site in ways that followed my research framework. I collected, categorized, and analyzed multiple data streams in order to present findings using a case study approach. Figure 4 summarizes how I analyzed data to explore my research questions and organize my case studies. It lists the data sources I drew from for each case. My study includes three cases, each focusing on presenting key participants' experiences working with the Hook-ups System in different settings. The first case covers a three day period. The second case covers a three week period. The third case covers three months of work. I revisit the third case to extend the scope of the case study to a three year period in section 7.1.

I collected data for each case from a variety of sources including participant notes, material archives, survey results, and audio/video recordings.

SETUP Research Sites	DATA COLLECTION Sources organized in annotated digital files	ANALYSIS Illustrative Accounts	RESULTS Cases

Research Site 1 - Charlestown Computer Clubhouse

and

Research Site 2 – South End Technology Center

Field notes

Material archives

Audio / video recordings

Survey results

Experiences in which:
-participants engaged in building, expressed themselves and transformed their approaches to design

-facilitators engaged newcomers, cultivated facilitators and supported successors

Case 1 – Olympic Events

Case 2 – Hot Potatoes

Case 3 – Stuffed Bears

Figure 4 flow of data collected from research sites to results

In each case I present the accounts of events, artifacts, and experiences indicating that the Hook-ups System enabled learners to have experiences that were engaging, expressive, and transformative. The accounts I selected to highlight were the ones that gave me a better understanding of the dimensions of my research questions and were instrumental in thinking through the Constellation of Connected Creators framework. I explored the data streams in the ways described in the subsections below.

3.4.1   Collecting data as a participant observer and more

I agree with Stake's assertion that researchers should view their cases as systems (Stake, 1999). Because I served as a staff member and mentor at my research sites during the course of this study, I was a part of the participants' educational systems that I explored in my case studies. As such, my role was that of the participant observer. Anderson helped make participant observation widely accepted as a tool for social

science research. In his own work, he served as an example of how powerful a case study could be when a researcher relates his or her own life experiences to the study. His most cited work on the sociology of the homeless (Anderson, 1923) is oftentimes credited as being the type of early research that helped expand the academic notion of what could be considered field research. My research necessarily incorporated my relevant life experiences - participating in and making programs for community centers that served as my research sites. My unique designer's perspective complemented the data I collected pertaining to participants. As a result of participating in the cultures of the research sites for several years, I have developed personal relationships with numerous participants. Pre-existing relationships caused participants to consider me more than a researcher; I was a part of the site's community.

The role of participant observer takes on different meanings depending upon the researcher. Some observers participate in a culture to understand it while taking great care to influence it as little as possible in the process. I approach participant observation expecting that I will influence and make positive contributions to the culture of my research sites.

In order to understand how the Hook-ups System's design met its goals in the research sites, I managed a multi-faceted data collection process. Accordingly, I took several measures to avoid becoming inundated with more data than I could realistically analyze for my research questions. I started a data reduction process at the time I formed my research framing and questions and continued drilling down until the data most relevant to my cases remained. As the design experiment evolved, I balanced collecting data by looking for specific indicators while at the same time remaining flexible to follow opportunistic leads. To keep the study opportunistic, I captured more data than I needed, but filtered uneventful footage incrementally – before the dissertation's detailed analyses.

The techniques Burgess includes in his field research book (Burgess, 1997) guided my note-taking such as jotting down the sentiments participants show toward people they refer to when discussing a topic. Recording such information made it possible to tease out how interpersonal relationships factored into activities.

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Surveys uncovered information about individuals whom I included in case studies. Survey responses of interest contained first-person accounts regarding how and/or why an individual became engaged in a particular project or activity – specifically, if the System allowed him or her to explore an existing interest in new ways. Analyzing survey responses and video transcripts revealed ways that participants designed their Hook-ups to express an idea about a topic of concern to them. Comparing survey results over time assisted in analyzing responses that suggested a participant's thinking had transformed about him/herself or his or her approaches to design. These data informed how the Hook-ups System was transformative.

I relied on more than field notes to analyze the complexities of interaction and collaboration. I captured audio and video of small group interactions. Since Brown's work, and the publication of many prominent field research manuals, the means for digitally capturing photographs and taking notes has evolved a great deal. Conventional cell phones have become "smartphones," devices that can take photographs capable of conveying the contents of a computer screen. They also excel at storing text notes entered through a computer-like keyboard. As I worked with participants, my smartphone afforded quick note jotting and capturing digital replicas of notes participants wrote or photos of an artifact being made. My smartphone also took low-quality video to complement footage captured by my high-resolution digital camera.

Because activities in the research sites flowed inside and outside of the room in which they began, I typically kept a camera with me to capture noteworthy events away from the main activity and at times, left a camera stationary to record the main activity area. The stationary camera's continuous recording captured more of unexpected behaviors in a certain area – thus, it supported an opportunistic case study approach.

I also examined video footage from others. A team of young people in the SETC research site were learning how to make video documentaries during L2TT2L sessions. They captured Hook-ups being worked on and presented at the end-of-summer project exhibition. At the project exhibition, groups spoke with visitors about how they went about building projects and what they learned along the way.

I examined continuous and targeted recordings with a community of learners lens. In looking for social structures a group establishes, these recordings revealed the shared understandings of activities that a group of people developed and showed how they constructed knowledge together. I took particular note of how groups gained perspectives about their work by engaging in dialogue with non-group members – a practice that Wenger looks to when cultivating CoPs as he describes in his book Communities of Practice, Learning, Meaning & Identity (Wenger, 1998).

3.4.2 Validating findings

In each case, I made efforts to incorporate support from multiple data streams as part of my cyclical analysis process. Yin provides a metaphor for building confidence with one's data that likens the process to how a lawyer builds up evidence for a case – each finding can be supported by a "chain of evidence" (Yin, 2008). Doing data collection and analysis in cycles allowed me to increase my evidence and confidence in findings related to my research questions. Over time in my design experiment, examining data to tease out themes of Hook-ups projects helped me gain confidence in the themes and build upon them in subsequent cycles.

Collecting data in cycles helped me gain a better idea of which Hook-ups creators were likely to develop as potential future facilitators (and possible illustrative case study exemplars). Reviewing observation notes taken over time revealed and confirmed the best accounts to use for the three cases. Because data is open for multiple interpretations, I incorporated transcript excerpts that include participants' words into the text and included images I had for many of the Hook-ups discussed.

I placed artifacts I kept from workshops in a cabinet. I took images of every item in the cabinet to keep inventory. Doing so made recalling attributes of archived Hook-ups more accessible.

My collective data analysis methods outlined above ensure the integrity of my work. I've discussed how I leveraged prolonged engagement with my research sites and triangulated across multiple sources (from surveys to video recordings). I wrote in a way that privileged "low-inference data" by including transcript excerpts so that readers can verify my interpretations.

4 The Hook-ups System

Section 1.2 featured an illustration and text overview of the Hook-ups System's elements – including tools, materials, and people (in Figure 1). In this chapter, I introduce the Hook-ups System's design goals in 4.1. Section 4.2.1 introduces the technological infrastructure of the Hook-ups System: the Scratch personal computer (PC) application (developed by the Lifelong Kindergarten group) - the base platform upon which the Hook-ups System builds and the core technology of the Hook-ups System – the Scratch Sensor Board. Section 4.3 covers the types of Hook-ups participants have created. Section 4.4 details the design approaches and engineering ideas that the Hook-ups System helped young people explore. Sections 4.5 presents three lines of related work. Section 4.6 examines the design space of physical computing toolkits and tangible user interfaces. Section 4.7 offers a scenario of the types of projects the Hook-ups System is ideal for supporting.

4.1 The Hook-ups System design goals

The ways in which people use chalk can serve as a powerful model for rethinking how people can harness the expressive power of computational technologies. Since well before computers were even imagined, chalk has helped people from all age groups and backgrounds express their ideas and engage in creating and collaborating - from caves to classrooms and from podiums to playgrounds. 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 – as shown in the following table:

Table 1 current conceptions of chalk and computers

Chalk	Computers
Typically viewed by youth to be: - convenient for delivering classroom lessons - enjoyable when used for well-established games	Typically viewed by youth to be: - convenient for delivering classroom lessons - enjoyable when used for well-established games
- adept at engaging both social and physical body involvement in creative processes - capable of evoking self-expression during creative processes - instrumental to activities that help children transform their approach to design processes	Less typically viewed by youth to be: - adept at engaging both social and physical body involvement in creative processes - capable of evoking self-expression during creative processes - instrumental to activities that help children transform their approach to design processes.

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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. Avid gardeners change the array of plants they can grow by adding chalk to soil to make areas more alkaline (where certain plants thrive). (See the Wikipedia page on chalk for more uses ("Chalk - Wikipedia, the free encyclopedia," n.d.).)

But 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 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. As indicated in Table 1, 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 in the summer inspires me to challenge creators of computational tools to strive to make computers as much a part of children's creative culture as chalk is today.

I use chalk as an aim for designing computational toolkits and educational programs. One of the criteria of success will be if my system can offer the same types of experiences chalk does – ones that are engaging, expressive, and transformative.

4.2   The Hook-ups System's technological infrastructure

This section describes the technological infrastructure of the Hook-ups System that I have been refining as I have introduced Hook-ups tools and activities to two after-school technology centers as described in chapter 3. The first subsection introduces the base platform upon which the Hook-ups System builds: the Scratch personal computer (PC) application (developed by the Lifelong Kindergarten group). The second subsection describes the core technology of the Hook-ups System: the Scratch Sensor Board. Figure 5 shows an architectural overview of the ways that the two technologies interact.

Together, they form the technological infrastructure that (when brought out in activities) embody the attributes of chalk by being: adept at engaging a diversity of interests (such as social concerns and physical activities), capable of evoking self-expression during creative processes, and instrumental to activities that help children transform their approach to design.
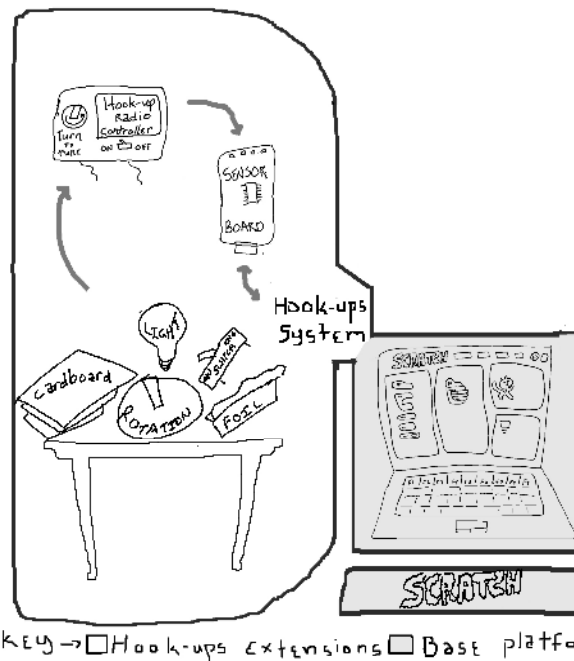
Figure 5 architectural overview of the Hook-ups System's technical elements

4.2.1 Scratch: A programming language and a research platform

Scratch is a programming language designed by the Lifelong Kindergarten group to run on personal computers (PCs) and make it easy for novices to create interactive stories, animations, games, music, and art, and share creations on the Web - all for free (Resnick et al., 2009). I have been a part of the core Scratch Design team since 2003.

Figure 6 the Scratch PC application screenshot

The Scratch PC application provides novices and experienced programmers with a means to create programs using graphical building blocks. The main parts of the Scratch interface include a palette of building-blocks in the leftmost column of Figure 6. The middle column is the area for placing blocks together to form scripts. There, Scratch allows users to build procedures by snapping together graphical building-blocks. The rightmost column includes a stage upon which objects behave according to the scripts. The rightmost column also features a list of a project's objects below the stage. The Scratch project in Figure 6, "Rock Band," shows a set of cartoonesque characters a 12-year-old drew on his screen to represent a rock band. He added behaviors to the band members by making stacks of Scratch blocks. Separate Scratch stacks constitute a script that caused his on-screen singer to screech at high volumes, a drummer's arm to animate up and down as drum beats played, and a guitarist's arm to move as guitar notes played.

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Certain blocks control the sequence in which Scratch executes commands. The graphical representation of some control blocks suggests that they can wrap around stacks of blocks to influence their execution - as the c-shaped blocks labeled "forever" and "repeat" are doing in Figure 6 (wrapping around seven command blocks). Other blocks are commands that change the behavior of Scratch objects (such as characters). The graphical representations of command blocks are intended to suggest that one or more modifier blocks can extended them. These modifiers change some aspect of the command or control blocks in which they are placed. Figure 6 shows a pointed-edge modifier block embedded in a control block. The command blocks inside of the control blocks each have text values that adjust how they behave. The color of blocks corresponds to the categories above the block palette. The shapes of blocks are the grammar. Some blocks are shaped in such a way that suggests that they modify other blocks.

The Scratch PC application features a top-level menu item labeled "share." When a person clicks on the label, he or she can select the first option to start the process for uploading a project to the Scratch online community (http://scratch.mit.edu).

4.2.2 The Scratch Sensor Board: the Hook-ups System's core technology

The core tool of the Hook-ups System is the Scratch Sensor Board (Figure 7). It is a printed circuit board that contains and connects a set of electronic components that detect changes to certain properties of the board's physical environment. The board reports digital information concerning changes in the physical environment to Scratch. The board supports a variety of sensors – objects that react to environmental conditions by changing their own electrical properties. The board uses the computer to which it connects as a power source. Four sensors affixed (soldered) to the board allow users to monitor light intensity, sound levels, a sliding shaft's position, and a pushbutton's position. Users can use the readings from these built-in sensors to control Scratch projects. Four alligator clip cables can connect and disconnect a variety of external sensors for monitoring properties of the physical world ranging from humidity to magnetic field strength or from the state of a switch to detecting a board's degree of tilt.
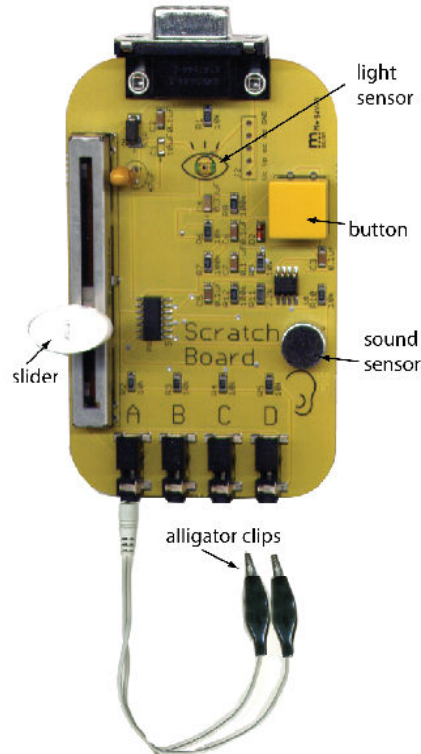
Figure 7 a Scratch Sensor Board

The Scratch Sensor Board (SSB) depicted in Figure 7 reflects a collaborative design effort. A subset of the Scratch team, John Maloney, Robbie Berg, and I brought our collective circuit-designing experience together to create a new device to make available around the launch time of the Scratch version 1.0 release at the beginning of 2007. Robbie was drawing upon experiences he had from helping develop the programmable bricks/Crickets and leading the LogoChip effort ("LogoChip," n.d.). John had designed an early Scratch Sensor Board alpha prototype that featured headers to receive sensor wires (after early experiments connecting sensors to early versions of Scratch using Arnan Sipitakiat and Paulo Blikstein's GoGo Board ("GoGoBoard," n.d.)). I had leveraged my Fab Lab / rapid prototyping experiences to design Scratch Patches (Millner, 2005) – a kit of reconfigurable puzzle pieces that present sensors to users in a myriad of forms. Figure 8 shows each of these SSB predecessors.
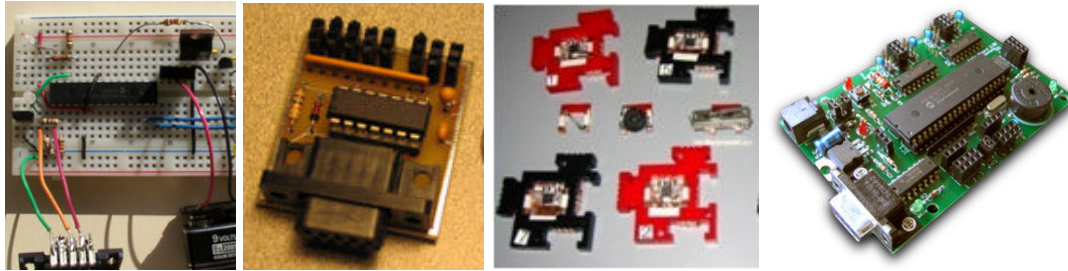
Figure 8 (a) LogoChip (b) Scratch Board Alpha (c) Scratch Patches (d) GoGo Board

John, Robbie and I, with Brian Silverman's guidance, based key design decisions on our workshop experiences with the tools depicted in Figure 8. My work with different forms of sensor boards influenced the shape of the SSB – to fit in a hand. Successes from having workshop participants get started with a Cricket kit's bundled sensors influenced our decision to provide popular built-in sensors with the SSB. We occasionally experimented with soldering different numbers of alligator clip cables to Scratch Board Alphas instead of providing headers for raw wire. We decided that four sets of cables was a number that could support many types of projects without intimidating newcomers. We decided on four cables after offering multiple workshops with two, four, or eight pairs of alligator clip cables attached to alpha Boards. We also opted to make the cables removable, like they were in the commercial PicoCricket kit ("PicoCricket," n.d.).

With key design features in mind, we started mocking up the SSB by cutting out a piece of foamcore to fit comfortably in our hands. We then attached electronic components we had around our Lab - such as pushbuttons and sliders. Once we figured out a layout that we liked, Robbie circulated schematics and mentored me through the manufacturing process. After determining cost-effective components, we did a manufacturing run to test 10 Boards. We then made minor tweaks and had 150 manufactured. Our next run was for 1,000.

During each test run, we made sure that the firmware on each Board communicated reliably with Scratch. In order to enable reliable communication between the Scratch PC application (version 1.1 and higher) and sensors attached to Scratch Sensor Boards, John, Robbie, Brian, and I discussed an appropriate communication protocol. John incorporated the protocol into Scratch (version 1.1) according to the specifications we made available online. Links to Scratch Sensor Boards schematics, firmware, and a bill

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of materials are available on the Scratch website's support page (Millner, Berg, Maloney, & Resnick, n.d.) and in the Appendices of this dissertation.

With our first run of SSBs in hand, I created an ordering and distribution process to get SSBs into the hands of educators (at the manufacturing cost with no markup). The MIT Scratch team distributed 1,600+ Scratch Sensor Boards from June 2007 to June 2008. From June 2008 to August 2010, the Playful Invention Company (Pico) distributed an additional 3,500+ sensor boards based on the same architecture. Each of the 5,100+ sensor boards currently in circulation cost $50 United States dollars (for the physical parts - shipping and handling costs varied).

Creators who want to integrate physical media and physical actions with digital media in Scratch projects use Scratch Sensor Boards. When I introduced the Rock Band project's creator to SSBs, he made a "Hook-up" – a physical object to control his Scratch project's behavior. He originally designed Rock Band to have a hand-drawn drummer animate when a person pressed the spacebar key. Replacing the control block that started a script when a user pressed the spacebar key with a control block that asked if a designated physical sensor had changed opened up opportunities for the creator to add a unique interactive experience to his project. The creator used a discarded case that previously held compact discs (CDs) to act as a drum control for his project. He turned the drum into a switch by adding aluminum foil to the points on the case's base and plastic cover that he made come into contact briefly when he struck the cover with a drumstick. Connecting this creation to his Scratch project through the SSB made his drum a Hook-up. When a person hit the drum, a Scratch command block he added to his program labeled "sensor-connected" registered as "true" and caused the on-screen drummer to animate and play sounds.

Putting together the Rock Band CD-case drum called for its creator to consider factors that each Hook-up creator takes into account – choosing different sensors, materials, and programs from many possible options to build a desired interaction. Scratch Sensor Boards stay in constant communication with the Scratch PC application to report when sensors on a Hook-up detect that their environment has changed. The board reports such changes to Scratch programs by adjusting the value of a Scratch modifier block. The built-in sensors (except the pushbutton) connect to a block labeled "___ sensor

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value." (See the uppermost block in Figure 9.) The _____ is filled in when a user chooses "slider," "light," or "sound" from a drop-down menu. Additionally, a choice for resistance-A, B, C or D can also represent numbers from 0 to 100 in a Scratch script that correspond to the state of a sensor connected to alligator clips. That is, these sensors alter the amount of electrical current that flows from one head of an alligator clip to the other (or across built-in sensors). When these blocks change values between 0 and 100, it represents the percentage of electrical current that faces resistance while traveling across the given sensor.
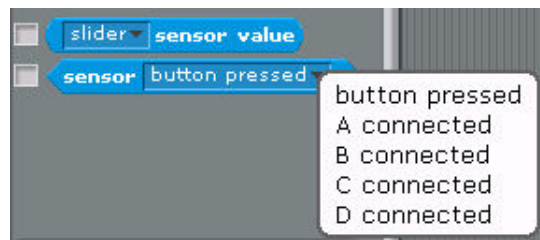
Figure 9 Scratch command blocks that report Scratch Sensor Board readings

The pushbutton built-in sensor and switches (like an on/off light switch) attached to alligator clips plugged into Scratch Sensor Board jacks labeled A-D modify a block in Scratch labeled "sensor _____." (See the lowermost block in Figure 9.) The ___ is filled by a drop-down menu from which a user can select the phrases "button pressed" or "{A-D} connected." When a board detects an open circuit - a switch in an "off" position - it changes the value "sensor _____" block. If a circuit is open, when a Scratch program encounters this modifier block in a script, the command block inquiring about a switch's status receives "false" or "not connected." When a switch is in an "on" position, a "closed" circuit results, and the sensor-connected block becomes "true" until the switch's contacts separate.

4.3   Types of Hook-ups

There are three types of Hook-ups classifications: *basic*, *repurposed*, and *fabricated*. Each term reflects how a Hook-up was made using a specific type of tool and material. The tools available and materials a person chooses for a project plays a role in how he or she shifts seamlessly between physical and digital design while integrating multiple types of media into Hook-ups projects.

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Basic Hook-ups are interfaces made of everyday objects that house sensors (manufactured or home-made). The flying saucer and Rock Band examples discussed earlier are basic Hook-ups.

Repurposed Hook-ups begin as electronic objects that were previously used to control existing consumer electronics (e.g., a model car remote control). A "repurposed" Hook-up results from learners discovering ways to redirect existing controls of a product to Scratch.

A *fabricated* Hook-up is a physical controller for computer programs that resulted from the creator(s) designing and building most parts using computer-controlled cutting machines. The availability of personal fabrication tools such as laser cutters, vinyl cutters, and desktop mills are integral to their creation. Fabrication tools, activities and materials give learners the ability to design objects such as sensors, circuits, and casings using a variety of stock materials. In building fabricated Hook-ups, youth who design, refine, and reprint physical components of projects can be shifting between digital and physical design well before connecting the physical output to a Scratch project.

4.4   Design styles, engineering ideas, and the Hook-ups System

This section discusses a particular design style that dovetails with the Hook-ups System's objectives. Innovative design firms such as IDEO have influenced design in ways that can inform how young designers develop. Recently, some of IDEO's designers have applied principles of designing prototypes to changing organizations (Coughlan, Fulton Suri, & Canales, 2007). The paper presents three key notions that mirror both the constructionist approach and the design styles I find the Hook-ups System to be particularly conducive to enabling.

They are:

1. Building to think—rather than discussing, analyzing, or hypothesizing in abstract terms before acting, creating tangible expressions of ideas early enables organizational thinking to develop concretely through action.

2. Learning faster by failing early (and often)—making things tangible allows many small, low-impact failures to occur early, resulting in faster learning about what does and does not work and why.

3. Giving permission to explore new behaviors—the tangible presence of a new thing, the prototype, itself encourages new behaviors, relieving individuals of the responsibility to consciously change what they do.

The Hook-ups work seeks to help as many people as possible to see their world as an infinite material palette and become capable creators who work with digital and physical media. I extend the third style to include: 3. Giving permission to explore behaviors *with new materials*. People working with Hook-ups find that their childhood possessions, recycling bin contents, and outdated electronics can serve as materials for projects and engaging entry points to new forms of self-expression. Turkle's work on evocative objects brings to light ways that our materials affect how and why we work (Turkle, 2007).

A goal of the Hook-ups project is to put young people in a position to learn as they adopt innovative approaches to design – incorporating their own physical and digital media along the way. I design Hook-ups activities to expose the interconnectedness of physical and digital entities. An increased understanding of how physical and digital worlds intersect creates endless educational opportunities. Repurposing rubbish, creating crafts, and controlling computer programs are each endeavors capable of sparking creative output from youth (as George Washington Carver intended). Where these endeavors intersect, opportunities emerge for children to complete projects – involving both computation and crafts - which might previously have been unimaginable.

Going through design processes and adopting new styles puts participants in a position to learn engineering ideas and concepts such as Boolean logic and electric conductivity. Participants reach understandings of electrical conductivity through a variety of paths. Through their own processes, Hook-ups creators discover that electric conductivity is a measure of an object's ability to conduct an electric current between two points. In the context of Hook-ups, creating hand-made switches provides opportunities to explore the conductivity of objects to which the participants have access. Switches are mechanical devices that connect or break parts of conductive paths in an electric circuit. Clipping one of a Scratch Sensor Board's alligator clip-heads to one part of an object and clipping the other to a different part measures the current along the path between those two clip-heads. A switch results when the clip-heads are put in a position where they have air (or

a poor conductor of electrical current/insulator) between them at some times and a highly-conductive material between them at others. Scratch Sensor Boards are tasked with telling Scratch programs when it is "true" that the clip-heads are connected via a conductive material (such as copper) or "false," that they are disconnected. Exploring "true" or "false" states of a switch provides a hands-on means for learning or helping others learn about Boolean logic.

Young Hook-ups creators are less than likely to introduce the term Boolean logic into daily conversations than adult designers, but they, too can come to understand how it is an underpinning of many interactive computer programs. Boolean logic is a system that can be used to communicate when the answer to a question is one of two answers – yes or no (on or off, true or false, 0 or 1, etc). Particular Scratch blocks change between one of two values when a Scratch Sensor Board notifies them that the state of a switch has gone from disconnected to connected or back. Boolean logic comes in handy when a Scratch program needs to know whether or not some or all of certain conditions are true or false.

4.5   Related work

This section introduces the trajectory of projects that bridge physical and digital design and serve as related work for my dissertation work. It is organized into three parts: (1) the Logo lineage; (2) physical computing, and (3) artistic practices and computing.

4.5.1   The Logo lineage

The progeny of the Logo programming language from over 30 years ago serve as foundations for the Hook-ups System (McNerney, 2004). Papert explored integrating programming and physical world activities in the earliest days of the project. A robotic floor-turtle was an early example of what he later termed *objects-to-think with* (Papert, 1980). Before programming a robotic turtle to move across a floor and change directions (oftentimes dragging a pen across paper), children would sometimes act out the intended movements with their own bodies. These children could predict what behavior a program would produce because they could imagine a physical turtle moving as they would. How they told the turtle to move has been a subject of interest in many projects that followed the floor-turtle.

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In the 1980's, a project gave imaginative 10-year-olds and older youth parts that they could use to build their own floor-turtle equivalents (or many other structures) that could be controlled with text-based Logo commands. The LEGO/Logo project, started by Mitchel Resnick, Steven Ocko, and colleagues, extended Papert's early wishes by integrating computation with LEGO brick building blocks (Resnick, 1991). The kit included the motors and sensors that learners could use to build floor-turtle-like creatures, or a variety of other robotically-controlled creations. For example, a person could program a LEGO motor-powered elevator car to change its travel direction when it hit a switch at the top of the LEGO shaft structure. The original LEGO/Logo kit featured an interface box linked (through a tethered wire) to a desktop computer running the Logo programming environment with sensors and motors attached to physical LEGO constructions. A family of behavior construction kits (Resnick, 1993), projects that combine physical and computational design, have grown out of the LEGO/Logo system.

A factor that made combining programming and LEGO brick construction popular was that building with LEGO bricks was something that youth from all over the world had already embraced in their cultures. A LEGO/Logo descendant combined the power of adding behaviors to creations with an ability to use the creation far from the computer. The "programmable brick" followed LEGO/Logo as a device that could store its own programs without being tethered to a computer, thus creating opportunities to take computation deeper into the physical world (Resnick, Martin, Sargent, & Silverman, 1996). Giving people the option to make a computer program affect the behavior of an object that could be embedded in their environment with no connection to a personal computer afforded both practical and conceptual advantages. Programmable bricks gave children a larger space to create within – from the computer desk to the closet. They also afforded opportunities to adjust one's conception of computing. The bricks challenged notions that computing had to be confined to a PC on a desk. Many variations of the programmable bricks have emerged, including the RCX (and later the NXT) brick commercialized in LEGO's Mindstorms robotics kit and a series of pocket-sized devices called Crickets (Mikhak, Berg, Martin, Resnick, & Silverman, 2000). Creators and educators have used these programmable bricks in many different settings for different types of applications such as interactive art, robotics, and music.

The languages to program the programmable bricks became visual in nature. LogoBlocks (Begel, 1996) presented users with a palette of shape and color-coded blocks that users could link together in a work area to make programs. These programs represented instructions that would control motors, read sensors, and run procedures on programmable bricks.

4.5.2 Physical computing kits

A number of recent text-based and visual languages for creating programs that control or respond to pocket-sized devices are becoming associated with an emerging field called "physical computing." Collections of languages, devices, electronic components, and physical materials (similar to what is illustrated in Figure 1) comprise physical computing toolkits. A recent IEEE article by Matt Cottam, who develops physical computing toolkits for (adult) designers, summarizes notable physical computing toolkits (Cottam & Wray, 2009). He recounts the trajectory of both the physical computing and the specialty toolkits focused on making "tangible interfaces" to graphical programs running on computers. The toolkits he describes represent those that are gaining traction within the designer community. These toolkits vary in intended use and audience, from MIDI-based toolkits for digital music enthusiasts to the BASIC Stamp for roboticists and hobbyists. He mentions none that are designed to appeal to young learners.

In the next subsection, I contrast several of the toolkits from the Cottam article with recently released physical computing toolkits tuned for constructing tangible interfaces, which I call tangible interface construction kits (TICKs), and the Hook-ups System. The toolkits I contrast vary in the degree to which they exhibit the attributes of chalk.

Part of what helps technological tools move beyond novelty or boutique projects is the materials that accompany them as they're introduced to communities of potential users. Marvin Minsky suggested that designers who wish to have their tools used widely (i.e., beyond early-adopters and technology aficionados) stand a better chance if they put effort into the tools' architecture as well as the support mechanisms that help communities of users exchange ideas and feedback. In critiquing why the 1980's Logo family of programming languages did not enjoy as much success in reaching the world as it potentially could, Minsky underscored the need for good exemplary programs to be accessible. When he was asked why the programming language Logo didn't make its

way into more schools in the 80's, Minsky responded, "It was a nice grammar, but there's no literature" (Minsky, 1986). This was Minsky's way of saying that the programming language itself had nice features, but needed a literature that showed people how the features could be used in examples with which they could relate. This metaphor echoes one of the reasons children read and write: because they see examples of written words that they enjoy. They might be motivated to make poems and stories that others will enjoy. Minsky felt that Logo never had such a literature. New physical computing toolkits are taking advantage of online and face-to-face venues for establishing the literature of their tools. Part of what makes the Hook-ups System unique is the materials, activities, and support structures that are co-evolving with tool development.

4.5.3   Artistic practices and computing

A goal shared by my work and some of the physical computing toolkits is to give young people from diverse backgrounds engaging experiences with computing. 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. Some work that inspires my research draws connections between artistic practices and computing. This connection resonates with fellow 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. A National Research Council report entitled *Beyond Productivity* (Inouye, Mitchell, blumenthal, Technological Innovations - National Research Council US, & Committee on Information Technology and Creativity - National Research Council US, 2003) and Graham's *Hackers vs. Painters* (Graham, 2004) both delineate ways in which painters and computer-savvy makers can benefit from adopting processes associated with learning each practice.

Graham shows in elaborate detail how painters have much in common with "hackers" (his term for creative computer scientists). During Graham's computer science studies, he found painters (and other makers) to be more similar to his maker-oriented computer scientist colleagues (in contrast to his computing theory-oriented classmates). He noted "I've found the best sources of ideas are not the other fields that have 'computer' in their

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names, but the other fields inhabited by makers. Painting has been a much richer source of ideas than the theory of computation."

Graham argued that "programming languages should be a pencil, not a pen. A language is for thinking of programs, not for expressing programs you've already thought of." Indeed, a pencil, like chalk, is conducive to constantly taking a creation in new directions – largely due to its erasable nature. Even though they are all sketching tools, Graham introduces pencils, pens, and paintbrushes at different times in his book due to their individual ability to support different arguments about how computing should be conceived – as have others (Resnick, 2004, 2006). For my purposes, chalk serves as a better model because of its larger stroke size that typically serves to broadcast what activities are happening across a longer distance to invite potential playmates.

There are projects designed with intentions other than facilitating children building tangible interfaces like the Hook-ups System, but which bring together artistic expression with computing in a way that can serve to broaden participation in computing. These projects dovetail with how I approach my work, leveraging artistic tools with wide appeal as a springboard into computing activities. Projects include Computational Sketchbook (Buechley, Hendrix, & Eisenberg, 2009) and I/O Brush (Ryokai, 2005).

In the Sketchbook, Buechley et al. bring parts of physical paintings alive by placing electronic components on the artworks where conductive paint can connect components. Her decision to utilize magnetic paint made exploring electronic aspects of projects more approachable than soldering wires (for would-be makers frustrated by the finicky art of soldering). Once a painting dries, a child can readily reconfigure electronic components to make part of the painting light up, vibrate, and/or make sounds. In Hook-ups work, a computer screen serves as the place to sketch paintings. The ways in which Hook-ups projects introduce sensors to the interactive sketch maintain the kind of tinkerability that the Computational Sketchbook does by providing a solderless means of connecting to physical objects.

Ryokai's I/O Brush also situates itself in an activity that has been popular among diverse groups of youth: painting. With the I/O brush project, Ryokai emphasizes the power of children turning the world into their palette by incorporating objects around them into

their dynamic visual art creations. The I/O brush takes a digital copy of an object and pastes a trail of its image across a computer screen following a path taken by an I/O brush stroke. Hook-ups tools also seek to turn a child's world into a palette. It does so by enabling children to connect physical objects to the computer in order to control dynamic media in a tangible way.

4.6   Tangible interface construction kits (TICKs) defined and compared

The Hook-ups System occupies a novel space in the larger picture of physical computing toolkits – an ever-changing landscape. This section establishes that most physical computing toolkits are designed from a similar set of electronic components, yet end up better suited for some contexts than others. I explore how the design of several kits that can be classified as tangible interface construction kits (TICKs) support children creating interactive experiences.

Many of the toolkits I described above (in 4.5) combine PC design applications with microcontroller-based devices in some way. PCs are machines that typically reside on a desk or a user's lap and run applications that entertain users, retrieve information, or assist in work activities. They provide a processor for handling the logic and math of applications, devices for storing applications and data, and a means for taking input from users and communicating output. These are typically separate components in a traditional PC. Microcontrollers, by contrast, are essentially shrunken computers that can approach the size of a few grains of rice. They offer a limited amount of processor speed, memory, and input/output options as compared to general-purpose PCs. They are usually powered by low-voltage batteries and end up embedded in materials or devices. An online guide that serves as a general overview of what microcontrollers are good for is on instructables.com at ("How to choose a MicroController," n.d.). In Table 2, I present differences between general-purpose PCs and microcontroller-based devices. It demonstrates how aspects of the architectures of each enable designers to create applications for diverse functions and scales. These architectures represent the state of the art, which changes at a rapid pace. (The table refers to microcontrollers that run closer to 10 million instructions per second [MIPS] than system on-chip processors like ARMS which run closer to 100+ MIPS – which give them properties on the PC side of the table.)

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Table 2 typical architecture for PCs and microcontroller-based devices

	Personal computers (PC)	Microcontroller-based devices
good for	running rich virtual worlds	running while embedded in physical world objects
processing	multiple threads of 32/64-bit instructions	single thread of 8/16-bit instructions
program memory and data storage	gigabytes of space in separate devices	kilobytes of space integrated into microcontroller
power requirements	large batteries/supplies provide amps of current for hours	small batteries/supplies provide milliamps of current for days
hardware placement	on desks, in walls, and in kiosks	exposed-circuit interface boards, enclosed in package with standard plugs
program switching	operating system (OS) can run many programs from storage devices	PC overwrites existing application with a new program (no OS)
pre-programmed application loading	download from network, copy from removable media	use pre-loaded application or download from a PC
likely inputs	keyboards, mice, joysticks, microphones, webcams, and scanners	passive sensors (light, temperature, switches), active sensors (ultrasonic and IR distance)
likely outputs	16/32-bit sound, high resolution 2D and 3D displays, printers	LEDs, motors, relays, low resolution LCD displays, speakers

Of the physical computing toolkits mentioned in the section 4.5, many have goals different from facilitating learning through design by lowering access barriers to blending physical media, digital media, and computation. Other goals include, for example, helping people who represent a range of ages, professions, and skill levels to be more productive, and entertain themselves. Even though the intended primary audience of another toolkit may not be children, attributes of its technical platform may serve to facilitate young people inventing interactive experiences. (One might craft activities around the toolkits with young designers in mind.)

A physical computing toolkit designer makes decisions about how to equip a microcontroller with programs and complementary peripherals that make it something that people can connect with programs on a PC to create interactive experiences and tangible user interfaces. The subset of those toolkits that support controlling PC applications with microcontroller-based creations can be called tangible interface construction kits (TICKs). The Hook-ups System has similarities with some features of

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other available TICKs. At the same time, I decided to take the Hook-ups System design into less-charted areas to meet my dissertation project's goals.

Below, I describe the basics of three platforms that have the infrastructure to support inventing tangible interfaces. I list a feature of each TICK that bears similarity to a Hook-ups System feature and one that is dissimilar. (For a non-exhaustive list of other attributes of each system, see Table 7.)

Table 3 LEGO WeDo overview

LEGO WeDo			
Programming environment	Interface board	Similarity to the Hook-ups System	Dissimilarity from Hook-ups
a drag-and-drop icon-based system	a USB "hub" that connects to a PC to allow control of tilt, motion sensor, and sound inputs and a motor	a tethered connection to the PC supplies power and communication for the kit designed for young people	the set of sensors is small and limited

Table 4 d.tools + Phidgets overview

d.tools + Phidgets			
Programming environment	Interface board	Similarity to the Hook-ups System	Dissimilarity from Hook-ups
the d.tools editor is based on states, events, and time/ordering. Nodes=state; arrows=transitions	connects devices with unique IDs to PCs: touch/force/ sliding/light/rotation sensors,switches, LEDs,a servo motor, and RFID	pre-conditioned sensors that give users a full range of values to work with	Hook-ups users do not set up events based on demonstrating the desired sensor – also, motors and lights are controllable

Table 5 NETLab Tools overview

NETLab Tools			
Programming environment	Interface board	Similarity to the Hook-ups System	Dissimilarity from Hook-ups
runs a server that establishes communication between Adobe Flash (MAX/MSP and Processing too)	the Make controller kit adapts well to almost any found part that a person plugs into it	approachable authoring of interactive rich media on the screen	the Scratch Sensor Board has built-in sensors while the Make controller ships with no devices

The intended audience of each TICK covered in this section influences the designer's development decisions. In Table 6, I highlight how each TICK navigated the TICK design space.

Table 6 design choices: several kits capable of supporting interface invention

	LEGO WeDo	d.tools+ Phidets	NETLab Tools	Hook-ups
kit includes computer programming environment with programs that can communicate with an interface board	*	*		*
kit provides a plugin/library for third-party programming environments to enable their programs to communicate with an interface board		*	*	
user-created programs can execute outside of the programming environment as stand-alone PC programs			*	
user-created programs can be transmitted to an interface board's memory so it can sense its environment and control its output devices			*	
an interface board can save data in its memory and report to a PC later			*	
kit has specialized interface board not intended for user-generated or third-party firmware	*			*
kit provides firmware for a re-programmable general-purpose or custom interface board		*	*	
a pre-loaded or downloaded program lets PCs send instructions to control connected output devices	*	*	*	
user-created programs on a PC can control output devices connected to an interface board	*	*	*	
user-created programs on a PC can listen to sensors from an interface board	*	*	*	*
a pre-loaded or downloaded program reports sensor readings to a PC	*	*	*	*
programming language is more visual than text-based	*	*	*	*

The final three rows in Table 6 show attributes that each TICK shares (outlined with dashed lines) to illustrate the dimensions along which I selected physical computing kits/TICKs that would compare with the Hook-ups System for supporting children inventing interactive experiences:

- programming language that are more visual than text-based,

- interface boards that report sensor readings to a PC, and

- programs running in a PC application can respond to interface board communications.

The first nine rows of Table 6 reflect different design decisions with respect to the base hardware, software, sensors, actuators, components, and cables each kit includes. The resulting combination has tradeoffs that present users with TICKs featuring varying cost points, degrees of learnability, robustness, and functionality. The Hook-ups System I described above reflects my process for continually refining the System while considering factors such as ease of installation/setup that my decisions affect.

Table 7 overview of TICK purchasing and installation information

	LEGO WeDo	d.tools + Phidgets	NETLab Tools	Hook-ups
base hardware cost	version 1 $~130	0.4b Starter kit 1 8/8/8 $265	Make Board v0.9 $109	PicoBoard $50
software cost	version 1 (included with kit)	Editor 2.0 $0	Widgets 2.0/Flash CS3 $690	1.3.1 $0
ease of set up / # of components to install	1 application to install	5+ applications to install	1 application to install + 1 software server setup	1 application to install + 1 hardware driver
Functionality on a low-end PC	Moderate	Low	Low	High

Whereas some TICKs, such as those intended for professional designers, may tune a kit for high-end PCs, kits like the Hook-ups System may pay more attention to running on low-end systems as well (those equivalent to Intel Pentium 3s or below). Decisions about how a kit is distributed, how the tools are protected and packaged also have a bearing on what types of intended users can access the kit.

Each of the TICKs above can make tangible user interfaces, but each of them offer children different pathways to projects they may wish to build. Table 8 through Table 11 lists some of the attributes that the hardware and software components of each TICK that support two types of interactive experiences: limited-functionality idea sketches or extended-functionality product prototypes.

Table 8 hardware attributes that support limited-functionality idea sketches

	LEGO WeDo	d.tools+ Phidgets	NETLab Tools	Hook-ups
documents are novice-friendly	*		*	*
boards have sensors are built-in	*			*
sensors use jacks (not raw wire)	*	*		*
sensor thresholds are pre-set	*	*		*

Table 9 software attributes that support limited-functionality idea sketches

	LEGO WeDo	d.tools+ Phidgets	NETLab Tools	Hook-ups
documents are novice-friendly	*	*	*	*
live sensor readings are viewable	*	*	*	*
testing program changes is quick	*	*	*	*
audio/video clips are importable		*	*	*

Table 10 hardware attributes that support extended-functionality product prototypes

	LEGO WeDo	d.tools+ Phidgets	NETLab Tools	Hook-ups
sensor set is extensible		*	*	*
a pre-existing shell protects board	*			
passive + active sensors can work	*	*	*	
sensor thresholds are tweakable		*	*	*

Table 11 software attributes that support extended-functionality product prototypes

	LEGO WeDo	d.tools+ Phidgets	NETLab Tools	Hook-ups
programs run >1 process at a time	*			*
unplugged sensors halt programs	*			
>1 format A/V clips are supported		*	*	*
programs can run in full screen			*	*

Table 8 through Table 11 reveal that I've designed the Hook-ups System to have attributes that support novices in building limited-functionality idea sketches and, to some extent, attributes that support them in building extended-functionality product prototypes as well. To help the Hook-ups System evolve to better support novices learning as they make interactive experiences, I focused significant effort on finding new ways to highlight the System's ability to connect many types of sensors and materials with multiple forms of digital media in a tinkerable way. With support for tinkering, live sensor feedback, and multi-threaded processes, the System gives a lot of support for controlling an assortment of media formats in an approachable way while offering opportunities for fine-tuning built-in sensors and adding custom ones.

The Hook-ups System supports building interactive experiences that have a range of functionality while keeping costs down for purchasers. Deeming a protective casing unnecessary, forgoing support for active sensors, and omitting automatic detection of sensors connected to boards, influenced far more than the toolkit's cost. These choices enabled the tools to facilitate the types of design consistent with the goals of my research while omitting a number of features that could have distracted novices. The System design is able to enjoy ease of set up and out of the box support for making projects that integrate physical and digital media seamlessly. People can engage in design processes that transform the tools into their own as they connect them to personally meaningful materials. A sizeable protective case would offer a higher degree of ruggedness, but potentially discourage embedding the tools in everyday objects. With Hook-ups connecting with a child's surroundings, computation can become a greater part of a child's play and learning space.

4.7   Interactive experience scenario

To exemplify how the Hook-ups System can support the types of creative processes afforded by chalk and, by doing so, empower youth to explore making interactive experiences, consider the following two processes: a child using chalk to turn a blank space on a sidewalk into a spaceship hopscotch grid, and a child creating an interactive flying saucer computer program that is controllable by a craft-based flying saucer model.

	Spaceship Hopscotch: For the basic rules of hopscotch, see ("Hop Scotch Games For Family Fun," n.d.). The site describes a variety of hopscotch variants – such as this spaceship theme. After a player traverses the numbers on the spaceship-shaped hopscotch grid, he or she must toss a marking stone into drawings representing asteroids. This version can be won when a player erases each asteroid. People can change any aspect of the game to suit their tastes. The shape of the spaceship can extend to make jumps more difficult. The asteroids can be drawn to make a marker landing in them less probable - and difficult tosses can be worth more points, etc. Variants of themes can be seen along the same sidewalk. The markings are usually washed away or walked over until they're no longer visible and the "canvas" can be used for other purposes.

	Interactive Flying Saucer: A 10-year-old created an interactive experience inspired by flying saucers. She controlled an animated flying saucer on her computer using a flying-saucer-shaped device. She made her flying saucer shape by stapling the surfaces of two paper plates together, then drew decorative lights on the shape and secured a pushbutton to the top plate. Next, she drew graphics for an on-screen flying saucer and wrote a computer program to animate an abduction beam drawing every time she pressed the pushbutton.

Both of the projects above reflect an outer space theme that promotes artistic expression. In the interactive flying saucer, the digital media component offered more means of bringing the project to life with sound effects and animations. The Hook-ups System made a richer exploration of the outer space theme possible by supporting the 10-year-old in combining physical and digital media. Given the properties of each TICK discussed above, Table 12 assesses how conducive the TICKs are to building an interactive experience like the flying saucer. The Hook-ups System has reached an area in the design space that made it the most conducive platform to carry out my dissertation work (and similar studies in the future).

Table 12 conduciveness of TICKs to building the flying saucer scenario

Physical building scenario	Hardware conduciveness more/somewhat/less			Interface invention kit	Software conduciveness less/somewhat/more			Digital building scenario
detecting a button on a paper-plate-structure			*	LEGO WeDo	*			animating a flying saucer drawing & abduction ray
	*	*	*	d.tools + Phidgets	*	*		
		*	*	NETLab Tools	*	*	*	
	*	*	*	Hook-ups	*	*	*	

5 The Hook-ups System: Case Studies & Analysis

This chapter includes four sections. The first three feature cases of small groups learning through creating interactive experiences using the Hook-ups System. The last section analyzes how the activities around the Hook-ups System made it possible for the System's tools to support Hook-ups creators in diverse settings. Section 5.1 features the first case – Olympic Events. It covers a three-day workshop that I introduced during a teen gathering. Section 5.2 features the second case – Hot Potatoes. It details three weeks of an effort that had drop-in participation. Section 5.3 features the third case – Stuffed Bears. It presents a project created over three months of a summer program. Each case concludes by highlighting how the Hook-ups System exhibited attributes that supported the participants having engaging, expressive, and transformative experiences. In each concluding part, I analyze how the case presented demonstrated that the Hook-ups System has:

- engaging attributes that help engage groups of young people who vary in culture, interests, and extracurricular activities,
- expressive attributes that support youth in creating and sharing projects that express parts of their personalities, passions or positions on social issues, and
- transformative attributes that transform how young people approach design – enabling them to explore design strategies and engineering ideas.

Section 5.4 sets out to bring to light ways that all three cases provide insight into my first set of research questions. It summarizes how the Hook-ups System demonstrated qualities that enabled youth to have engaging, expressive, and transformative experiences. It then explains how I structured Hook-ups activities around groups in different ways to enable the System's tools to realize their potential in diverse settings. It presents ways that I adjusted activities to support cases in which the age range, number, and demographic of participants changed (as did many other factors).

5.1 Olympic Events

In 2008, Coordinators from each Clubhouse nominated one or two exemplary members (who were between 14 and 18 years of age) to attend the 2008 Computer Clubhouse Teen Summit gathering in Boston. A coordinator in Columbia selected Vic as a delegate. Rose joined the Costa Rican delegation. Like the other 200 Teen Summit attendees, they both indicated the types of activities they liked on a registration form

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before they traveled. Teen Summit planners placed Vic and Rose in the workshop I was running called Renovating Rooms to React. When they showed up at the start of the three-day workshop, they, and 10 other participants from around the world, were excited to learn how to work with Hook-ups. Vic and Rose paired up with an adult mentor from Argentina and engaged in creating expressive interactive experiences with an Olympic theme. The duo ultimately created a High Jump Hook-up.

My team of facilitators and I began the workshop by showing an Olympic-like opening ceremony. I was working with four Clubhouse coordinators and three Media Lab co-workers. We showed a Scratch project meant to convey the Olympic spirit. The project was a multi-frame animation of an Olympic torch flame that animated and played music when a person shined a flashlight onto a Scratch Sensor Board's light sensor. Once the music ended, we showed a second project that featured a two-frame animation of an athlete running in place. Vic and Rose chose to start their Olympic Hook-up explorations by examining how the animated runner project worked and expanding upon it.

As the 12 workshop participants spoke with each other to discover common interests, Vic and Rose found that they both liked the idea of creating a character capable of jumping over a high jump bar. Other participants teamed up over events such as soccer, basketball, and hurdles.

To start their project, Vic and Rose focused on on-screen elements first. They remixed the animated runner they saw demonstrated as an example project. They used the image editor in Scratch to draw their own front-facing character that appeared to have his left foot on the ground and his right foot kicked behind him. To create another costume that would show the character with his other foot on the ground, the duo copied the original costume image and performed a "flip horizontal" operation – mirroring the image along the x-axis to achieve the desired effect.

They started from the script that they saw in the example project that made the character run in place. The small script essentially was a "forever" loop that told the character to change from its first costume to its second and back with a half-second wait time between changes. Vic and Rose created an effect to suggest that the character was running from the background to the foreground – toward an image of a high jump bar

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that they sized to suggest it was closer to the foreground. To make this effect, they used Scratch command blocks from the Looks category to start a script. They began by setting the character's size to 20 percent of its original size. They repeated through a stack of blocks that called for the character to change from a costume featuring one leg kicked in the air to a costume of the other leg in the air every second. After each second, another command block would call for the character to increase in size by 1 pixel. This contributed to the effect of the character running toward the screen.

Vic and Rose wanted to allow multiple users to interact with their project at the same time. Accordingly, they designed it to sense sound. They explored the sensing category of Scratch command blocks until they discovered how the "loud" block worked. They used this block in their program in such a way that detected when an audience cheered loudly. Upon detection, one of their scripts would respond to loud sounds by taking the character from the small size he starts the program as and incrementally increasing his size with each animated step he took. Very loud cheers made the character grow large quickly to appear as though he was picking up speed moving toward the high jump bar.

Vic and Rose added a script to the program that would measure how long it took for a crowd to cheer for the character toward the on-screen high jump bar. If the script determined that the audience took longer than a time value set by Vic and Rose, it would start an animation to show the character making an unsuccessful attempt to jump over the bar. The character would move high on the screen to suggest it was ascending into a jump. The bar graphic would fall on the character during his descent animation. The character would then wave his arms in dismay with a frown on his face. If the script determined that the audience reached a loud cheer quickly and sustained it until the character reached the bar, it would animate a successful jump. The on-screen bar would remain on its stand and the character would dawn a smile and dance happily.

They changed the way that they sensed how loud a crowd was. They tested their early project prototypes using their laptop's built-in microphone. They replaced the program's "loud" blocks, which continuously measured the intensity of the sound coming through the laptop's microphone, with "sound sensor value" Scratch blocks. This change placed the focus of where the crowd was cheering to wherever they placed the Scratch Sensor Board. When they projected onto an overhead projector they could change how the

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crowd interacted with the Hook-up by moving the Board's sound sensor around. Changing the sound sensor's location dynamically caused onlookers to cheer louder to make a successful jump or direct their attention to where the character was projecting instead of where the laptop happened to be at the time.

Vic and Rose had created a Scratch program with which they could get an entire room to engage through cheering. They switched their focus to creating a physical portion of the project so that one person could engage with the project by jumping over a high jump bar. They made careful considerations about the person physically jumping over the high jump bar. They wanted players to approximate a high jump to the highest degree possible. They sought to make the best high jump bar they could with what they had in the room. They were looking to realize their idea quickly so building a custom structure was not the first option they leaned toward. They asked my permission to borrow two easels that held up posters outside of the workshop's room. They set up the easels to stand approximately two-and-a-half feet from each other. They noticed that a fencing foil that was in the pile of Olympic-themed objects the facilitators provided. They laid the fencing foil across the two easels to serve as a bar that they could jump over. They had to try different configurations of laying the fencing foil so that it would fall off easily if a person touched it while attempting a jump. They then had to figure out how they could determine whether a jumper displaced the "bar" during a given jump.

Figure 10 the High Jump Hook-up

Once Vic and Rose had a physical high jump bar approximation constructed, they needed a way to inform the computer if a person kicked the bar off of its stand during a jump attempt. They reviewed the example projects we had loaded onto each laptop.

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They were able to change the blocks in Scratch to Spanish so that the team could communicate in their native language as they figured out which scripts they should draw upon to sense the high jump bar's status. They discovered that the "forever if" block could make part of a script run if the condition of "sensor A connected" was met at anytime while a person interacted with the program. (Vic and Rose had extended an alligator clip cable from the jack-A of their SSB.)

They experimented with connecting the alligator clip-heads to different parts of the high jump bar and the stand upon which it rested. They ended up clipping one alligator clip-head onto the easel support upon which the fencing foil rested and the other onto the fencing foil itself. The facilitators helped them understand how clip-heads would be considered to be "connected" if they are both attached to a conductive material (such as metal). Because the easels were plastic, they added copper foil to the platform upon which the fencing foil rested to make it conductive. Because of the way the fencing foil felt, Vic and Rose didn't have an accurate idea of the type of metal or plastic it was made of. They figured that it was best to wrap the tip of the fencing foil in the same copper foil that they used to make the easel support conductive. Vic and Rose were able to modify their Scratch program to run the sad animation if the fencing foil separated from the easel. The program asked about the condition of the bar. If it remained on the stand during a jump attempt, their script would follow its instructions for the true condition. Facilitators and their own tinkering helped Vic and Rose understand the way electrically conductive materials could influence such scripts.

Figure 11 the High Jump bar version 2

They continued to improve the Hook-up, giving the physical interaction another revision. They took over the portable coat rack in the workshop's room. They added foil to platforms they found on both poles of the coat rack. They placed a straightened wire-

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hanger across the platforms. They attached one alligator clip-head to the platform then clipped the other to the hanger wire. They continued to tweak the program until they moved it to the Teen Summit closing exhibition open house. At that event, Vic and Rose joined other participants who built Hook-ups based on other Olympic events to host the Scratch Olympics for the Teen Summit attendees.

Additional outcomes of the Olympic Events workshop – soccer Hook-ups

In the workshop, participants ultimately brought six events to the exhibition. The High Jump Hook-up, soccer, futbol, basketball, hurdles, and… paintball (a modified archery theme). The way that each Hook-up functioned varied. For example, the soccer Hook-up attempted to capture the fun and pressure of shooting a soccer penalty kick. The group's first attempt to detect when a soccer ball-sized wad of duct tape struck a "goal" entailed kicking the ball at the built-in button on the Scratch Sensor Board. The button was too small a target for most non-Olympian soccer enthusiasts to hit. Like Vic and Rose, the soccer Hook-up creators learned how to connect alligator clip-heads to two pieces of conductive material in a way that gave them an on/off switch (with a two foot surface area for the ball to strike in the soccer Hook-ups' case). They designed the software portion of the Hook-up to give feedback to users to let them know if their kick resulted in a goal or not.

Like the High Jump, the soccer Hook-up also featured a countdown. A time-keeping script would give players only a matter of seconds to attempt kicks. This design feature gave players a sense of urgency as they tried to score as many points as possible by hitting the goal target frequently in under a minute. The soccer Hook-up featured a character on the screen who moved around to guard the virtual goal from a player. This character would taunt players upon a missed kick attempt. On a successful kick, the computerized crowd would cheer for the human player – instead of the other way around – as was the case in the High Jump.

Examining the Olympic Events experience

The Hook-ups System helped Vic and Rose gain experience designing interactive systems and learning engineering concepts. Different aspects of its tools and activities contributed to Vic and Rose being engaged, expressing themselves and transforming their approaches to design.

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How the Hook-ups System helped bring about engaging experiences in three days
Focusing introductory activities on the Olympic Games opened a multitude of engaging project entry points. Every four years, the Olympic Games engage many people worldwide in some level of participation. The theme already had cultural connections to the countries from which participants came. With international soccer being an event many people follow, it is not surprising that two groups out of six in the workshop focused their projects on the sport.

One factor that made the Olympic events theme generative for projects was that it engaged participants who were interested in the physical skills that Olympic events call the athletes to develop and exhibit. Vic and Rose's interest in cheering on high jumpers and performing jumps themselves sustained their engagement in constructing the High Jump Hook-up. As they tested their prototypes, they drew upon the event's engaging nature to have others excitedly test it out for them and give feedback.

Participants leapt at the opportunity to try Vic and Rose's High Jump. The Scratch Sensor Board's ability to connect with sensors through the alligator clip cables helped make the High Jump Hook-up work at the full-body scale to capitalize on people who were interested in full-body physical challenges. Vic and Rose were able to make a switch that was large because they understood how to extend the alligator clip-heads with conductive material to make larger sensing surface areas.

How the Hook-ups System helped bring about expressive experiences in three days
Vic and Rose made the High Jump Hook-up to express what they felt was an important component of success in Olympic events: crowd participation. They created their project to include a high-jumping character that had a greater chance of jumping over the on-screen bar based on how loudly the people watching the Scratch project would cheer for it. The duo's choice to invite crowd participation in their initial project prototype reflected how they like to be active spectators at sporting events (or have people actively support them as they compete in sports). The design of the Scratch Sensor Board gave Vic and Rose an additional option for fine-tuning the crowd participation part of their system. Shifting the location of the sound sensing from the laptop's microphone to the Scratch

Sensor Board's sound sensor helped them solicit cheers toward different directions or of different magnitudes.

The soccer Hook-up creators were able to express how they felt about the sport. They were able to record their own voices in the taunts that followed a missed kick attempt. They also incorporated images of players making silly faces to distract the kicker.

How the Hook-ups System helped transform creators' approaches to design in three days
When transforming an approach to design, the style with which one builds, and the attitude taken while doing so, evolves. Vic and Rose took advantage of the System's ability to connect to materials quickly and reversibly in order to switch from one mock-up to another. They transformed their Hook-up from one way of functioning to another – changing its form along the way. These project iterations gave them opportunities to hone several skills. For example, when the High Jump team transitioned from the fencing foil mock-up to the hanger-based prototype, they proved that they had a grasp of how to make objects conductive in order to make a switch.

Vic and Rose were comfortable that each prototype they made was just a sketch. Each time Vic and Rose broke down one of their High Jump bar apparatuses (e.g., making the portable coat rack function as a coat rack once again), they were not worried that they wouldn't be able to create a better experience later. Similar to how some children might wash off chalk sketches on a sidewalk in front of their house when they finish playing, some Hook-ups designers understand that they too are sketching when they make versions of Hook-ups. They return objects to their original configuration when they're no longer being used. They take comfort that they've learned what it takes to sketch something similar or new altogether should the opportunity to do so avail itself.

In doing the rapid project iterations, they had new updates at the end of every workshop day. Their attitude toward sharing those updates with other workshop participants changed each day. Vic and Rose became comfortable communicating with each other in Spanish as they designed their switch-based high jump bar and tweaked how cheering played a role in their project. They started out having less comfort discussing what they were working on with their peers in English. As they showed their work-in-progress to the predominantly English-speaking audience, they realized that their ideas

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communicated a lot for themselves. They became more confident as they made their project inviting to walk up and try. Satisfying that design criteria helped them rely upon their limited command of English less and focus more on embodying their ideas in Hook-ups.

The more times they received the feedback of an entire room cheering loudly, their attitude toward showing their work shifted. By the time they were showing their High Jump Hook-up to others during the Teen Summit open house exhibition, they were beyond worrying about communicating with the diverse set of visitors. They were eagerly greeting anyone who stopped by to demonstrate how they could attempt a high jump for themselves.

5.2   Hot Potatoes

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's held for too long. It was also a theme around which a group of young creators at the Charlestown Computer Clubhouse collaboratively built a Hook-up.

The project started when a small group of members (aged 13-16) came together to learn how to make interactive experiences that called for full-body interactions, similar to Nintendo Wii games. This group first came together on an afternoon during drop-in hours. I had arranged to be at the Clubhouse and have the Nintendo Wii running to welcome members who came in after hearing that I was hosting a workshop for interested members. Members who noticed the flyer about the workshop (or who had spoken to the coordinator) took opportunities to play a game called Wario Wares Smooth Moves on the Clubhouse's Wii as members trickled in for the afternoon.

Once about five members had played a few rounds of Wario Wares' mini-games such as fly-swatting and shaving, I engaged them in a discussion before beginning to make Hook-ups. We discussed the types of objects that Wario Wares emulated using the Wiimote. They noted interactions from swatting flies to slashing swords and from throwing balls to reeling a fishing pole.

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They wanted me to show them how a Scratch Sensor Board (SSB) could be used to make Scratch project that involved movements like a person swatting a fly. The group learned about the light sensor on the SSB. We had done some searching on the Internet to find out how light sensors helped the Nintendo Wii recognize where Wiimotes faced. The light sensors in the Wiimote bar were encased, but the light sensor on the SSB was exposed for them to see. They covered the SSB's light sensor with their hands and toyed with a script I put together on their computer to serve as an example. As they thought of interactions with hands, the idea of hot potato came up. 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). They draped the Scratch Sensor Board in a brown paper bag to make it look like a potato - to suggest the type of interaction they designed their game to support. One member made sure to cut a hole in the bag where the light sensor was so that they could use feedback from that sensor in their Scratch program.

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. They set out to make a hot potato game that could have more of the properties of the actual game such as an ability to throw an object however they saw fit. The group had to make a potato that they could throw around in a way that Scratch could keep track of it.

Figure 12 the Hot Potato Hook-up

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They covered a tennis ball with foil. They 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 decided that they could show that Scratch was keeping track of which player was holding the potato by putting graphics on the Scratch screen.

Four people wore hot potato Hook-up gloves. The fifth person sat at the computer running Scratch. When Rex was sitting in front of the computer and Scratch program, he drew an image that vaguely resembled a hand. As he used the mouse to draw, erase, then redraw the rough approximation of a hand, his peers chided him about each version. The jokers in the group embraced one drawing even through it only had four fingers. He used the fill tool in Scratch's image editor to make the hand different colors. He settled on green. The group urged him to copy the hand and make each copy a different color to represent each person around the hot potato circle. The color options were not limited to human skin tones. He responded to each player that shouted any color he wanted his hand to be. Rex had already made one hand grey. One player shouted green, another said red, the last player picked blue.

Once the drawing was copied and re-colored three times, they had to make sure that the Scratch script they were using to identify when the potato was in a hand would function for each new hand sprite.
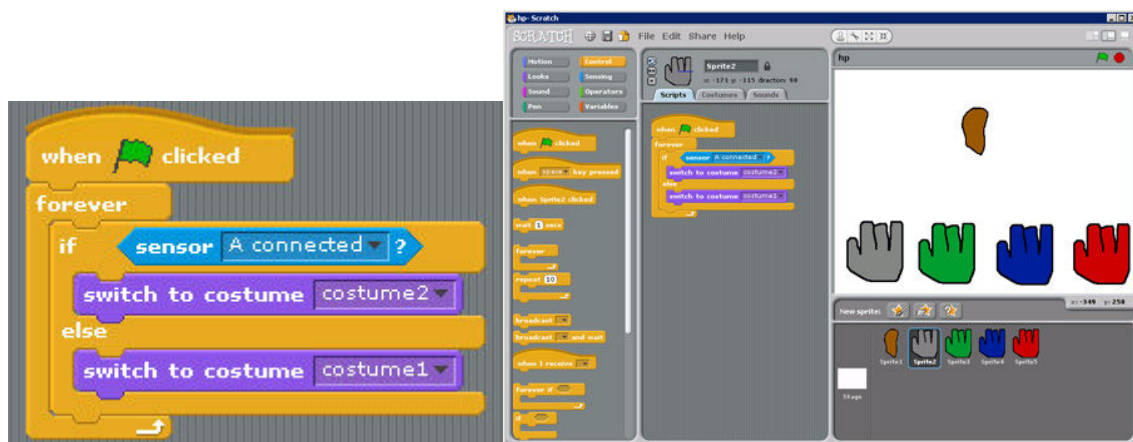
Figure 13 the Hot Potato Hook-up script stack

The group saved time by copying the script to each sprite because they only needed to change one aspect of it. It would have been arduous to recreate a similar stack each time. They only needed to change the drop-down menu on the "sensor-A connected" block to be read sensor-B for the second hand, C for the third, and D for the fourth.

Each player in the group had to hold the foil-covered "potato" in order to assign the player the color he chose. Rex started by arbitrarily assigning hand images to sensor jacks A,B,C or D. Once a player held the potato, one of the sprites on the screen changed its costume from an empty hand to a hand holding a potato. The player would ask Rex to re-assign a hand image to a particular jack if he saw the image of a potato appear in a hand on the screen of a color different than the one he chose. The group repeated that process until each player had the color he chose. They could have physically swapped a plug in jack A for a plug in Jack C to achieve the same result, but elected to rework the script.

The group tossed around the potato and joked for a while until one player became annoyed at one of the program's features. Kendi wasn't satisfied that his group of peers had succeeded at making an on-screen potato graphic appear in a hand that corresponded with whichever one of four players was holding the potato being tossed around. Kendi identified a feature he felt was noticeably missing from the early version of the Hot Potato Hook-up. He wanted to explore the possibility of making the on-screen potato appear to be in the "air" (away from any particular hand on the screen) if the physical potato was in-flight going from one player to another.

To implement this, 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. He tried to concentrate despite the ever-present banter coming from his peers as they played hot potato. One of his colleagues, Henry, 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.

Kendi opted to make his own script. Using Boolean-inspired thinking, Kendi 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 sprite of the flying potato change to a costume that was a small white dot (as to make it look invisible against a white background) instead of the costume that shows the potato in the air. Figure 14 shows the long argument Kendi constructed for this script.
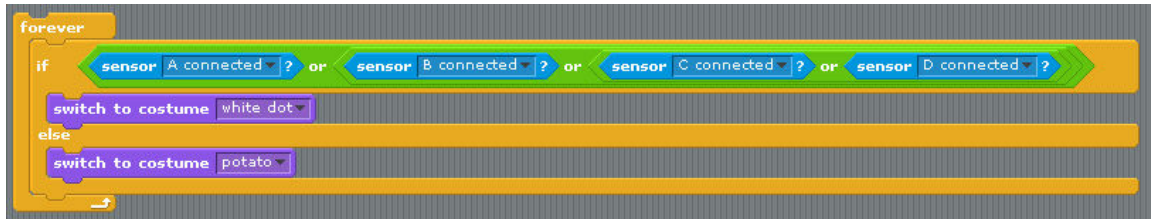
Figure 14 the Hot Potato Hook-up script 2

When Kendi finished his fix for the program's flaw, he instructed his peers, who had continued tossing the potato, to stop so that he could see his fix work or flop. When he felt as though his programming work was finished, he did a physical step-through of the Hook-up's program to check its accuracy. He had become accustomed to giving Scratch instructions so when he interacted with his peers to test the program – he did so in a methodical fashion similarly to how he added command blocks. He pointed at peers one by one, telling each to hold the potato while he examined the on-screen hands. He'd instruct each one when to pass it on and whom to pass it to. His physical run-through confirmed his two suspicions: (1) that he had found a way to make the on-screen potato appear to be in the air and (2) that he was a genius. Kendi was elated when he looked

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back to the computer screen to see that the potato image appeared by itself in the middle of the screen when the physical potato was in flight. He wasted no time in leaning back, raising both hands as high as he could and exclaiming, "I'm a genius!"

During other parts of the project, the group tried multiple members' ideas to get around an impasse. Members understood that the dynamics of this group made it so that everyone's ideas had a chance to play themselves out, but no one person's had priority. For example, several members had to guess what was causing the potato drawing to appear to be flashing between two on-screen hands in the middle of a hot potato game when the actual potato remained in one person's hand – countering what was happening on the screen. Rex suspected that the Scratch program might have been the source of the erratic behavior. He checked the scripts but did not find anything unusual. Henry double-checked his glove's connection to the Scratch Sensor Board by grabbing the potato. He did not see the problem occur with him because the on-screen potato appeared to be in his virtual hand – as it should. Pete noticed the actual problem as he laughed at a comment made by another member.

Pete's full-body chuckle caused the wires that connected his glove to the Scratch Sensor Board to cross and induce the potato flashing-potato problem. It was at that point that we collectively realized that we 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. There was no plastic-coated wire to be had in the Clubhouse's electronics drawer so exposed wire was the only wire we had to work with. As the group continued to play, they made efforts to keep wires separated – some did so by sticking a blue-jean-covered leg between the wires.

After resolving the flashing-potato issue, the members of the group freely offered suggestions to whichever member happened to be controlling the keyboard and the mouse at the time. The person programming had to ignore, incorporate, reject or remix ideas proposed by peers.

A side project of one of the Hot Potato Hook-up creators – Spin Selector

Even though much of the time I spent at the Charlestown Clubhouse was spent supporting collaborative projects, members like Henry broke off to do individual projects on occasion. When members would work on independent projects, they'd work their way to one of the other computers that had Scratch running and a Scratch Sensor Board attached to them. Henry broke away from the Hot Potato Hook-up activities to build a Hook-up that he thought of - a Spin Selector. It consisted of a plastic soda bottle perched on a LEGO axle. The bottle was raised over a Scratch Sensor Board that sat on top of a small pizza box that stabilized the whole setup. He painted the bottle black to ensure that it blocked light each time it spun past the Sensor Board's built-in light sensor. He wrote a Scratch program that would rotate through a different background costume every time it sensed the bottle casting a shadow over the light sensor (causing its value to temporarily drop). Each costume contained a name surrounded by a flat background color. This interface was a play on games such as Truth-or-Dare which sometimes involve spinning a bottle – the player at which the bottle points after a spin plays the next turn. (Henry also playfully suggested that his Hook-up could have been inspired by a version of spin-the-bottle-based games that call for selectors and selectees to temporarily…chew each other's gum.)

Examining the Hot Potatoes experience

The Hook-ups System helped Kendi, Henry, and other Hot Potato Hook-up creators gain experience in designing interactive systems and learning engineering concepts in a group setting. Different aspects of its tools and activities contributed to the group being engaged, expressing themselves and transforming their approaches to design.

How the Hook-ups System helped bring about engaging experiences in three weeks
There are some games that children around the world play with slight variations. Hopscotch is one. Hot potato is another. These are games that invite people of all ages to join in. Hot potato proved to be a game that was engaging for teens when they could explore learning about technology through playing it.

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 interactions which the participants found engaging in Wii games such as Wii's

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Wario Wares. More and more adults are finding mini-games that invoke their childhood to be engaging (the Hot Potato 2010 iPhone app already has thousands of high ratings and Nintendo Wii games such as Backyard Sports features mini-game variants of Hot Potato). The group found designing their own mini-games based on throwback games to be engaging.

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 Potato, one switch on each jack could be a separate player. Four jacks (clipped to wire extensions) 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.

How the Hook-ups System helped bring about expressive experiences in three weeks
The Hot Potato 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 on the screen that he could control with the hot potato glove mapped to his hand. He told his friend who was drawing the on-screen images to draw a square potato in *his* hand instead of the oval potato that the friend 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.

As different participants took charge of the Scratch computer's keyboard and mouse or manipulated physical materials, they were able to quickly try both silly and serious project ideas. In doing so, they could express their agreement with an idea by implementing it and express their disapproval of other ideas by making fun of them in the project. While working on the Hot Potato Hook-up, the five-person group would frequently blurt out ideas for project directions as they tossed the foil-potato around to the play the game. One way that emerged for the participant who was actively changing the Scratch program to acknowledge feedback from other participants was to implement an exaggerated version of their suggestion. One occurrence of that technique involved turning a drawing of a hand hot-pink when one of the members suggests that the graphic should be "a little more red." The ability to sketch quickly on the screen – even for silly diversions – kept the entire group engaged. To react to a different suggestion in a silly

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way, one participant made a script repeatedly increase a sprite's size until it was too big to fit on the screen. This came after a peer suggested that a particular sprite was too small. The Scratch software's ability to rapidly change the way a program worked while it was running opened doors for the silly interactions.

The process of creating the Hot Potato Hook-up exposed the playful personalities of its creators. They enjoyed joking around with each other as they worked together. When Kendi exclaimed "I'm a genius," he was being playful with friends – not purporting intellectual superiority over his group. With Henry's bottle-spinning Hook-up, he used the Hook-ups System to express his flirtatious personality. He made the girl from which he sought attention in the brightest version of her favorite color and used the largest font.

How the Hook-ups System helped transform creators' approaches to design in three weeks
When transforming an approach to design, the style with which one builds and the attitude taken while doing so evolves.

The Hot Potato 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 Potato prototype running quickly, no one in the group (myself included) noticed that we wired the hands of each participant using exposed-metal wire instead of plastic-covered/shielded wires. This oversight helped the group learn about electrical conductivity. As the group debugged the issue, they discovered ways in which wires in an electrical circuit could be connected or interrupted. When the group realized that bare-metal wires inadvertently touching each other was causing the Scratch program to behave in unexpected ways, they determined that separating wires with a leg served as a solution. They developed the skill to insert their bodies into the interface's circuits when and where doing so was appropriate.

Once they had comfort with having wires touch their bodies, their attitude toward tweaking the project changed. At a point in the project when participants had been playing Hot Potato for a while, the hands they had inside of the gloves (that were designed to hold the finger-tip foil connectors) became uncomfortably hot. The participants began to take off their gloves for relief. Kendi was the first one to realize that he could remove the finger-tip foil from the glove and place it on his finger without

causing the game to function any differently. He was relieved that introducing his skin into the circuit didn't change how the Hook-up behaved. Conducting the mini-experiment gave the group a greater understanding of what types of materials were conductive, like foil, or not-so-conductive, like denim.

5.3 Stuffed Bears

The first year of my Learn 2 Teach, Teach 2 Learn journey, I was grouped with about six or seven 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 called it Proper 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. We recorded songs the sensors would play. The songs would be either teaching the kids how to recite their ABC's, their 123's, or just have positive messages that they hear over and over every time they press the sensors. 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... you know the cycle wouldn't be continuous. The basic idea was just to create a positive role model for the kids so this was Proper Bear.
-Shawn

The idea for Shawn's project came when one of his 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. 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 the neighborhoods most of the group called home. 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 modified bear Thugaboo.

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Figure 15 Proper Bear and Thugaboo Bear Hook-ups

At the beginning of the project, Shawn spent the bulk of his time coordinating the voice recordings. He played with different ideas for what Thugaboo Bear would say. Friends and groupmates would listen to the playful recordings and give feedback about the word choice and tone of what they heard. Others in the group set out to make the bear toy play the recordings when someone squeezed it. They started trying to figure out how to make their Scratch Sensor Board detect the squeeze of a sensor in the bear's paw and distinguish it from squeeze signals from the other paw or feet sensors. The group members who were at the Saturday session that introduced Scratch Sensor Boards tried a few approaches to making a Scratch script dedicated to each sensor in the bear. They found it difficult to map the bear's internal switch sensors to Scratch command blocks. In the process, they brought Shawn in to help – bringing him up to speed on working with the Scratch Sensor Board.

The group was repurposing an existing electronic product for the first time. They were looking to learn about how the existing electronics worked inside of the talking bear so that they could know where to modify it. Shawn's group also sought help from staff as they attempted to understand how the toy's sensors were connected. The toy's owner didn't mind if the modifications were irreversible because he no longer played with it. 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 a Scratch

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Sensor Board's alligator clip-heads. They 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 for a "sensor A connected" block. It would toggle from "FALSE" to "TRUE" when a person squeezed the part of the bear that contained the sensor that was physically connected to the wires to which had the alligator clip-heads were attached. The group labeled the wires accordingly to keep track of the useful pairs. Once the group determined which wires were critical to keep, they removed non-essential wires and electronic components to make room for the Scratch Sensor Board they embedded inside of the bear.

The Thugaboo group based their project on the assumption that promoting children educating themselves and staying in school would contribute to the main goal of their project: preventing gun violence. Once the group identified how to wire Thugaboo's sensors, Shawn helped map the squeezes of its different parts to different voice-recorded messages. Each message touched on early education issues such as learning the alphabet. The 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 involved with becoming a neighborhood thug. The "A" and the "K" alluded to the first letters of the 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. On a more serious note, 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 the Proper Bear. They dedicated two alligator clip cables of a Scratch Sensor Board to Thugaboo and the other two to Proper Bear for a demonstration at the 2007 L2TT2L final project exhibition (that was open to the community). They used one Scratch program that had a

drawing of a bear on the screen to show users where the bears' 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.

Examining the Thugaboo and Proper Bear experience
The Hook-ups System helped Shawn and his collaborators gain experience in designing interactive systems and learning engineering design practices (and concepts) in a group setting. Different aspects of its tools and activities contributed to the group being engaged, expressing themselves and transforming their approaches to design.

How the Hook-ups System helped bring about engaging experiences in three months
The Thugaboo and Proper Bear Hook-ups engaged numerous participants who were interested in impersonating people around them. With Hook-ups, they were able to let others interact with their impersonations by embodying them in stuffed bears. The group shared an interest in making up voices to caricature certain lifestyles (thugs or over-articulate people). This interest inspired the group to make exaggerated voice recordings on the digital end of the project to match the extreme attire they made for the toys on the physical end of the project.

The Hook-ups System is helping participants take new approaches to design when it gives participants opportunities to engage in design in both physical and digital media based on their interests (as was the case with the stuffed bear Hook-ups). 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.

How the Hook-ups System helped bring about expressive experiences in three months
The Thugaboo and Proper Bear Hook-ups were expressions of multiple issues 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. As they recorded their own voices and made custom clothes for the bears,

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they were creating an interactive product that they would not be likely to find on store shelves. The company responsible for Talkin' Bubba Bear, TYCO, was appealing to major markets to make the kind of profit necessary to justify the costs of design, production, and distribution. The exaggerated southern accent could sell worldwide, however, localized Boston slang would be less likely to end up in a product.

The content of what the two bears were programmed to say was in and of itself expressing a lot. Both bears were giving stay-in-school message using different delivery styles. The creators were expressing that positive messages are received differently when delivered by someone you identify with. This is not to say that young people who live near people who speak like Thugaboo identify with the people the bear caricatures. However, the project creators understand the weight of messages coming from people who play prominent roles in a neighborhood – which can be local thugs in some cases.

Shawn's group implemented the project in a playful way – having the bears recite funny statements at times. They still understood the gravity of the problem they were addressing.

How the Hook-ups System helped transform creators' approaches to design in three months
Before Shawn's group could create Thugaboo, they had to figure out how to repurpose Talkin' Bubba Bear. They 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.

One of the approaches to design the Hook-ups System encouraged was build-to-think. The approach I helped the Thugaboo group take to understand how to begin their work applied that idea in the opposite direction – unbuild to think. That is, 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.

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The group also realized that a fruitful approach to design was to ask everyone. In traditional school systems, the dominant model is often to ask an expert/teacher. The Thugaboo group asked each other how to get through challenging parts of the project. They were aware that exploring solutions with novices can be a valuable experience. When the group took on outfitting a bear with sensors from Scratch, they exhibited a higher than novice level of understanding switches. When the group made switch sensors, they discovered properties of conductive material.

5.4 Analyzing elements of Hook-ups System experiences across cases

This section sets out to bring to light ways in which all three cases provide insight into my first set of research questions. The section begins in 5.4.1, which discusses how the Hook-ups System demonstrated qualities that enabled youth to have engaging, expressive, and transformative experiences. The next subsection, 5.4.2, explains how I structured Hook-ups activities around groups in different ways to enable the System's tools to realize their potential in diverse settings. Subsections 5.4.3 through 5.4.6 detail the conditions to which I had to adapt Hook-ups activities across the cases to ensure that participants had experiences that engaged them in building personally meaningful projects, expressing themselves, and transforming their approaches to design across different settings. Each of these subsections begin with a table highlighting one dimension along which each case differed. They focus on the following workshop dimensions: participant demographics (5.4.3); number of participants (5.4.4); workshop duration (5.4.5); and contexts and materials (5.4.6).

5.4.1 Supports for engaging, expressive, and transformative experiences

As the cases in this chapter highlight, the Hook-ups System demonstrated qualities that enabled it to support young people in having engaging, expressive, and transformative experiences. A key quality that made engaging experiences possible was the System's ability to connect with participants' personally meaningful activities. The High Jump Hook-up represented an especially engaging project. Its creators built upon one of the Olympic events they were interested in – the high jump. The Hook-ups System enabled them to do so in a way that engaged them in one of their active interests while at the same time engaging many around them. They used the sound sensor to engage as many people as possible in cheering to help determine the outcome of their Hook-ups' virtual character's jumps. They then used the alligator clips to extend the Board with a switch on a high jump bar that was challenging to jump over. The physical challenge

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coupled with the crowd participation allowed the creators to not only engage themselves, but engage a wide audience as a popular project at a culminating expo event.

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 with him at the South End Technology Center. 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 size of the Board was conducive to embedding inside of the bear so that people were interacting with the bear instead of the Board. The bear provided an extra-expressive platform as it communicated the age group the project sought to target and also communicated that thugs influenced the bear's attire. The old materials that the group used to make new clothes for Thugaboo took on new meaning as they became a baggy t-shirt and bandana (to complement the bear's new bling).

A key quality that made transformative experiences possible was the System's ability to encourage and support iterative design processes. The Hot Potato Hook-up represented an especially transformative project. Its creators changed both the scripts that governed their game and the physical components of the Hot Potato 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.

5.4.2   Activities for groups

The projects presented in the cases were each group collaborations for a myriad of reasons. One such reason was that participants were able to try multiple approaches to making parts of a project. If one participant ran into trouble, he or she had groupmates nearby to try a different approach to the task. They could repeat that process until one of their approaches worked, or they could seek additional ideas from people outside of their group. Although inefficient in terms of project throughput, the type of innovation that came from multiple people spending time thinking about the same part of a project was worth the time investment. Sawyer highlights that successful design firms don't mind overlapping efforts (Sawyer, 2008). He argues that when creative people go off and work

on the same objective but come to the table with different approaches, the most innovative products are the result. Sawyer praises such redundancy and inefficiency in his seven characteristics of effective creative teams. Innovation is inefficient is included in the list: 1. innovation emerges over time; 2. successful collaborative teams practice deep listening; 3. team members build on their collaborators' ideas; 4. only afterwards does the meaning of each idea become clear; 5. surprising questions emerge; 6. innovation is inefficient; and 7. innovation emerges from the bottom up.

In the case of the High Jumpers, its creators started the workshop like the six other groups – with a charge to create an Olympic event. The chances were high that teams would overlap and create two versions of the same event. To no one's surprise, two groups created soccer-related Hook-ups. However, the overlap in effort from different groups was helpful when groups presented their progress at the end of each day (similar to how crosstalk worked in communities of learners classrooms). The soccer teams drew ideas from each other, yet still ended up with distinct interfaces. One called for players to make a soccer-playing Popsicle-stick figure kick a small foil ball past a paper goalie. The other required a player to actually kick a soccer ball of sorts toward a wall with a sensor-goal on it. Other groups hearing about those two approaches found ways to incorporate the other groups' desktop-scale or body-scale explorations into their own projects.

As was the case in the Olympic Event workshop, peer interactions helped steer the direction of the Hot Potato Hook-up. The drop-in nature of the Clubhouse led to Hot Potato creators working on different parts of the project at different times - similarly to how the Stuffed Bears case featured project group members working on different parts of the project at different times. When one participant got stuck, they knew that another person would think about the problem he or she was stuck on and take a shot at solving it.

As a facilitator, getting groups to jell to a point that they could complete a project required different thinking. The next four subsections explore the thinking behind how I organized activities to support the diverse cases.

5.4.3 Workshops for diverse demographics

As Table 13 suggests, the backgrounds of the participants for each case were different. For example, the workshop of the Olympic Events case fielded youth from around the world, the workshop of the Hot Potato case brought together teens from the Clubhouse's immediate surroundings, and the workshops of the Stuffed Bear case attracted youth from a diverse set of neighborhoods around Boston.

Table 13 workshop participant demographics

Olympic Events case	Hot Potato case	Stuffed Bears case
15-19 year-old leaders within their Computer Cubhouses came to the workshop from around the world.	14-17 year-old teens with an interest in robotics came in from the Charlestown neighborhood surrounding the Clubhouse.	L2TT2L hired 14-19 year-olds from a multitude of Boston neighborhoods as summer employees to work on projects focused on community problems.

In introducing the Hook-ups System in workshops that differed along the demographic dimension, I found that activities which grouped people from different cultures contributed to diverse thought in projects. For example, I asked the participants of the Olympic Events case's workshop to work in groups to make their own events but did not suggest that they each create a unique event. The two soccer-related projects exhibited different thought processes about which elements of the event were important to highlight. One group felt that the interactive event should put one human player against another while the other group designed their event to have a human challenge a computer-based character. In facilitating group-based activities in the Hot Potato case context, the entire group of about six participants was usually amenable to following project ideas put forth by their peers. Because the participants had long-term exposure to one another, they eagerly tried ideas for projects that they might not have thought of because they were willing to try new activities with friends. Instead of splitting into smaller groups, the Charlestown crew pursued project ideas with peers as a larger group and then would try out a different participant's take on the topic.

5.4.4 Workshops for different numbers of participants

The number of participants that the workshops of each case varied – ranging from six to 28.

Table 14 number of workshop participants

Olympic Events case	Hot Potato case	Stuffed Bears case
12 teens, 2 adult facilitators, (6 adult mentor / facilitators)	6 teens, 2 adult facilitators	28 teens, 3 adult staff facilitators, (5 adult mentor / facilitators)

In introducing the Hook-ups System in workshops that differed in number of participants, I found that facilitating group-based work with fewer participants allowed me to help each group learn what they needed to minimize the amount of time they spent stuck on a problem. In the Olympic Events case, I could help Vic and Rose explore one of the possibilities of working with Hook-ups while still being able to check on the progress of other groups – keeping them all moving toward their goals. In facilitating a number of participants that far exceeded the number of core facilitators working with me, I implemented the L2TT2L program's plan to help participants feel empowered to help each other. The core facilitation team of L2TT2L understood the need to capitalize on the leadership within the cohort of participants and develop future facilitators. When Shawn teamed up with five others on the Stuffed Bears project, his team knew that they could always ask me for help with anything if I was available. If I wasn't, they also knew that groupmates could contribute to getting them past problems.

Negotiating how to facilitate when participant numbers would be small or large was difficult. A factor that warranted consideration was whether the workshop was drop-in or opt-in. In an opt-in situation, participants committed a fixed amount of time to working with Hook-ups and potentially participating in a culminating event. In the Olympic Events case, participants opted in to work for three full days on Hook-ups and show their work at an expo. In the Stuffed Bears case, the participants would all learn about Hook-ups for the first three months, but opt-in to working Hook-ups into group projects during the remaining six weeks of the summer program. Groups could elect to drop Hook-ups components of their projects, but the likelihood of that decreased as they invested weeks into a particular design.

The Hot Potato case was drop-in. That called for me to anticipate what workshop needs would be for the core participants who were somewhat reliable regulars. I could never be fully sure if they would show up or if extra participants would take interest during a

particular visit. Preparing materials accordingly for the Hot Potato case took more estimation in the preparation than the others.

5.4.5 Workshops offered for different time periods

The time participants spent working on projects in each workshop context varied from multi-hour building sessions over back-to-back days to three hour sessions separated by a week of other activities to intermittent building over the course of months.

Table 15 workshop duration

Olympic Events case	Hot Potato case	Stuffed Bears case
In three back-to-back full-day immersive workshop days, participants were expected to work on Hook-ups exclusively during a set aside time block from 10AM-3PM. Participants did not know each other prior to the workshop.	Three hour-long sessions happened over the course of three weeks. Participants got involved as much or as little as they desired in a drop-in fashion.	Participants took workshops over a three month period (as part of a multi-year L2TT2L program). The Hook-ups creators learned about Hook-ups in two one-and-a-half hour workshops. They then spent six weeks incorporating Hook-ups into group community-based projects and teaching.

In introducing the Hook-ups System in workshops that differed in duration, I felt more comfortable keeping a topic going over multiple sessions if the participants had roughly 15 hours of building time for their Hook-ups. I believe that the time between sessions was one factor that led to Vic & Rose logging nearly twice as many hours on creating their Hook-up than the Hot Potato creators. The High Jump team returned to the workshop each morning to continue their project with momentum. As a facilitator, I enjoyed having the ability to leave projects-in-progress in a room overnight right where it needed to be in the morning for the participants to continue working where they left off.

The Hot Potato Hook-up creators could have elected to spend more weeks extending that project – potentially to include music and/or more complex interactions. However, the conditions required to revive interest in continuing a project the previous week were difficult to achieve repeatedly. During the course of a week between sessions in a drop-in situation, a lot of time exists to get involved in activities that would conflict with the next scheduled Hook-ups session. One participant was apologetic for scheduling a

kickball game during the time he really wanted to continue working on the Hot Potato Hook-up with his peers.

After a workshop had been packed away, it took set up time to restart where a group left off. These conditions contributed to Hot Potato creators to request starting on a fresh idea after eight hours of working on Hot Potato-based Hook-ups.

The work-schedule for L2TT2L participants like Shawn included roughly 40 hours of group project time (over six weeks). Groups like the Stuffed Bears crew spent some time after-hours to work on projects that they enjoyed developing. The problem that the group was addressing with the project was a factor contributing to after-hours work. Another was a desire to meet as a whole group – given that a day of L2TT2L would regularly have part of the group off-site working with pre-teens. Regardless of the motivator, the longer the time groups had to make mock-ups and prototypes, the more creative the facilitation crew had to be to store artifacts when the South End Technology Center needed its space to run a different program.

In choosing to host workshops that differed in duration and downtime, I became aware of the tradeoffs associated with the various configurations of time in and between sessions. When time between sessions was likely to be a week, I had more time to prepare and react to what happened in a session, but also had to creatively store accumulation and restore a workspace's state when participants returned.

5.4.6 Workshops with different space arrangements and access to materials
The materials participants used and the spaces in which they used them differed from workshop to workshop.

Table 16 workshop contexts and materials

Olympic Events case	Hot Potato case	Stuffed Bears case
A dedicated (reconfigurable) conference room featured facilitator-provided craft materials selected to support a theme.	A shared room pre-configured for collaborative work featured proximity to materials from participants' homes, a nearby art room, recreation room, and music room.	A shared room that featured proximity to materials from participants' homes, access to electronics testing benches, and places to store long-term projects.

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In introducing the Hook-ups System in workshops that had different space, equipment, and materials available, I found ways in which each configuration could support Hook-ups activities in unique ways. I was most surprised by the blandness of a conference room becoming an asset instead of a setback. When presented with white walls, conference tables, chairs and little else, the challenge was clear: the workshop participants needed to know that they would be responsible for bringing liveliness to the room through their projects. I informed the participants that I would support them in using any part of the room as long as it could be returned to its original state at the conclusion of the workshop. Before I knew it, there were soccer balls hanging from ropes over the light fixtures and there were parts of a coat rack strewn about. (Facilitators and participants were able to return the room to its normal shape.)

Participants created the Hot Potato Hook-up as a part of the seventh Hook-ups design experiment cycle. By the time I reached that design experiment iteration, I had confidence in my abilities to try out an activity I would not have in early Hook-ups cycles: have a Nintendo Wii in the room with me (and expect participants to focus on Hook-ups work). During the years between Hook-ups-cycle1 in the Charlestown Clubhouse site and Hook-ups-cycle7, the Boys and Girls Club purchased a Wii. The Clubhouse could request the Wii for activities if the coordinator so chose. I crafted activities in the Hot Potato case to begin with playing a Wii game. Doing so served as a successful starting point – I surprisingly did not let the Wii's presence turn into a distraction.

I facilitated activities for the Stuffed Bears case understanding that L2TT2L had priority use of much of the South End Technology Center's (SETC) resources for the majority of the day. The Center continued to offer its services during after-school hours during the summer so that other programming would not conflict. Having semi-exclusive access to SETC's resources enabled me to negotiate time for working with participants in resources like the Fab Lab. Coordinating within the group of L2TT2L was less of a burden than negotiating access with other community groups who made use of the Lab in the picture. With such access, projects like Thugaboo gave L2TT2Lers opportunities to fabricate parts of their Hook-ups to enable new kinds of designs.

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6 The Constellation of Connected Creators Framework

In the process of facilitating Hook-ups workshops for the Learn 2 Teach, Teach 2 Learn (L2TT2L) program at the South End Technology Center (SETC), I had a chance to work with a multitude of talented creators and facilitators. I shifted my roles in working with participants from helping them create projects to coaching them as they began to run workshops themselves. In the time I worked with them, they were becoming a part of a Constellation of Connected Creators.

The Constellation of Connected Creators is a framework geared toward helping facilitators introduce technological tools and activities to communities of learners. It helps facilitators engage diverse newcomers, cultivate future facilitators, and support their successors in taking young creators through that process. The framework describes five roles that the initial facilitator plays to groom future facilitators to adopt those roles over time: creator, co-learner, collaborator, coach, and colleague. I represent these five roles developing in an individual as different points of a star (as shown in Figure 16). I named the framework based on how each individual in a learning environment develops as a star and adds his or her own presence to a Constellation of Connected Creators, and, in turn, invites others.

In this chapter, I illustrate the ways in which facilitators and participants typically play the roles in the framework. Where appropriate, I give examples of how I played roles as a facilitator and how Shawn (the participant featured in the Stuffed Bears case study of section 5.3) played roles as a participant. In chapter 7, I offer an extended case study that illustrates how Shawn and one other participant experienced the three stages of the Constellation of Connected Creators.

The first section (6.1) of this chapter gives an overview of the roles and stages of the framework. The next three sections (6.2 - 6.4) are organized to each cover one of the framework's three stages: Engaging Newcomers, Cultivating Facilitators, and Supporting Successors. They include details of how facilitators and participants play roles differently in each particular stage. The fifth section (6.5) details the specifics of each role and why each one is important to the framework. The sixth section (6.6) shows ways in which the Constellation framework dovetails with communities of learners ideas.

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6.1 Roles and stages of the Constellation of Connected Creators overview

In each stage, facilitators and participants play the following roles:

-A creator makes projects and prototypes that are new to him or her.

-A co-learner explores ideas with peers and reflects on what he or she learns before sharing knowledge – establishing new skills.

-A collaborator works with peers to complete tasks on short-term projects – sharing pre-existing skills.

-A coach mentors others on lengthy endeavors – providing advice based on experience.

-A colleague gives and receives advice from long-term peers using a vocabulary understood by people who share a hobby or career trajectory.
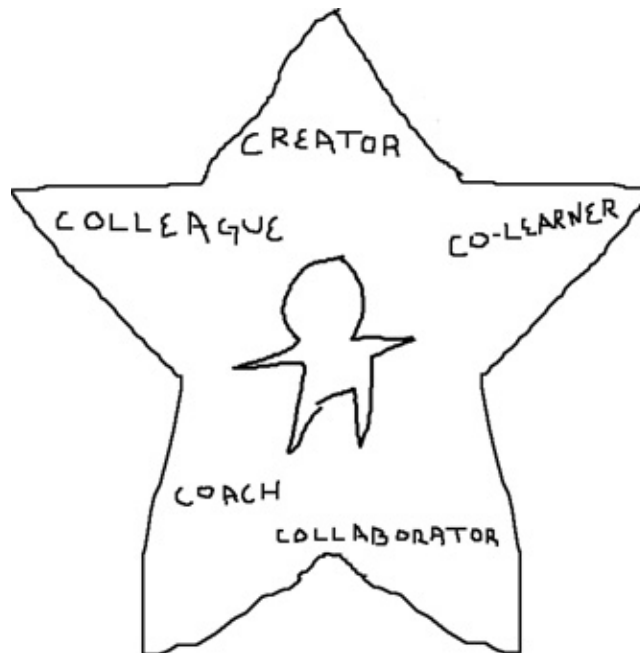
Figure 16 a star representing roles one participant can play in a Constellation

Figure 16 illustrates how participants in this framework are individuals capable of playing the roles (to varying degrees) at each point of the star. Participants' activities, roles and relationships to peers shift over time through each stage of the Constellation of Connected Creators framework. Figure 17 illustrates the stages through which an initial facilitator traverses in a Constellation of Connected Creators learning environment: Engaging Newcomers, Cultivating Facilitators, and Supporting Successors.
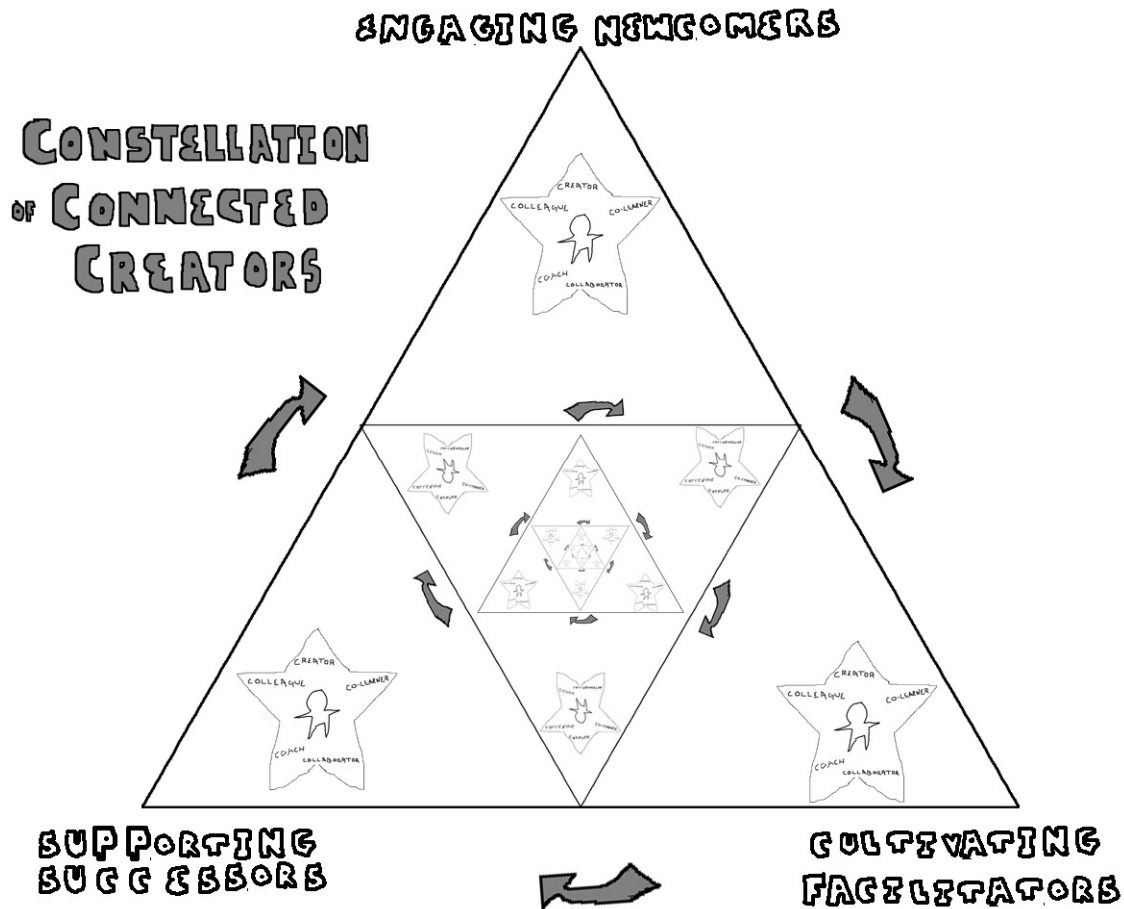
Figure 17 the Constellation of Connected Creators framework stages at-a-glance

While in each stage of the Constellation, the initial facilitator plays each role to the degree he or she deems necessary to engage the early participants. In the Engaging Newcomers stage, initial facilitators engage participants in activities of choice. When the initial facilitator notices that participants have taken to engaging in activities to the point where some show signs of an ability to engage their peers in activities, the initial facilitator can begin to shift to the second stage – Cultivating (future) Facilitators. In this stage, the initial facilitator plays the five roles described above in ways that focus special efforts to communicate, model, and allow participants to try strategies that help keep participants engaged in an active learning environment. When the initial facilitator gets the sense that future facilitators are demonstrating they are responsible and willing to run the learning environment with autonomy, the third stage begins. In the Supporting Successor stage, the initial facilitator begins transitioning out of the facilitation focus – yielding increasing facilitation responsibilities to participants. The successors can then steer the environment where they believe it should go, with support from their predecessors.

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Initial facilitators can support their successors and coach in a style that suits him or her. As new facilitators lead activities, it becomes their responsibility to engage newcomers – thus starting a new cycle of the three stages that will add to a learning environment's Constellation of Connected Creators. The initial facilitator can remain active as a colleague to the participants while continuing to coach and/or collaborate with them. As new facilitators assume the roles in every stage of the Constellation of Connected Creators, they infuse their unique identities into each. The model works best when the participants' backgrounds influence how they carry out each role.

Learn 2 Teach, Teach 2 Learn and the Constellation of Connected Creators co-developing
As a staff member of the South End Technology Center and a co-coordinator of its L2TT2L program, I have drawn much from the program's model as I developed the Constellation of Connected Creators framework. As my thinking with the framework evolved, it informed my suggestions for improving the structure of L2TT2L. As a result, both structures have co-evolved and dovetailed.

Each year, I meet up with Mel King, Susan Klimczak, Ed Baafi and L2TT2L returning youth teachers to discuss various aspects of the program. Several returning youth teachers decide to work with me on Saturdays to be the primary facilitators for the sessions that cover computer programming (with Scratch and Scratch Sensor Boards). In working with the new facilitators, like Shawn, I thought about the roles they would be taking on and the ways that I could help them prepare. I formulated and refined strategies for helping them shift in their roles. These strategies helped became part of the Constellation of Connected Creators. The thinking involved with formulating the framework influenced the ways in which I suggested structural changes to the L2TT2L program each year. Shawn and his fellow facilitators are likely to share strategies I shared with those they found useful (and add their own).

Although the experiences I highlight in this dissertation focus on the Hook-ups System, the framework L2TT2L staff can apply it using the toolkits of the other L2TT2L concentration areas. The framework is well-suited to support facilitators introducing toolkits of their choosing (such as any of the kits discussed in section 4.5). My strategies

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draw heavily from L2TT2L experiences, but not exclusively. I incorporated lessons learned from activities in Computer Clubhouses as well.

An example: roles I played facilitating activities that led to the Stuffed Bear Hook-up
Shawn was one of the Thugaboo Bear creators (discussed in section 5.3). When he went through his first spring and summer session in L2TT2L in 2007, I spent the bulk of those 16 weeks playing the role of creator. As a facilitator, I was in the Engaging Newcomers stage. I equipped the SETC with Hook-ups tools, introduced example projects, and refined workshop strategies around topics he and his peers found engaging. During that time, Shawn also played the role of creator, yet in a different way. He began exploring ways to create a new toy from parts of an old one. I was creating tools, activities and examples to make it possible for Shawn to create projects.

I also played the co-learner role with Shawn as I helped learn how the existing electronics in Talkin' Bubba Bear worked. We were also both playing the collaborator role – but to different groups of people. I frequently collaborated with other L2TT2L staff to ensure that the types of collaboration Shawn did in his project group would go smoothly.

When Shawn returned for a second year of L2TT2L, I played primarily a coaching role while working with him. My shift in roles corresponded with a stage transition – I was beginning the Cultivating Facilitators stage. As a Returning Youth Teacher in L2TT2L, he was learning how to be a coach as well – as he was charged with facilitating sessions for first-year youth teachers to learn about Scratch and Sensor Boards. We spoke about the examples he'd show and how to engage newcomers. I showed him video clips I had found useful for conveying some of the fun of making Hook-ups.

By the end of Shawn's second year, he and I became colleagues, he had worked with Hook-ups long enough and coached others long enough to talk with me using a vocabulary shared by people who have programmed computers, worked with sensors, and taught. With Shawn in a position to coach others without needing/requesting as much coaching from me, I could play other roles in different ways in the Supporting Successors stage. For example, I played creator in a new way when participants like Shawn were creating the content for sessions with newcomers. I could create

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documentation of certain projects that I wanted Hook-ups creators and coaches to see for ideas. Shawn played the role of collaborator more when I was in the Supporting Successors stage. He had learned a lot with his peers and could solve problems related to projects or teaching with them.

The interactions I describe with Shawn were not limited to those roles. I selected a few of our interactions to illustrate how a facilitator and participant evolve in their roles over time. Chapter 7 presents a more thorough treatment of how Shawn and another participant went through the Constellation of Connected Creators stages.

6.2   The Constellation of Connected Creators: Engaging Newcomers

The activities associated with playing a particular role vary for participants and facilitators in each stage. In the previous section, I gave examples of what I did as a facilitator and what Shawn did as a participant. Here, I offer an idea of what facilitators and participants do in general in the Engaging Newcomers stage. For contrast, I describe how facilitators and participants typically play each role. The order in which I present them does not imply which roles are played more frequently in a given stage. I end each section with a graphic depicting which roles facilitators and participants typically play in a given stage. These side-by-side graphics aim to provide an at-a-glance view of the ways in which roles shift in different ways for facilitators and participants across the three stages.

Creator

In the role of creator in the Engaging Newcomers Stage, facilitators design and/or refine tools and activities and use them to create projects while getting a feel for the degree to which participants express interest in project topics. Participants create initial projects using the technological tools such as the Hook-ups System. These projects might be original, minor revisions to sample projects, or remixes of peer work.

Co-learner

In the role of co-learner in the Engaging Newcomers Stage, facilitators get an idea of what the participants enjoy doing and how technology-supported design might play a role in their life and learning. Participants learn which types of projects the technologies can support and explore the tools' affordances with peers.

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<u>Collaborator</u>

In the role of collaborator in the Engaging Newcomers Stage, facilitators work regularly with research site staff to create a space conducive to the activities they have in mind. Participants work with peers while engaging in the design-based activities.

<u>Coach</u>

In the role of coach in the Engaging Newcomers Stage, facilitators introduce audience-appropriate initial projects and activities. Participants make projects based on their interests.

<u>Colleague</u>

In the role of colleague in the Engaging Newcomers Stage, facilitators establish a common vocabulary with staff and participants in order to speak as peers. Participants begin absorbing the language around designing using a given set of tools.

Figure 18 shows which roles facilitators typically play the most and least in this stage. The triangle indicator points to the most dominant role – which also is underlined five times. The role with the least amount of underlines is typically the least dominant role in the particular stage.
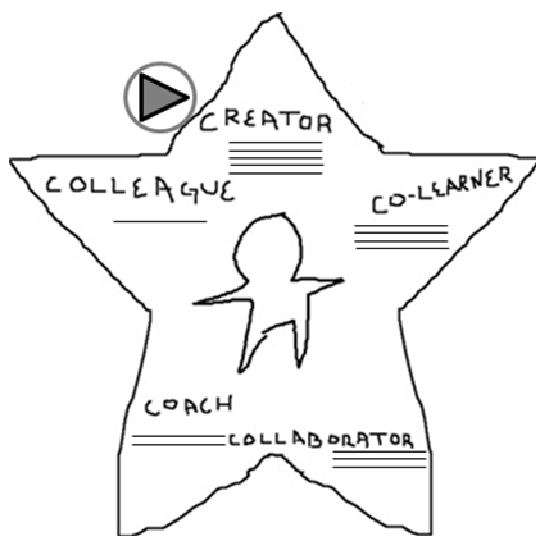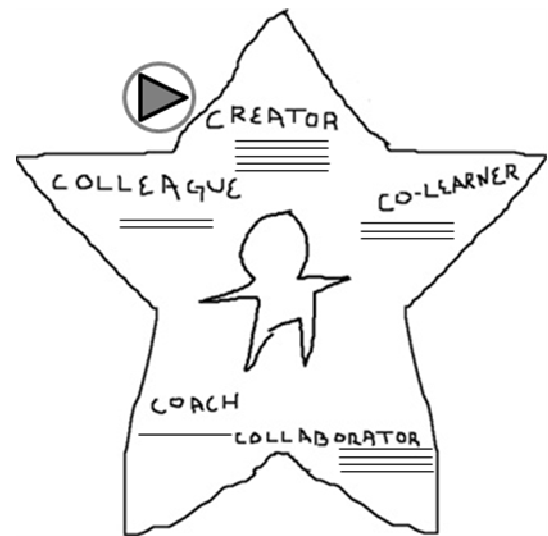
Figure 18 most and least dominant roles in the Engaging Newcomers stage

6.3 The Constellation of Connected Creators: Cultivating Facilitators

This section lists the types of tasks facilitators and participants typically carry out in the Cultivating Facilitators stage. The order in which I present the roles below does not imply which roles are played more frequently in this stage. Figure 19 ends this section with a graphic that depicts which roles facilitators and participants typically spend more or less time playing in this stage.

Creator

In the role of creator in the Cultivating Facilitators stage, facilitators make necessary modifications to activities, strategies and materials that accompany the technological tools. Participants create projects that are not based on a facilitator's example.

Co-learner

In the role of co-learner in the Cultivating Facilitators stage, facilitators learn from how participants made their way through activities in early stages and what participants say while working. Participants work with a peer to learn how to take on projects they perceive to be challenging.

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<u>Collaborator</u>

In the role of collaborator in the Cultivating Facilitators stage, facilitators collaborate with participants on multi-session projects while making sure to help establish an appropriate culture for collaboration. Participants work with peers as they design multiple projects together.

<u>Coach</u>

In the role of coach in the Cultivating Facilitators stage, facilitators provide guidance not only on how to solve a problem participants are experiencing, but also on how the participants can solve similar related problems that might arise (and to the degree possible, help them empower themselves to help peers model how to approach similar problems). Participants take the lead on bringing peers up to speed on working on projects that do not replicate example projects (but rather reflect original ideas).

<u>Colleague</u>

In the role of colleague in the Cultivating Facilitators stage, facilitators explain activities in terms based on common experiences with participants. Participants critique the work of peers and offer ideas for starting or refining projects.

Figure 19 shows which roles facilitators typically play the most and least in this stage. The triangle indicator points to the most dominant role – which also is underlined five times. The role with the least amount of underlines is typically the least dominant role in the particular stage.

Facilitators

Participants

=> indicates the typical dominant role of the stage

Figure 19 most and least dominant roles in the Cultivating Facilitators stage

6.4 The Constellation of Connected Creators: Supporting Successors

This section lists the types of tasks facilitators and participants typically carry out in the Supporting Successors stage. The order in which I present the roles below does not imply which roles are played more frequently in this stage. Figure 20 ends this section with a graphic that depicts which roles facilitators and participants typically spend more or less time playing in this stage.

Creator

In the role of creator in the Supporting Successors stage, facilitators refine the technological tools and activities. They create projects intended to take the learning environment in less-explored directions. Participants create projects that can be models for others to follow and create activities for others.

Co-learner

In the role of co-learner in the Supporting Successors stage, facilitators encourage continued co-learning by bringing to the forefront examples of participants connecting

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and learning from one another. Participants learn how to engage peers in gaining understandings that are needed to complete projects.

Collaborator

In the role of collaborator in the Supporting Successors stage, facilitators enable collaboration between participants based on shared interests and work styles. Participants work with people who complement the participant's preferred style and those who challenge it.

Coach

In the role of coach in the Supporting Successors stage, facilitators reflect on what they learned as a coach, creator, co-learner, collaborator, and colleague. Participants develop the capacity to cultivate a technology-rich learning culture – becoming the initial facilitators of Engaging Newcomers stages for participants who join the community after them.

Colleague

In the role of colleague in the Supporting Successors stage, facilitators make themselves accessible via remote communication more than in-person discussion and continue connecting participants to resources. Participants share designs with a community beyond their peers. They capture their thoughts in webpages in ways that others can benefit from their knowledge.

Figure 20 shows which roles facilitators typically play the most and least in this stage. The triangle indicator points to the most dominant role – which also is underlined five times. The role with the least amount of underlines is typically the least dominant role in the particular stage.

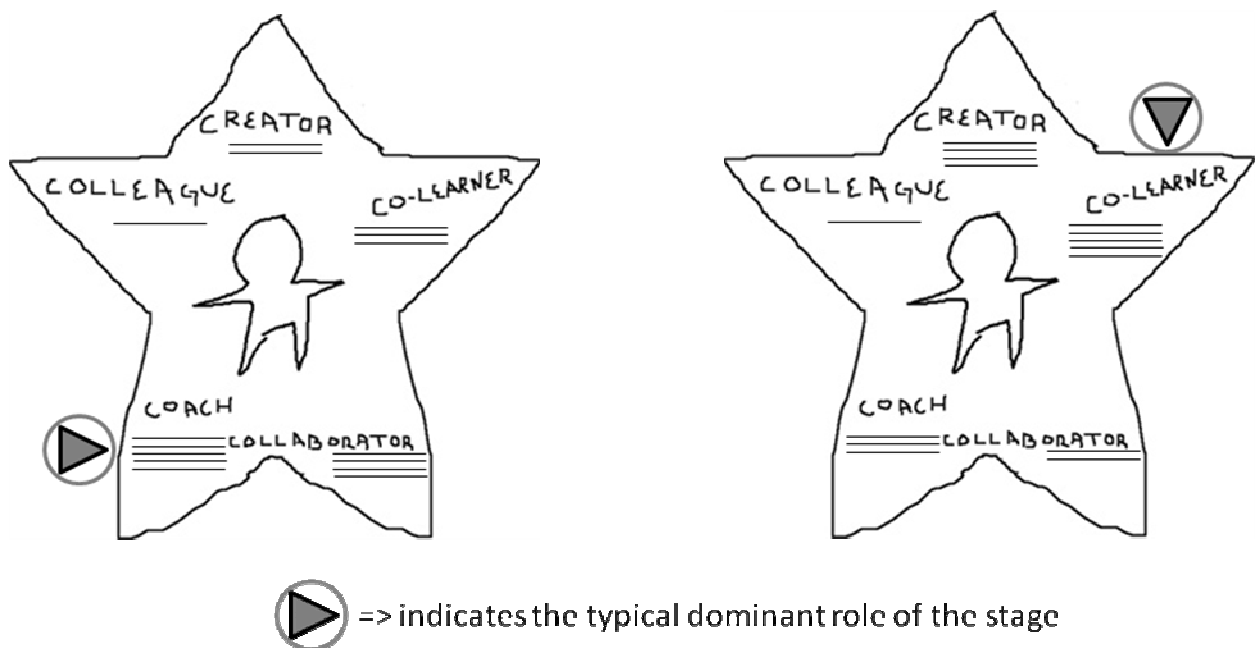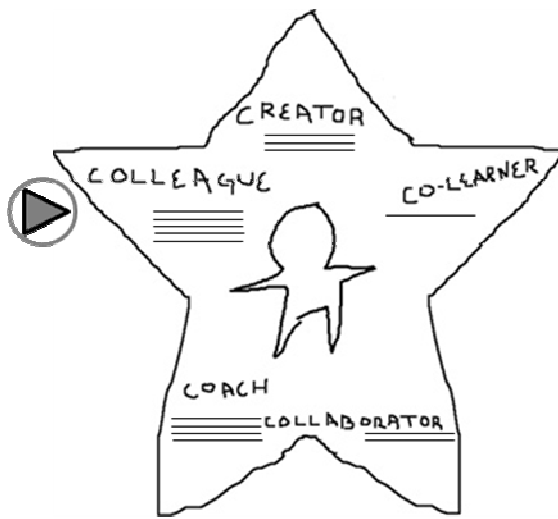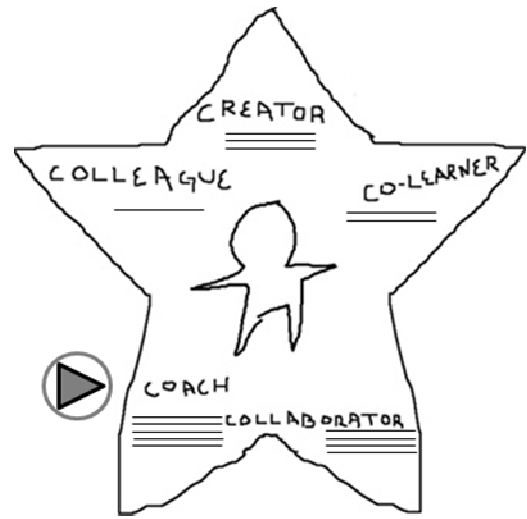**Figure 20 most and least dominant roles in the Supporting Successors stage**

6.5 Detailed Roles in the Constellation of Connected Creators framework

The brief descriptions of the framework's roles in 6.1 are useful for quickly conveying their differences. Sections 6.2, 6.3, and 6.4 gave examples of activities that facilitators and participants are likely to play in each stage. This section offers detailed descriptions of each role. The descriptions capture the nature of each role's importance to sustaining a constellation.

In the **creator** role, a person:

- strives to be innovative and inventive;

- allocates time to making things he or she has not made before and/or something that no one has made before; and

- identifies with being able to take the lead on producing a personally meaningful artifact either alone or with others.

It is important for facilitators to create because that provides a model for participants to see before adopting creative practices.

In the **co-learner** role, a person:

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- actively thinks (and reflects) about what he or she is learning from peers during and/or after exploring ideas;
- during a short period of time, shares approaches with interested peers; and
- partners with a peer to build joint understandings that may be applied to common or differing tasks.

It is important for facilitators to learn how to best support participants based on their interests and abilities. It is important for participants to be co-learners with one another so that they can gain the skills they need to collaborate on projects that are more involved than ones that they would complete by themselves.

In the **coaborator** role, a person:
- sets common goals with peers and offers or develops skills necessary to work toward achieving them;
- allocates specific time to working intensely with peers to reach one or more goals; and
- helps peers do more as a result of partnering on a task with an understanding that doing so results in shared ownership of artifacts developed and compromises autonomy on projects in the interest of reaching richer results.

The collaborator role is key to the framework because facilitators must collaborate with the research site/community technology center's staff in order to establish the workshop schedule and respond to the needs of the desired demographic. It is especially important for participants to gain comfort in collaborative roles, especially for programs that increase in scale over time (to the point where participants vastly outnumber facilitators).

In the **coach** role, a person:
- has developed strategies that he or she is willing to share with less experienced individuals and provides bridges to resources that are appropriate for those individuals' development;
- accumulates the trust necessary to mentor others on lengthy endeavors; and
- sees abilities within peers that they do not see in themselves and is willing to help them develop those abilities in a variety of ways – not necessarily needing mastery of the skills being developed.

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Coaching is a critical role in the framework as it is an activity (carried out by both facilitators and participants) that contributes to the Constellation sustaining itself.

In the **colleague** role, a person:

- uses a vocabulary shared with peers to exchange information about distinct areas of expertise, respond to calls for advice, counsel, and lend expert opinions related to a common area of interest/specialization;

- stays in contact with peers who share a similar long-term career or hobby trajectory; and

- shares a specialization, set of experiences, or area of expertise with a group of people who have access to common resources.

The role of colleague is an essential element of the framework because more newcomers have a chance to make a collegial connection with someone if the network of colleagues grows larger and more diverse over time. The chances that someone will be in the extended network with whom newcomers can identify increases as more generations join the ranks of colleagues. My work involves gathering a community around a joint activity/endeavor and sets of processes in ways that mirror the model of how alumni play important roles in the lives of students currently being served by their alma mater.

Role dependencies

Some of the roles in the framework benefit from participants playing other roles first. For example, some participants may develop skills as they spend time early on as a co-learner that will make them a sought-after collaborator in their later stages. Similarly, a person who has been visibly coaching peers and protégés for an extended period of time is likely to become someone that others consider to be a colleague that they can come to about coaching strategies. Because each person brings an existing set of capabilities and comforts to workshops, they may gravitate to roles they've played extensively elsewhere. No matter where participants start, a well-run Constellation would put them in a position to play other roles regularly as well. The full potential of the framework is most likely to be realized when an environment evolves with multiple participants playing different combinations of roles over time.

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6.6 The Constellation framework and communities of learners

This section discusses how the Constellation of Connected Creators framework and Communities of Learners work have approaches that share common elements. Specifically, both frameworks believe that facilitators' and participants' roles should rotate regularly. I draw upon ideas from the intersection of the communities of learners framework (Rogoff, 1994) and design experiment methodology (Brown, 1992). At this intersection, the work of the Fostering Communities of Learners (FCL) in classrooms (Brown, 1997) produced vibrant learning communities (with science, technology, engineering, and math [STEM] subject matter connecting with students) using approaches that dovetail with my own.

In order for the Constellation of Connected Creators to stay vibrant, facilitators must help participants become facilitators. Over time, in a Hook-ups culture, the roles that teen facilitators play give them many of the responsibilities that the adult facilitators/staff have. The Constellation of Connected Creators delineates when and where facilitators of evolving learning environments shift strategies in the interest of sustaining a creative environment.

In my work, groups of Hook-ups creators formed according to the environment's practices. The ways that groups formed varied, but the roles that participants played within them were similar. Most participants rotated naturally through building, learning, and helping others. The Constellation of Connected Creators added strategies for facilitators to model additional roles that contributed to sustaining creative environments.

In FCL classrooms, structures were in place to allow students to change their roles and practice serving as experts and coaches. FCL teachers used methods such as research rotations, the jigsaw method, cross-talk, and benchmark lessons. In each of the following participation structures, FCL students changed their roles at different times to achieve different goals. In research rotations, as a part of the students' regular day, they would use computers to research subjects and teach each other about findings. In the jigsaw method, groups would teach other groups about distinct topics they were researching and would learn from what their peers were exploring on a given day. In cross-talk, research rotation subgroups would share approaches and present to the whole class to

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keep everyone abreast of different facets of a subject. With benchmark lessons, facilitators would introduce practices and techniques that would be useful to all students.

A team of adult staff and I helped prepare teen-aged Hook-ups creators to work with pre-teens. The teens took responsibility for making projects and teaching as they enjoyed an appropriate degree of autonomy. Research site staff fit into the modified FCL model where parents served in Rogoff's model. Part of the role that the research sites played for participants was providing caring staff that worked with parents who cared about their children's education but had not joined their schooling community or STEM development (sometimes feeling like they did not have an adequate background to do so – especially ones who were products of the schools that weren't meeting their children's STEM needs).

The role Rogoff described for the parents bears similarity to roles facilitators played in my research sites. Their activities were flexible. Teens who took on teaching roles had to fight a dilemma COL parents faced. Rogoff found that facilitators should avoid adult-run or child-run extremes, yet understand that their roles may not become symmetrical with participants'. Rogoff exercises care to communicate that Communities of Learners aren't simply a balance between two extreme educational approaches: adults exclusively running classes or children freely acquiring their own knowledge with little interference. Rather, she highlights instances when parents, teachers, and students all used their minds well to learn together. She stresses that students in FCL classrooms should have autonomy and responsibility, but an asymmetry in the roles should remain. This belief was based on the notion that teachers and parents were often more experienced in practices and, as such, should play more of a modeling role for students (who go on to use the adults models to teach peers).

Rogoff highlighted how parents/adults working with COL students initially had difficulty managing the learning environment that put them in a position to respond to a student's desired learning trajectory rather than setting the learning agenda – as teachers had done for them. Many of them experienced a different style of learning practice in their formative years. In my research sites, the school-style learning practice did not hinder new facilitators in significant ways as they took on more responsibilities in the learning environment. A mitigating factor in the teens avoiding such setbacks was that their

experiences with formal education were still forming (with them having accumulated less prior classroom experience than adults). Another factor was that the teen-aged participants carried out the Hook-ups work outside of a school building – in a community setting that is less likely to invoke thoughts of school practices.

Changing roles provides opportunities for students to see other students as people with competencies in areas that they might not have expected to take interest in. Rotating through roles and different aspects of subject matter allows young people to try out a variety of practices and topics. FCL work and my beliefs share an understanding that almost any subject matter can connect with learners' interests.

In Hook-ups work, young people explored concepts that are typically the subject of courses taught in advanced placement high school electives or on college campuses. (Typically, the participants from my research sites have not had as much access to such courses as their peers have in more affluent school districts.) Hook-ups activities have put these young people in contact with ideas of physics and computing – such as electrical conductivity and Boolean logic - in their own neighborhoods, on their own time, without depleting their savings or putting them in danger of feeling the effects of imposter syndrome (Ewing, Richardson, James-Myers, & Russell, 1996) after leaving their communities.

In the case of some communities, such as the ones served by my research sites, some subject matter and practices – especially those related to sciences and technology – have not yet reached the state where they are viewed by community members as an essential subject for youth development. Hook-ups work shows that STEM work can contribute to young people developing creatively, expressing themselves, and aiming to mitigate problems in their communities with what they learn. The Hook-ups System helped them do so by working in both physical and digital media – as such an approach has proven to be appealing to participants (as explained in chapters 5 and 7). It also gives them experience with practices that are a part of creative industries such as product design.

FCL notions were rooted in thoughts that teachers and/or experienced members of a practice could teach most subjects to students in a way that preserved the richness of

the practice. Brown put particular focus on life sciences subject matters because she felt that it appealed to students, had an engaging quality, and dealt with important ideas through which students could learn to reason. She also felt that too many students needed high-quality science learning in the inner-city Oakland schools in which she worked, but were not receiving it (Brown, Campione, Metz, & Ash, 1997).

Brown's and Rogoff's classroom communities of learners concentrated on challenges of K-8 grade levels. Adult parents serving as extra teachers to introduce content, concepts, and practices shaped Rogoff's work. In my work, adult facilitators ensured that teens became practitioners in areas such as designing tangible interfaces. These teens then became the facilitators for younger peers of the K-5 grade range learning the practices as well. Engaging teens and having them serve as the primary experts for peers younger than them was an exercise in positive community development. It established that young people (ones from marginalized communities included) could be seasoned practitioners in emerging fields such as computing.

7   Constellation of Connected Creators: Case Study & Analysis

Section 5.3 introduced one of Shawn's projects that he created with peers in three months of his first year of participation in L2TT2L. Shawn spent two years with L2TT2L over a three year span (with a year-off between his two terms as a youth teacher). This case study expands the scope through which we look at Shawn's Hook-ups history. It starts with Shawn's L2TT2L trajectory and goes into details of his interactions with another participant named Val. Shawn and Val's experiences provide two perspectives into how participants evolved in a Constellation of Connected Creators. Section 7.1 revisits and expands upon the stuffed Bears case. Section 7.2 analyzes how Shawn and Val played the roles within the Constellation. Section 7.3 offers generalized strategies for cultivating and sustaining a Constellation of Connected Creators.

7.1   Stuffed Bears revisited

In the spring of 2007, Shawn interviewed to be a part of L2TT2L. Staff selected him as one of the 19 new (first-year) youth teachers who would join the nine returning (1+ years of experience) youth teachers. Prior to building the Thugaboo and Proper Bear Hook-ups, he went through a series of Saturday workshops (as shown in Figure 21). The program utilized Saturday mornings during April, May, and June to introduce new participants to a set of technologies and concepts they would be learning (and later teaching to their younger peers). L2TT2L staff randomly assigned participants to four subgroups of roughly nine participants (comprised of both first-year and returning youth teachers). Staff and college mentors would host workshops to help the groups become confident creators with competence in the five core L2TT2L areas of concentration: physical design and fabrication; alternative energy; graphic design; computer programming; and physical programming (robotics). The multi-phase program supplied powerful, yet novice-friendly technological tools that enabled participants to build projects that put them in contact with L2TT2L's areas of concentration. To supplement the concentration areas, staff brought in area experts to expose participants to additional domains via electives such as e-textiles, the chemistry of personal products, storytelling, or digital music.
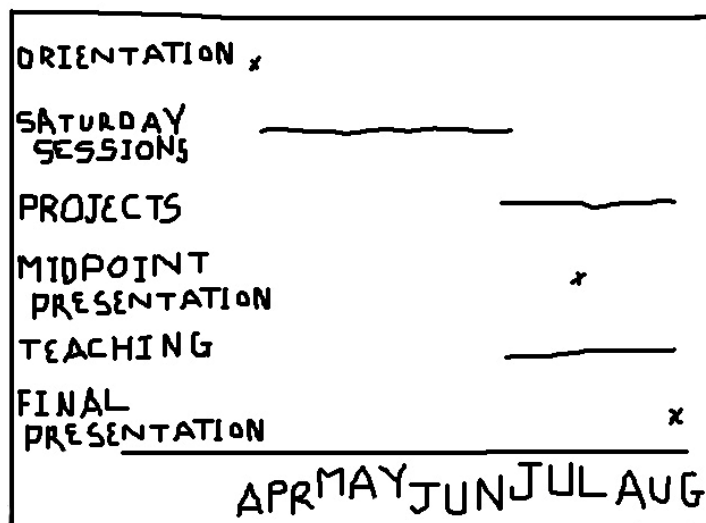
Figure 21 a collapsed calendar of L2TT2L events

L2TT2L staff, college mentors, and experienced returning youth teachers ran workshops on alternative energy, digital design and fabrication, and graphic design for the subgroups on Saturdays at the South End Technology Center (SETC). Every Saturday, I hosted two of the four subgroups at the MIT Media Lab to offer additional space to run the computer programming and physical programming workshops (with the help of interested college mentors).

In 2007, Saturday sessions ran from 10:00 AM until 2:00 PM. Each subgroup would start with either a computer programming or physical programming workshop in the morning. In the afternoon, after a 20 minute break, subgroups would switch to the workshop they did not take in the morning. The entire group would close the day in a discussion circle (called circle-ups), reflecting upon what participants found to be fun and what they learned or struggled with. Over the course of the eight Saturday sessions in the spring, each subgroup would work at MIT four times. The groups would spend the other four Saturdays at SETC. At MIT, staff, college mentors, and returning youth teachers introduced participants to the basics of Scratch for the first two sessions. The third and/or fourth MIT Saturday sessions typically introduced Scratch Sensor Boards.

In 2007, staff and college mentors were the primary organizers of activities for Shawn's cohort on Saturdays. Experienced returning youth teachers contributed to running the activities as well. These facilitators would offer a similar Saturday session to each

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subgroup – calling for them to run each lesson up to four times. Staff had opportunities to model ways of introducing an example project and a topic with one of the first subgroups. College mentors would lead activities for other subgroups. When a subgroup had a returning youth teacher who had previous experience using Scratch Sensor Boards, he or she was welcome to run the activity of the day or contribute in his or her unique way. (2007 was the first year that Saturday sessions offered Scratch Sensor Boards activities so returning youth teachers from 2006 didn't necessarily have experience with them.)

The 2007 facilitators offered the following four sessions related to Scratch: the basics, working with multiple characters/broadcasting, mini-games (such as virtual mini-golf), and physical carnival games with the Scratch Board. Shawn had learned Scratch at some of the Saturday sessions in April and May, but had an arranged absence on the day in June which called for participants to make carnival-inspired Hook-ups. I led that session - featuring example projects inspired by classic carnival games such as skeeball (rolling a ball up a ramp into holes worth different points) or ring toss (tossing a plastic ring onto the neck of a bottle to win). In Shawn's absence, his peers created their own carnival-inspired game Hook-ups such as tossing a beanbag at a bullseye or shooting a laser gun at a target.

Figure 22 carnival theme Hook-ups

In July, after the Saturday sessions concluded, participants started their mid-summer schedule of working at SETC from 9:00 AM to 3:00 PM Monday through Thursday. On the first day of the new schedule, staff prompted all L2TT2L participants to spend the next three weeks making projects that responded to what they perceived to be problems

in their communities (such as Shawn's Stuffed Bears that responded to gun violence). The four subgroups that had spent Saturday sessions with one another disbanded. Participants formed new project groups - three groups of six and one group of seven. (The number of participants joining project groups was smaller than the number of youth teachers hired because of the level of expected attrition.) Shawn joined a group with five peers. Participants identified issues they cared about in an early July brainstorming session. In a large circle, they announced a problem that they would like to address using technology. Participants grouped themselves according to the level of interest peers showed in working on a particular issue. (Staff would approve groups and issues.)

Shawn's group wished to reduce the amount of gun violence people from their neighborhoods experienced. They had roughly six weeks from July to mid-August to spend constructing a project that leveraged their knowledge of at least two of L2TT2L's areas of concentration. The L2TT2L groups no longer worked on Saturdays. The participants began working from 9:00 AM to 3:00 PM from Monday through Thursday. During the July to mid-August time frame, youth teachers would also rotate through teaching assignments at one of the ten community centers that signed on as L2TT2L partners that year. The project groups worked as a full team on days when none of the members ended up teaching away from SETC. It was during this period that Shawn helped create Thugaboo and Proper Bear as covered in section 5.3.

Working on the Thugaboo and Proper Bear project helped transform Shawn's perception of himself. He grew up thinking that his education future was in music: "I'm a drummer and I wanted to pursue my career at Berklee College of Music and if I didn't go to Berklee, I would probably end up finding myself tuning steel drums, I wanted to master the art of that." He began to realize that some of what he was learning in the technological domain could also incorporate aspects of music. After having a great summer of L2TT2L making Thugaboo and Proper Bear in 2007, he was unable to set aside the required time to participate in 2008, but continued to perform as a steel drummer. In 2009, he returned to L2TT2L and teamed up with a three other participants who also enjoyed Scratch and took the opportunity to build Sensor Board-based drum projects as example projects for others.

<u>Shawn meets Val</u>

Val was one of three returning youth teachers who teamed up with Shawn in 2009 to facilitate Saturday sessions about Scratch for first-year youth teachers – including ones that used the Scratch Sensor Board. During Shawn's year off in 2008, Val was a first-year youth teacher. She learned about the Scratch Sensor Board during a Saturday session run by two people who were participants when Scratch first became a core tool of L2TT2L in 2007: Brian and Karl. In 2008, Brian was a 2nd-year returning youth teacher. Karl was a 3rd-year participant who had transitioned from being a returning youth teacher for two years into serving as a college mentor. As facilitators in 2008, Brian and Karl created an interactive project that featured an on-screen Scratch Sensor Board image that prompted the first-years to try out the features of the Scratch Sensor Boards which they had attached to staff-provided laptops. For example, it greeted participants like Val with:

> *"Yes! Today we get to work with SCRATCHBOARDS so I want to see some enthusiasm people!" "First off I'm going to show you my light sensor ummm can you please cover my eye? Thanks." [The program waits for the light sensor value to read less than 10… Val paused for a few seconds while identifying the Scratch Sensor Board's light sensor] After three seconds, the on-screen Scratch Sensor Board graphic changes the text in its cartoon bubble to read "I SAID COVER MY EYE!!!" Once Val put her hand over the light sensor, the text changed to "That's more like it.....my apologies for the yelling." The program then playfully urged users to try other Scratch Sensor Board built-in sensors.*
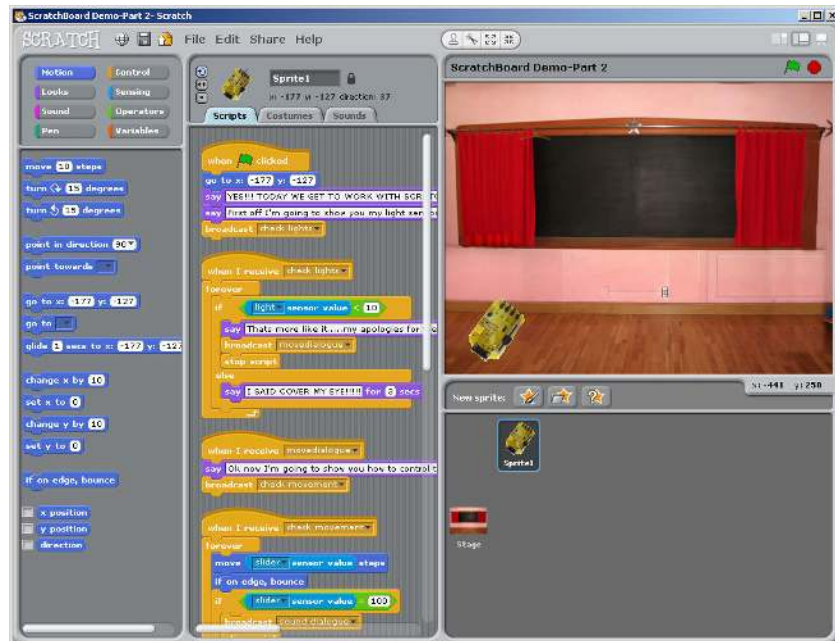
Figure 23 the L2TT2L Scratch Sensor Board intro project

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After Saturday sessions ended in 2008, Val ended up in a project group with which she had a hard time making contributions that she could be proud of. One member of her team steered the group toward using technologies that Val found confusing. The project was called "The Better Mouse Trap": her ambitious team decided to interface multiple technological platforms, such as Processing ("OpenProcessing.org," n.d.), to achieve the task of securing a home. (The name referred more to catching a cat burglar rather than a rodent.) They designed a cheap and robust system to take pictures of a potential human thief that would not be triggered by a mouse. Her group split up the work in such a way that left Val with the feeling that she wasn't excited about contributing to the project all of the time. Val expressed "I didn't really understand some of the technology we used so there was nothing to do but watch a lot of the times."

The Better Mouse Trap system combined several technological toolkits (that were not a part of Saturday sessions) to achieve its objective. For detecting an intruder, the group used an Arduino ("Arduino playground," n.d.). For panning the security webcam to take multiple photos, they used a GoGo Board ("GoGoBoard," n.d.). (GoGo Boards had been part of L2TT2L Saturday sessions in years prior to 2007.) Writing programs in Processing itself was not too tall of a hurdle for Val. Rather, integrating the technologies proved to be a time-consuming task with more nuances than Val was comfortable taking on. She struggled to understand what types of inter-program communication would enable the Better Mouse Trap to make multiple devices work in unison – she also was not very interested in that level of code tweaking.

The Better Mouse Trap team consumed much of Karl's time with troubleshooting that required him to get up to speed on making multiple toolkits share information with one another. He was happy to help, but his attention to one group made one less college mentor available to help the other six groups working on projects. The community project group members who set up the physical components of the Better Mouse Trap system often found themselves as onlookers and unfortunately, not learning much about the programs and the device integration that was central to their project.

In working with Processing in 2008, Val learned debugging techniques to help her make text-based programs work. She expressed "when we were working on our summer projects and we tried to write programs sometimes the lines we wrote would fail. We just

had to go through the lines again to make sure everything agreed and we learned to check every line that we wrote." She was more excited by programming when it didn't entail her constantly debugging errors in text-based code. Scratch served her well in terms of reducing typo-induced errors, which plagued her Processing experience. When Val first used Scratch in 2008, she found it appealing that it was not susceptible to typing errors the way that she found text-based languages to be. In 2009, she took the opportunity to show others a pathway to programming that she felt would present fewer stumbling blocks than introducing people to a text-based language. She teamed up with Shawn in their 2nd years of L2TT2L (2009) to show first-year participants how to create using Scratch in the Spring Saturday sessions.

Val and Shawn's drums

After showing introductory Scratch programs in the early 2009 spring Saturday session, the time came for Shawn, Val and their peers to introduce Hook-ups. The duo used a drum-based theme they thought of as an example. Val, Shawn, and the two participants they co-facilitated with spent two Saturday sessions in June showing first-year youth teachers how to cover an upside-down paper plate with foil so that it could be a large conductive surface – forming the foundation of their drum example. With the first alligator clip-head of a cable attached to the foil on the plate, Scratch programs could sense and respond to someone striking the plate with a foil-covered stick that would be connected to the second alligator clip-head on the cable. Val and Shawn started with straight-forward programs that would use the sound command blocks in Scratch to play a particular synthesized (MIDI-based) drum note through a computer's speakers each time the stick struck the drum.

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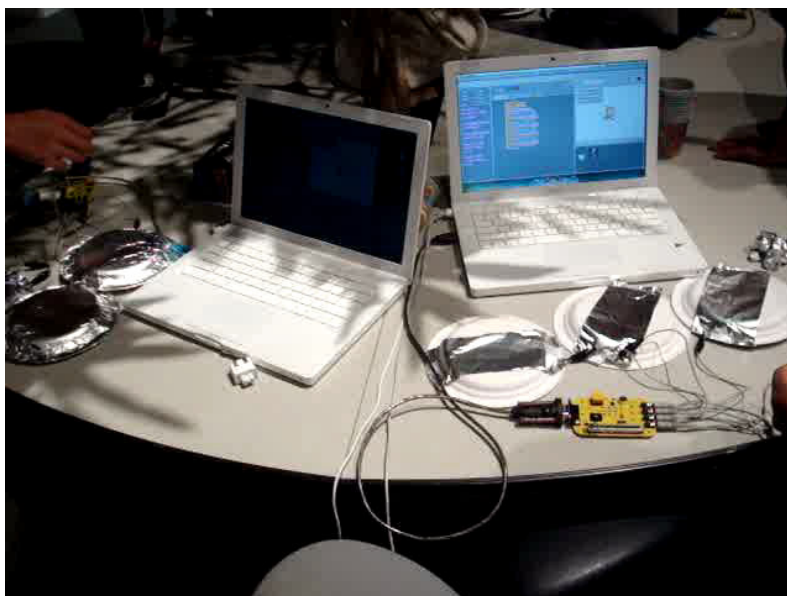
Figure 24 Drum Hook-ups

The first-year youth teachers were able to start their own projects after Val and Shawn demonstrated their example. Some projects were nearly carbon-copies of the example drum. Others weaved multiple parts together and also created stories. Two participants in particular put together what they called Rock Band 7. In their words, it was a video game "so cool that the series had to skip all those numbers." "Those numbers" referred to the fact that the popular Rock Band video game was only up to Rock Band 2 at the time. These participants did not change much of the example project. They used foil-covered paper plates as drums. They let their imaginations develop an elaborate story as they made striking the drum produce sounds of different instruments. Hearing gong-like sounds come from their plate-drums made them introduce a samurai character into the imaginary band scene the two participants were actively constructing together.

Even though first-year youth teachers had success expanding upon the drum-based demo project, many of them had trouble making the drum trigger digital sound recordings when struck by a stick. Part of extending the one-drum example to multiple drums involved connecting more of the extra drums to one Scratch Sensor Board. Mapping more than one alligator clip-head to a Scratch program was not trivial. Val made a valiant effort to explain the steps necessary to build a drum-based project that would avoid confusion about which clip-head should be connected to the stick. On the webpage that any L2TT2L participant could edit (a wiki), she eventually found that she

could quell a lot of confusion by supplementing an online activity guide with a video. In her video, she covered a concept with which she found her peers struggling to understand. She explained that one alligator clip cable featured two clip-heads that look the same, but behaved differently. One sent a low-current electrical signal while the other received it. Many extensions to the drum-inspired Hook-ups that Val and Shawn were introducing to first-year L2TT2L participants called for an understanding of which clip-head was sending and which was receiving. She demonstrated a way to test how each clip-head functioned and showed how to label each accordingly. The clip Val put online received over 500 hits, suggesting that people took interest in the concepts and approach she was talking about.
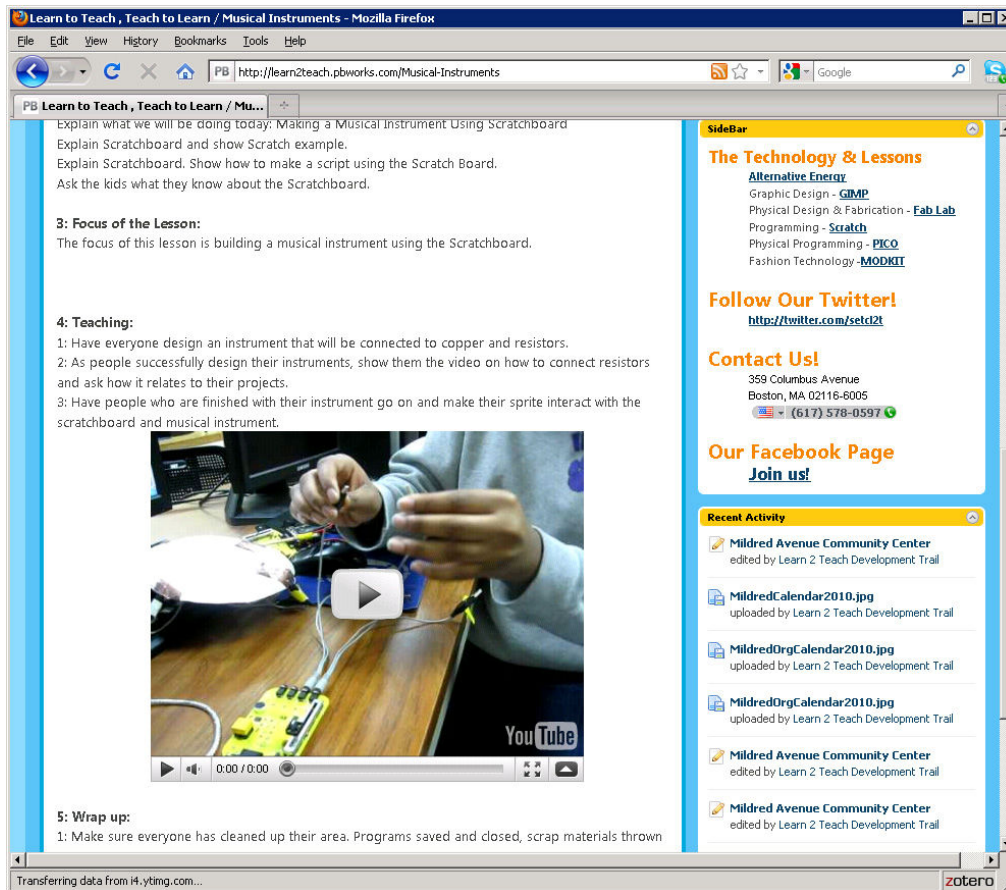
Figure 25 an L2TT2L wiki page featuring a Youtube video about building a drum

7.2   Shawn & Val's roles in the Constellation of Connected Creators stages

This section summarizes the ways that Val and Shawn played different roles over time as I facilitated L2TT2L activities that engaged them as newcomers, cultivated them as facilitators, and supported them as successors.

The first subsection summarizes the roles Val and Shawn played as I facilitated experiences for them in different ways during the years they participated in L2TT2L. The second subsection presents what Shawn and Val articulated about aspects of their experiences related to how they shifted through roles over time and how they evolved as learners and teachers.

7.2.1   A summary of ways Val and Shawn played roles differently over time

Table 17 highlights how Val and Shawn played roles as I introduced them to activities that engaged them as newcomers - from April to August of 2007 for Shawn and April to August of 2008 for Val (when they completed their respective first years of learning and doing group projects). Those are roughly the dates in which I facilitated activities for Shawn and Val using strategies associated with the Engaging Newcomers stage. (During that time period, I also facilitated for other participants with whom I'd had a longer relationship using strategies associated with the Cultivating Facilitators and Supporting Successors stages.)

Table 17 how Val & Shawn played roles as I engaged newcomers – 4-8/07 & 4-8/08

Creator	As a creator, Shawn repurposed an old toy – realizing part of the Thugaboo project. Val was also a creator – creating structures for the Better Mouse Trap camera.
Collaborator	As collaborators, Shawn and Val worked on common goals with their respective groups and shared ownership of artifacts with them.
Co-learner	As a co-learner, Shawn's peers helped him learn how to connect sensors to Scratch. Val and her project group learned how to make toolkits communicate with one another to achieve their project's goal.
Coach	As coaches, both Shawn and Val observed the ways facilitators introduced them to Hook-ups – internalizing the models for later use.
Colleague	As colleagues, Shawn and Val started to gain comfort with a vocabulary that helped them talk with peers about programming projects that had sensors and physical components.

Table 18 shows how Val and Shawn changed the way they played each role as I began cultivating them as facilitators from April to July of 2009 (when they were leading Saturday sessions).

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Table 18 how Val & Shawn played roles as I cultivated facilitators – 4/09 to 7/09

Creator	As creators, Shawn and Val came up with their own projects – drum Hook-ups – which didn't replicate projects their facilitators introduced to them.
Collaborator	As collaborators, Val and Shawn would help each other try different drum Hook-up configurations until they decided on one version to use as an example for a Saturday session. They shared ownership of artifacts and activities – encouraging others to improve the design.
Co-learner	As co-learners, Shawn and Val learned which approaches to introducing drum Hook-ups worked well, captured attention, and could be explained with minimal risk of confusing novices.
Coach	As coaches, Val and Shawn encouraged first-year youth teachers to explore their own types of projects and also helped the first-years make their project ideas functional.
Colleague	As colleagues, Shawn and Val shared the responsibilities of teaching and supporting learners when other returning youth teachers were working in other roles such as facilitators of wrap-up discussions.

Table 19 highlights how Val and Shawn played roles as I supported them as successors from August to December of 2009 (when they were each working on their second community group projects). Shawn was unable to participate past early August as he shifted attention to starting college. Val continued as a returning youth teacher during the L2TT2L (smaller) fall session – where she was able to engage newcomers.

Table 19 how Val & Shawn played roles as I supported successors – 8/09 to 12/09

Creator	As a creator, Val worked on a summer project that integrated several of the L2TT2L technological tools in ways that addressed a community problem and drew upon efforts from most members of the group.
Collaborator	As a collaborator, Val created conditions in which she felt comfortable in a project group so that the inclusive nature of the construction process was equally as impressive as the product.
Co-learner	As co-learners, Shawn and Val learned how to apply what they knew about electrical current flow to resolve challenges their peers encountered as they built upon Shawn and Val's example projects.
Coach	As a coach, Val provided bridges to resources that were appropriate for less-experienced peers, mentored others on projects that happened over multiple meetings, and helped others develop abilities they weren't aware that they could.
Colleague	As a colleague, Val returned to eat lunch with L2TT2L friends during breaks from the varied activities she took on while she couldn't participate in spring 2010 L2TT2L activities (before returning fully in the summer). Shawn went to a nearby college and he remained visible to participants as someone who leveraged L2TT2L into college studies (as several of his fellow alumni have also done).

As the tables above suggest, Shawn and Val both played roles differently from stage to stage as I facilitated their activities according to strategies that ultimately became foundational to the Constellation of Connected Creators framework.

I based my summary above on my observations and the kinds of activities I did with Shawn and Val. I present some of the sentiments they verbalized to reveal ways that they thought about different roles they played during their time in L2TT2L.

7.2.2   Val and Shawn articulating their experiences

Both Val and Shawn had opportunities to respond to questions about their experiences – verbally or in writing (via surveymonkey.com). Some of their responses made it clear that they learned to play different roles from their predecessors. Staff, college mentors, and returning youth teachers influenced them in numerous ways. Shawn felt that "we were surrounded by skilled people. What got me really into the program was that we were exposed to programs like Scratch, PicoCrickets, and Fab Lab. I just couldn't stop thinking about it…The returning youth teachers who were training us had really high expectations. We could definitely have the high expectations since we were around skilled people - they knew what we could do and they also pushed us to get where we wanted to be. Factors that got me hooked to the program were that my teachers and my co-workers were similar to me - they lived in the same neighborhoods."

Shawn admired the people who facilitated activities for him when he was learning in L2TT2L. He did not feel as though L2TT2L's reward for participating in the program was just knowledge skilled people helped him acquire, he stated that: "my reward was passing my knowledge on."

Val appreciated learning from skilled staff as well. Doing so caused her to question how she compared to her predecessors as a coach. She spoke highly of several staff members she learned from, likening Ed to a "get-things-done" figure, Susan to "a caring mother," and me to "the funny older brother who made us do work but also made us laugh." She mentioned that she looked to us a model for being coaches.

She considered Staff to be coaches and also held us in high regard. She was reluctant to consider herself as a coach as well. She said "I think that I personally haven't reached that level [of coach] yet, but returning youth teachers, college mentors, and adults have."

Playing a role versus having the *status* associated with a role is a tricky distinction. In L2TT2L, it is not uncommon for participants to feel mismatches between what they do and what their title is. For example, people join L2TT2L as "youth teachers" in title. They begin the L2TT2L playing more of a student role. They adjust to people their age teaching them. Then, these first-year youth teachers begin teaching pre-teens. Even then, it has taken participants time before they identify with the title youth teacher - even after carrying out the tasks a teacher does for weeks – such as preparing lessons and facilitating activities to help others learn. Over time, they recognize that the status they've earned and the title L2TT2L gave them match up. A similar dynamic was at play for Val with the term coach. It is something that she did not readily assign to herself but realized that she was doing tasks of a coach and that others might identify her as one.

When I asked Val if she thought that others might feel as though she served as a coach for them, she replied "maybe." In talking about roles that she played while building the Talking Trashcan group project, Val realized that she was carrying out tasks that a coach would and began referring to herself as a coach to her groupmates. For Val, facilitating Saturday sessions was something that L2TT2L staff and others had done before her. She didn't consider how she ran the Saturday sessions as on the same level as she remembers others doing it before her. She was initially reluctant to accept the same designation of coach. When she thought about her role on a project that had no prior history in the program, she thought of her role as being a coach in the project context. She brought knowledge about working with sensors to the table and helped her groupmates understand how to incorporate them into their Talking Trashcan project. She readily identified with being a coach after that realization. She continued to consider me and other staff members to be different kinds of coaches.

Val understood that she played roles differently from her predecessors. She was also aware that she played roles differently as she evolved. When Val and I discussed ways that she played roles differently during certain time periods than others, she mentioned that at the time near the beginning of her first year in L2TT2L "I was more of a creator

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and co-learner then... and probably collaborator too." At the start of her second year, she noted, "I was also a colleague then and more of a collaborator." Near the end of her second year, she added, "I was a colleague, but in a different way." Val understood that she, and the roles she played, co-evolved.

Val's thinking about what she was good at evolved as well. She proudly mentioned "[I found out] that I'm good at programming things! I feel like when I first came here, I didn't know that I could solve a community problem or make sensors and devices that can help solve break-ins and solve litter problems. Now, I feel like I can build things I didn't know how to." Shawn evolved in similar ways. He stated: "I came into the program knowing nothing about Scratch or PicoCrickets. At the end of the summer, I was creating projects I would have never thought of even trying to start."

They both appreciated that they could take on active roles in their learning environments - participating in ways that they believed differed from how they participated in school classes. Val said that L2TT2L "is more hands-on. They don't tell you what to do or how to do it." Shawn commented: "[L2TT2L] is definitely the way to go for hands-on learning and an alternative way for teaching young kids rather than the old-fashioned type of teaching."

Some of Val and Shawn's responses to surveys echo their sentiments above. (L2TT2L staff asked participants to fill out at the end of each summer.) The responses below also illustrate other ways in which they viewed themselves as creators, co-learners, collaborators, coaches, and colleagues.

Val as creator	
Prompt: What was the best thing about your project?	Response: The best thing was that it was actually like something that you see in stores and it ended up working really well.
Shawn as creator	
Prompt: What was the best thing about your project? The hardest?	Response: Building the sensors – connecting the wire so the sensors worked when connected to Scratch.

Val surprised herself by helping to create something that she considered to be comparable to a product that people would see in stores. She was proud of her group's

prototype. Shawn felt accomplished as well, having helped build sensors that worked in a prototype.

Val as co-learner	
Prompt: How did the program *change* your *thinking* about your *ability to learn*?	Response: I think that now I learn better by doing and not just listening. I thought that I didn't learn fast enough but when you have kids to teach, you end up forcing yourself to get up to speed in time.
Shawn as co-learner	
Prompt: How did the program *change* your *thinking* about your *ability to learn*?	Response: I can take in a lot more information than I thought I could.

Val and Shawn both credit L2TT2L for helping them think about themselves differently. Prior to L2TT2L, Val didn't feel as though she learned fast enough. Shawn was surprised by how much more information he could take in than he thought he could. Val attributed her learning to the need to teach, and get up to speed with content before doing so. Shawn's response suggested that he was more capable than he initially thought – and the people who facilitated his initial activities were always aware of that. They set high expectations for him. He became comfortable setting those high expectations for himself.

Val as collaborator	
Prompt: What are three things you learned while building your project that you did not know before?	Response: …I learned that communication within a group is very important.
Shawn as collaborator	
Prompt: Why did some of the people have a difficult time working together and what could L2TT2L Staff have done to prevent this from occurring?	Response: Most people had different points of view.

Val and Shawn learned two valuable pointers to keep in mind in collaborative settings: that communication is important and that people's views often differ from your own. These lessons served them well in both project contexts and teaching contexts.

Val as coach	
Prompt: Tell us about one moment when you felt you were a great role model.	Response: I felt like a role model when we were explaining PicoCrickets to kids and they weren't really getting it, but after we explained it thoroughly they got it and

	really liked it, and us for taking the time to explain and not giving up on them.
Shawn as coach	
Prompt: What would you tell someone about the L2TT2L?	Response: I would tell them that it is a great program to join because of the atmosphere. You can learn a lot and also you can broaden the minds of younger children.

Val learned an attribute that good coaches employ: not giving up on people. Shawn's response touches on a motivating factor for coaches: a desire to broaden minds. These responses reflect the type of mentality George Washington Carver urged us all to adopt – we all need to stimulate and encourage creative minds in every way possible. That includes never giving up on them.

Val as colleague	
Prompt: Tell us about a change that you see in yourself as a result of the program?	Response: I think that I've become more patient and understanding of both younger and older people.
Shawn as colleague	
Prompt: How can the L2TT2L improve the environment so you can work better with your peers?	Response: I am not sure because I got along with my peers fine.

Val's response indicated that she has come to understand part of the practice of being a colleague: being patient with people and understanding those who are younger and older than you who enter a shared enterprise with you. Shawn's ability to get along with his peers is not only a reflection of his personality, but it's a testament to the collegial environment that L2TT2L has established and maintained.

7.3   Strategies for Facilitating in Constellations of Connected Creators
This section draws upon my experience of working with multiple participants from L2TT2L (over 100 teens) to offer more generalized strategies for cultivating and sustaining a constellation of Connected Creators. Experiences I've had working in Computer Clubhouse environments on short-term workshops also influenced the strategies I present – particularly the ones pertaining to engaging newcomers.

I outline strategies for transforming participants into facilitators ready to offer engaging activities, cultivate environments conducive to creative expression, and help peers

transform their attitudes and approaches to designing. Each subsection focuses on one stage of the Constellation framework. Each starts with challenges of facilitating in the particular stage. They each offer three strategies for overcoming those challenges.

7.3.1 Facilitators engaging diverse newcomers

As the initial facilitator, I employed several strategies for engaging diverse newcomers. I describe key strategies for this stage and refer to relevant events from my three cases that demonstrate how the strategy developed or played out in my research sites. The three main strategies were: seek to spark and spread, show start-from and shoot-for projects, and adapt to interests on-the-fly.

<u>Challenges in this stage</u>

I faced several challenges in this stage that led to the strategies below. The nature of getting people who just met each other to start working on joint endeavors is a challenge that I face as a facilitator each time I meet new workshop or program participants.

Challenges arise when young people come to workshops from backgrounds where creative uses of computing were not presented to them as extracurricular options. In these cases, youth are thinking about how computing can enhance activities they're interested in for the first time. Facilitating youth exploring a new imagination space takes care. As a facilitator, it is important to have a good idea of what is possible to do in a workshop setting and what is possible to make with a particular toolkit given extended amounts of time. It is essential to convincingly communicate that you, the facilitator, believe it is possible for the workshop participants (regardless of their background) to realize some of the possibilities in the workshop and in some cases beyond. Exposing what is possible given the various starting points of a diverse group is oftentimes more of an art than a science. Learning how to accurately gauge a group's likely trajectory early on in a workshop is daunting – especially when the workshop has limited time. Special care is also needed when a participant comes to a workshop believing that his or her performance in school will dictate how they perform in the workshop. They need to know that school and workshop achievement does not have to correlate.

Determining when the trajectory of a workshop should follow a flow brought up by participants instead of continuing a pre-planned set of activities is tricky. Careful

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consideration must be made on-the-fly in assessing whether ideas introduced by some participants will engage an entire group potentially more than the pre-planned flow would.

<u>Seek to spark and spread</u>

In each workshop configuration, aim to spark the interest of participants. Tap into an existing interest that participants have. If the interest connects to or turns into a passion, that participant is likely to spread what he or she learned in the workshop. In Hook-ups workshops, I sought to spark interests in participants in ways that would encourage them to spread what they learned of the practice of creating with physical and digital media. I did so by making references to topics the participants were discussing and objects they had, such as handheld devices. If possible, derive cues about what's of interest to the participants before the workshop begins – based on how participants are engaging with each other.

Understand what sparked the participants to come to your workshop. I took a particular spark and spread strategy in the workshop setting of the Clubhouse Teen Summit, in which the Olympic theme Hook-ups played out. I understood that each participant was in the workshop because he or she was an exemplary member of his or her Clubhouse. That meant that each had displayed to their respective Clubhouse coordinators that he or she was already capable of expressing him/herself using a variety of technologies. Many of the coordinators also selected participants based on their ability to lead others.

Spend the time necessary to ensure the participants are excited by the initial project they will be working on. Given that the group coming to the Teen Summit workshop had exhibited leadership, I supported them to take the lead on generating their own initial project ideas after I showed them examples. I spent time with each small group of two or three to give bursts of strong support as they worked – with the idea that those participants would go back to their Clubhouses and communities able to spark the interest in Hook-ups work there. The coordinator who worked with Vic and Rose on the High Jump Hook-up catalyzed a strong community of mentors and teens making large-scale Hook-ups in Argentina – building off of the Olympics workshop spirit. He sent me an email two years after the Scratch Olympics workshop that included an exhibition he

held that featured Hook-ups bowling and more. He also hosted a workshop with Hook-ups at its core during the 2010 Computer Clubhouse Teen Summit.

Find ways to connect your workshop's theme to activities that have proven to engage the demographic of your participants. The participants who created the Hot Potato Hook-up at the Charlestown Computer Clubhouse had interest in playing video games – including those on the Nintendo Wii. I sparked interest in Hook-ups work there by introducing Wario Wares Smooth Moves – a Wii game that feature unique interactions with a Wiimote similar to those a Scratch Sensor Board could support. The approach in Charlestown was to add new dimensions to an existing interest. The participants were able to help spread interest in Hook-ups work by connecting with the interests of their peers. Some workshop participants spread interest by explaining what they were working on to curious peers who approached during workshops. Others connected Hook-ups activities to different interests that had social appeal. The spin-selector Hook-up's creator leveraged the interest in social games of people around him to include them in his Hook-up creation process.

Facilitators in programs like L2TT2L that draw from the participant pool to develop facilitators for future workshops: understand that projects that people make as they're excited can cause them to be the ones who spread creative ideas to newcomers as facilitators later on. Foster excitement to fuel projects that can help spark an interest in the project's creators to become a facilitator. When participants excitedly contribute to projects, the resulting artifact is something that can spread the excitement. Seeing people excited by a project is one of the factors that can cause participants to facilitate activities – knowing that people appreciate the projects they create.

In working with L2TT2L, the Saturday sessions needed to get people interested in coming up with their own idea for a project and support them in carrying out that idea. The participants who had completed an original Hook-up that varied from the example during a Saturday session had adequate knowledge to draw upon when considering using Hook-ups tools in their summer project groups. The projects that the participants created during the summer could spark interests in Hook-ups among others (as was the case with Shawn) and spread that way. The positive feedback Shawn received from his peers on the Stuffed Bears project encouraged him to continue learning Scratch and

Sensors by teaching the related Saturday Sessions. The drum examples Shawn and Val created became a great introductory platform to Hook-ups. One of the participants who made "Rock Band 7" after Shawn and Val introduced her to the drum examples ultimately became a Scratch Saturday Session facilitator the next year.

<u>Show "start-from" and "shoot-for" projects</u>
Having a strategy to select which projects newcomers see first is an important part of the Engaging Newcomers stage. Whether a workshop is for a full-day or broken up across several days, a factor that is critical to getting participants engaged is showing start-froms and shoot-fors. As a facilitator, I learned that showing a combination of "start-from" projects and "shoot-for" projects was a useful approach to engaging multiple participants in creating Hook-ups.

Know when to show a start-from. The creator of the first Hook-up initially interacted with a shoot-for project: a paper-plate steering wheel that featured multiple sensors for controlling the speed and direction of an on-screen car. That somewhat polished project reflected multiple revisions and sported several improvements I had made since the original. Nevertheless, she was able to see how a paper plate could be the basis for her own project. Hers started as a rough sketch, but had promise (given more time) to reach a level of functionality on par with the example she saw. A young man who accompanied her did not start his own Hook-up after expressing his apprehension to attempt to make one that was comparable to the example. It became clear to me that enticing start-from projects would provide more entry points than would projects meant to show what is possible.

<u>Adapt to interests on-the-fly</u>
Adapt to interests on-the-fly. I found such a strategy to be useful in the Engaging Newcomers stage. The strategy shows how the FCL classroom approach to curricula was similar to my approach to engaging young people in activities. In the Stuffed Bears case, the teens who ran Val's Saturday Sessions were open to adapting a theme to fit participants' interests and embraced unexpected directions.

Go with the flow if a failure to do so would lose momentum. The facilitators who ran Val's introductory session had a plan for the day, but went along with the flow of ideas they

were met with. The Hot Potato Hook-up grew out of the participants' interests as well. When possible, the interests of the students dictated the directions of the FCL learning.

Introduce themes that fit your own interest to start, then make an effort to support ideas outside of your set of interests. (This could seem counter-intuitive if you believe that you're best suited to support projects that dovetail with topics you're interested in and knowledgeable about.) After introducing projects within themes that related to my own interests, I ended up supporting participants' projects that fell outside of my interests and passions – which was a sign that participants were buying into the culture. I helped participants pursue the paintball Olympic event Hook-up they imagined – paintball being one of the activities I would probably not have used as an example because I do not partake in paintballing nor is it an Olympic event. It was, however, a creative expression for the young ladies who wished to turn it into an Olympic event. They extended the existing archery event to include paintball guns.

7.3.2   Facilitators cultivating future facilitators

In the Cultivating Future Facilitators stage, I found three strategies useful: prepare, care, and show you've been there; help groups help themselves and others; and switch activities in stride. To cultivate future facilitators, I had to employ the strategies at one point and explain the strategies to those who would benefit from using them at a later point.

Challenges in this stage

Giving ideas to a participant can be drastically different from giving him or her responsibilities. When a participant either self-selects or a facilitator calls upon him or her to assume facilitation responsibilities, a different relationship is established between the facilitator and participant. Giving trust and earning trust are two challenges at play during this transition.

Establishing trust between facilitators and participants requires thought, as does establishing trust between peers. It is an intricate process to get participants to trust that older and younger peers with different experiences from their own can contribute ideas, solutions, and strategies that help projects advance.

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Ultimately, it is the participants who drive each project as far as they want to take it. Facilitators can set up an environment in which participants become engaged in a particular topic, but cannot predict how long they keep participants' interest in making projects related to a particular topic. Determining when to stay consistent to a topic or to infuse a fresh set of ideas is tough.

<u>Prepare, care, show you've been there</u>
Participants that can relate to you are ones who are more likely to see you as a model. This strategy is helpful for cultivating future facilitators because it shows that there's a path from newcomer to facilitator. You should be as good a facilitator as you can, but do your best to avoid coming across as someone who is "just good at facilitating." We all started off as participants somewhere; your participants should know that – and communicate that when they're facilitators.

As the name of the strategy indicates, there are three steps. To prepare for Hook-ups activities, explore how a variety of personal interests can be incorporated into Hook-ups. Gaining experience incorporating interests into Hook-ups puts facilitators in a better position to help others facilitate projects among people they connect with in ways that incorporate the peers' interests.

Young people came to the table with a wealth of experiences they've accumulated from involvement with activities that do not initially appear to have intuitive pathways into Hook-ups projects. With experience facilitating Hook-ups activities, it became more intuitive to me to help participants identify parts of activities that were likely to be enriched by adding computing. Doing so capitalized on existing engagement and used computing to open doors to more creative output. For example, when the Hot Potato idea came up for a project, participants did not need much of an introduction to how the game was played.

To care about the development of participants, support them on their own unique paths through Hook-ups activities. Start by incorporating their existing interests. Continue by providing feedback as participants work. Note that giving appropriate feedback is an art that needs due care (Dweck, 1999) – especially for young people from groups that are not well represented in computing fields (Margolis et al., 2008). In the case of the High

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Jump Hook-up, the feedback of people wanting to experience what Vic and Rose created alone was an appropriate acknowledgement of the effort they put into the project. They benefited from having a group working environment that was conducive to soliciting feedback from peers before their project was ready to show widely. The duo enjoyed the feedback of having people lined up to try out their Hook-up at the project exhibition – in addition to the verbal feedback they received.

To show you've been there (the last, but most important step to cultivating future facilitators), be open about your path through early Hook-ups projects. Sharing a personal starting point to Hook-ups work can serve as a reminder that people who become capable of facilitators of Hook-ups workshops all started somewhere. My path to creating Hook-ups started with a steering wheel. It was made from a paper plate. Sharing that information with the flying-saucer Hook-up creator was likely to influence her examining a paper plate to find that it reminded her of a flying-saucer shape. She started her project from there.

Help groups help themselves and others

Using this strategy is not only a means of empowering participants to find ways to solve their own problems, it is also is a strategy that can mitigate fears that future facilitators might have. For example, if participants think that they need to know all of the answers before they can run successful workshops, they'll be reluctant to facilitate. Demonstrate to participants that the onus of answering all questions does not have to lie with the facilitator. A strategy for doing so is to help groups help themselves and others.

Put participants in situation in which working with peers, both younger and older, will help them recognize that they all contribute. Having group members rotate through roles was a key step in establishing the learning environment of respect and both inter- and intragenerational learning. In order to leverage the expertise among peers in the same age group who possessed different levels of experience with the community's practices, much of the Hook-ups research leveraged group work. In groups, participants were able to build off of others contributions. When the L2TT2L schedule called for some group members to be away from group work, other members had to fill in for the roles that group member played.

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Part of what made inter- and intragenerational learning, teaching, and respect possible was the lack of grades. There were no grades so participants were able to see each other as resources and collaborators rather than competitors. When competition for grades was not inhibiting collaboration, participants engaged in shared activities that carried on when an experienced practitioner (of any age) was not on-hand. Participants who were novices relied upon working with peers in groups to develop expertise. When conditions were conducive to group work going smoothly, there was a better chance that people could form complementary pairings of facilitators for the next year's workshops.

Switch activities in stride

An effective way to build confidence in participants that their ideas can drive workshops is to refocus pre-planned activities to incorporate their ideas. If an initial activity isn't inspiring participants to generate their own ideas, don't be afraid to switch in stride. If participants finish projects related to a particular idea and don't have any other projects they'd like to pursue, that's also a good time to switch the core activity of the workshop (or series of workshops).

I have learned that a facilitator should always have an additional activity ready for one or more individuals who might become a disengaged group. It is natural that some participants will have different notions of what it means to be done with a project. When participants feel as though they have sufficiently explored one of the workshop's areas, they typically let the facilitator know. When two participants in the Olympic events workshop were not excited about making a project related to an existing event, I did a strategic switch by making their activity to invent a new Olympic event. They took the new opportunity to make the paintball event.

Because cultivating facilitators entails sustaining interest over time, it is important to "bounce back from boring." Tasking someone who is bored with a topic to facilitate others learning it is a recipe for fun-for-no-one. Having multiple activities ready will help you "keep it fresh" (as Kendi once encouraged me to do). One week, he was into the activity until it was time to go home, the next, he didn't want to get started on the same topic. I was able to switch to a backup activity that felt more like hanging out than working toward an elaborate project.

7.3.3 Facilitators supporting successors

Three strategies were key in the Supporting Successors stage: intervene out of sight; share successes and serve from the background; and demonstrate patience and prod appropriately. To support the facilitators who were in a position to succeed me, the strategies below involved shifting the type of support I gave to participants.

Challenges in this stage

Even though after-school programs like L2TT2L put students in contact with one another in ways that differ from school, the age stratification that students experience in most schools don't make the best conditions for older participants learning from younger ones. If participants come from schools where they little experience working with younger students, and thus don't see the value of doing so, putting them in positions in which younger peers are expected to facilitate their learning needs to be handled with care.

A challenge that facilitators face in the Supporting Successor stage is managing how to redirect participants with questions to new facilitators. After being one of the main people who helps participants think through problems for an extended period of time, supporting new facilitators helping participants get past problems is a must. A factor that is extra challenging is when you have the answers to many questions a particular community is likely to raise readily at hand. Experienced facilitators need to know when to give new facilitators a chance to develop answers to those questions as well. Knowing when and how to hand over the facilitation reigns requires significant thought.

By this stage, facilitators are aware that one size does not fit all in terms of helping participants advance their projects. Understanding what motivates different learners is tricky. A facilitator has to try multiple ways of encouraging and supporting participants – being mindful of approaches to which particular participants do not respond well.

Intervene out of sight

One way to make a space for young facilitators to gain and maintain respect as facilitators from older peers is to coach the young facilitators behind the scenes. When newcomers have become accustomed to adults in the room driving the learning environment, avoid intervening as much as possible when a young facilitator is leading a workshop. It is important to establish early on that the facilitator who prepared the

activity, regardless of age, deserves the respect to lead it. Facilitators who are interested in supporting successors should have meetings with new facilitators prior to workshop days and give them day-of feedback during breaks. Doing so helps avoid undermining new facilitators' plans.

I was in the best position to yield facilitation duties to new facilitators when they had developed introductory activities based on their interests that I did not have as much interest in as they did. I was happy to help Shawn and Val with constructing the physical drums, but knew less about how to make good MIDI-synthesized sounds than they did.

Having engaging examples to base a workshop upon is only part of what new facilitators need support with. Communicate the strategies you think will be of use to the new facilitators in meetings before the workshop and at breaks during the workshop. For example, it was helpful for me to remind Shawn and Val that it was okay that they wrote a program during the introduction of a workshop that didn't do quite what they expected it to. Because that was part of what new participants would be experiencing, it was great that they didn't get frustrated when it happened. I told them that they had given a great introduction. When they had participants settled on computers to work on their own projects, they spoke with me about ways to get the program to do what they intended.

Share successes and serve from the background
In this stage, continue to encourage new facilitators to take the foreground of leadership within the learning environment. Stay available for them until they become comfortable in the new role they are taking on. Initial facilitators should understand that strategies for the successes they share with new facilitators may not have the same effects in the settings the new facilitators inherit. Explain that advice from previous facilitators will usually need some adapting to the current situation. This understanding encourages the new facilitators to embrace their own styles that may differ from their predecessors'.

During the 2010 L2TT2L phase of Saturday Sessions, the returning youth teachers who facilitated the sessions decided to respond to first-year youth teacher feedback and offer full-day competitions on occasion. The returning youth teachers decided to craft Saturday sessions to accommodate the desire for mini-competitions, but still cover the material they thought would be important for participants to know to thrive in L2TT2L. In

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my role of serving from the background, I helped them think through the potential ripple effects of changing the Saturday structure. They took the lead and ran successful Saturday mini-competitions that I probably would not have offered as a facilitator. I learned from their approach. They filled the role of facilitator. I supported their ascension to the core of facilitation by creating space for them there as I transitioned to the periphery of activities.

<u>Demonstrate patience and prod appropriately</u>
In asking participants to take on more of the role of primary facilitator, it is important to avoid asking them to do new tasks in ways that aren't likely to get the results you're looking for. The strategy for getting new facilitators to work better with you is a strategy that they can use to get new participants to work well with them. This strategy involves demonstrating patience and prodding appropriately. To strike the appropriate balance between patience and prodding as projects and people develop, determine what motivates the new facilitators early on in the relationship – before you need to rely on your approach to motivating them to get a critical task done. For example, if you ask a new facilitator to unlock the building doors early in your absence during one session, be patient if they don't do it as early as you agreed upon. Participants interested in developing into a lead facilitator will take the feedback from their peers seriously and, if ever called upon again to unlock a door early, are likely to remember that waiting outside of a locked building upset their peers.

Get to know who you're working with early on. If you have meetings to discuss workshop planning on a non-workshop day, arrange to meet with one of the participants before the meeting if there was something that they wanted to discuss with you. It is convenient to stay after a meeting to hold such discussions, but if a participant is prompt for the pre-meeting, you can start getting an idea of who to count on when tasks need to get done before a workshop.

Similar to how experienced facilitators work with new facilitators differently based on their interactions over time, new facilitators need to develop an awareness that each peer is likely to have differing levels of understanding, comfort with a topic, workflows, and attitudes. It is important to help new facilitators understand that it is essential to prepare for working with various learning styles and that entails having more patience

with certain participants and occasionally needing to prod others to realize their ideas. Shawn and Val found that having participants show their projects to others at the end of a workshop was an activity they did when they were participants in the workshops that they wished to keep in their facilitating repertoire. Over time, as they walked around from one participant's project to another, they developed a sense of who they could prod to explain more about a given project and who would not respond well to such inquiries.

7.3.4   Employing the strategies effectively

I based the strategies on my petite generalizations - refined understandings of the patterns I encountered that other facilitator / researchers are likely to encounter. The measures I put into play were adapted specifically for my settings, but stand to impact other environments once adapted to the local nuances.

In order to set up the kind of group work that leads to children expressing themselves creatively, the strategies of the next section came in handy. They are best applied in a Design Experiment manner. That is, as Brown and Campione carried out their work, they developed principles from research, modified the learning environment, analyzed the effects, revised the learning principles and revisited research. Your mileage may vary with my strategies, but analyze their effects in different settings and update as necessary.

8 Conclusions and Contributions

My dissertation work contributed to two areas of research: (1) developing engaging technological tools that promote learning and creative expression and (2) designing supportive environments that invite broad participation with these technologies. Using chalk as an inspiration while designing the Hook-ups System contributed to the first area of research. To help people rethink how they can harness the expressive power of computational technologies, I developed the Hook-ups System to be a set of technologies and activities designed to enable young people to create tangible interfaces. This dissertation detailed how I led the effort to design the Scratch Sensor Board to be the core technology of the Hook-ups System - an extension of the Scratch programming language developed by the Lifelong Kindergarten group.

My Hook-ups research involved introducing the System to Charlestown's Computer Clubhouse and the South End Technology Center (SETC) over a five-year period. Offering opt-in workshops at the Clubhouse and working with participants of a multi-year youth development program at SETC provided me with opportunities to continually refine the System's tools and activities and the learning environments.

This dissertation presented four case studies. They covered three days, three weeks, three months, and three years of Hook-ups work in different environments. These cases brought to light ways in which attributes of the Hook-ups System enabled diverse audiences to engage in building personally meaningful projects, express themselves, and transform how they approached design in diverse settings. My findings can serve as a blueprint 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.

For educators, analyses of the four cases offered insights into how and what children learn as they build Hook-ups. These insights contribute to the body of work that can challenge what types of activities should take place in formal and informal educational spaces alike.

Developing the Constellation of Connected Creators framework contributed to the second area of research. I described its charge - provide facilitators with strategies for

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introducing technological tools and activities in ways that cultivate and sustain creative communities of learners. The dissertation highlighted how the work identified several roles that both facilitators and participants adopt over time to sustain youth engagement in technology-rich learning activities: creator, co-learner, collaborator, coach, and colleague. The document detailed ways in which facilitators and participants played these roles over three stages that involved facilitators engaging groups of newcomers, cultivating future facilitators and supporting their successors.

The strategies for cultivating and sustaining creative communities can serve as catalysts for future facilitators to implement innovative educational programs. I developed ideas for the framework within the context of Hook-ups work I carried out at my research sites. I intend for the framework to be a model that supports efforts involving a variety of technological tools and learning sites.

A George Washington Carver call to action inspired me to contribute to the two research areas my work covered. I have taken on his challenge to stimulate and encourage creative minds in every way possible. I drew motivation from my father's generation – a group that did not capitalize on opportunities to reap the benefits of developing a diverse corps of creative minds – especially in fields related to computing. I offer my contributions in order to catalyze efforts that share my dissertation's aim: to invest in a diversity of minds having creative experiences early (especially the kinds of experiences that working with technological tools enables).

I hope that my dissertation work influences current and future colleagues to use the Constellation of Connected Creators to help more young people create with confidence, co-learn with colleagues, value collaboration, and continually coach peers along the way. As they do so, I anticipate that academics will rethink their approaches to educating tomorrow's creators. Community organizations will think about their programming in new ways. Resulting collaborations between people in academic institutions and community organizations would lend credibility to University of South Florida professor Stephen Sundarrao's measure of success. He argues that intellectual success used to be how many papers were published; now it's how much of what you produced at the university is in the community (Associated Press, n.d.). I intend for this work to continue taking hold

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in creative communities (across academic institutions and community organizations) in ways that would make Carver proud.

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A. Appendices

A.1   Brief biography of external reader
Melvin H. King

Senior Lecturer Emeritus of the Department of Urban Studies and Planning at the Massachusetts Institute of Technology, King has extensive experience in the design and implementation of vocational education programs. As executive Director of the New Urban League of Greater Boston, he was involved in various community organization efforts and business development programs in the Boston-Roxbury area. In an attempt to share his experiences during his many years of community involvement, Mel has documented the development of the Black community in Boston from the 1950's to the 1980's in his book *Chain of Change.* A former State Representative, Mel served the 9th Suffolk District of the Commonwealth of Massachusetts from 1973 to 1982, and was a 1983 mayoral candidate for the City of Boston. After twenty-five years of leadership of the Community Fellows Program, Mel King retired from MIT and currently directs the South End Technology Center in Boston's South End neighborhood. To add to his long list of contributions to low-income communities and urban development, King uses his technology center to host a CBA sponsored "Fab Lab" – a place where people from the community can use desktop fabrication to make almost anything.

A.2   Participant Pools

Learn 2 Teach, Teach 2 Learn
Participants of the L2TT2L program from 2004-2009 heard about the program from peers or community technology centers they visited. They were interested in learning about the program's concentration areas by building community projects and teaching young people in various community centers around Boston. The returning youth teachers hosted interviews and helped select new first-year youth teachers. They put applicants through a series of group challenges and evaluated who they thought would be a fit for the program. Once the returning youth teachers submitted their recommendations to staff, a subset of the staff members made hiring decisions based on the funding available and considerations such as diversity in representation, grade level, gender, neighborhood, and success along conventional school standards.

Computer Clubhouse Teen Summit
Clubhouse coordinators nominated participants who exhibited leadership in their Clubhouses and communities to be the one of the two delegates each Clubhouse could send to the 2008 Teen Summit gathering in Boston. The total Teen Summit attendees indicated the types of activities they liked on their registration forms. Teen Summit planners placed the attendees in workshops that the planners felt were a good match for the attendee's interests. The dozen participants who ended up in the three-day workshop were excited to have an opportunity to learn a new way of completing projects that they could introduce back to their communities once they returned home. Members of the Charlestown Computer Clubhouse attended the Teen Summit.

Charlestown Computer Clubhouse
For the workshops I facilitated at the Charlestown Computer Clubhouse, I welcomed any member of the Boys and Girls Club who wished to join. I arranged to visit the Clubhouse from approximately 4:00 PM to 7:00 PM on Thursdays from January to February 2010. The Boys and Girls Club facility had a building for pre-teens adjacent to the Teen Center building in which the Clubhouse was located. The pre-teens could make use of the Computer Clubhouse up to 5:00 PM. From 5:00 PM to closing at 8:00 PM, teens had

priority use of the Clubhouse. I elected to start Hook-ups activities at 4:00 PM to make it possible for interested pre-teens to join.

Participants discussed in the case studies

I use pseudonyms when referring to the participants discussed in this dissertation.

A.3   Scratch Sensor Board Technical Information

This section provides information regarding the technical aspects of how a Scratch Sensor Board can communicate with a Scratch computer program. If you are interested in creating new designs and/or hardware using this information, you can find the Scratch Sensor Board license at

(http://scratch.mit.edu/files/scratchboard/ScratchBoardLicense.txt).

Scratch Sensor Board Serial Communication Protocol

The Scratch Sensor Board allows inputs from real-world sensors such as switches, sliders, light, or sound to control Scratch programs. It does this by converting sensor inputs into numbers and communicating them to a computer running Scratch over a serial data connection.

Communication is via RS-232 protocol at 38.4k baud. The serial version Scratch Sensor Boards are devices that can communicate with standard serial ports or other USB-to-serial cables. (http://www.playfulinvention.com/picoboard.html now has a USB version that requires no USB-to-serial cable.) In most cases, the Scratch software (version 1.1 and above) automatically detects which COM port that the Scratch Sensor Board is plugged into when a Scratch project using sensor value blocks is run (recognition can take from 1.5 seconds to a few seconds in rare cases). One of the serial port pins provides enough current to power a Scratch Sensor Board (but not an additional load).

Polling: Scratch sends a "1" data byte (i.e. 0x01 not the ASCII character "1") out of the communications port; the Scratch Sensor Board responds by sending the sensor data encoded in an 18 byte packet with ~ 400 uSec delay between bytes in the packet. The packet consists of 9 high byte / low byte pairs. Scratch checks to make sure that it receives a complete 18 byte packet in response to each poll request and will ignore data that is not part of a well formed packet.

Encoding: Raw sensor values measured by the Scratch Sensor Board are 10–bit numbers. Each sensor value is encoded along with a 4-bit channel number as a two–byte pair transmitted by the Scratch Sensor Board according to the scheme illustrated below. The first byte in the pair, (the "high byte") has its most significant bit set to "1",

followed by 4 bits (labeled ch3-ch0) that contain the channel number, followed by the three most significant bits (labeled d9-d7) of the 10-bit sensor value. The second byte in the pair (the "low byte") has its most significant bit cleared to "0", followed by the 7 least significant bits (labeled d6-d0) of the 10-bit sensor value.

High Byte

1	ch3	ch2	ch1	ch0	d9	d8	d7
bit7	bit6	bit5	bit4	bit3	Bit2	Bit1	bit0

Low Byte

0	d6	d5	D4	d3	d2	d1	d0
bit7	bit6	bit5	bit4	bit3	Bit2	Bit1	bit0

For the Scratch Sensor Board Release 1 firmware and Scratch release 1.1 and later, the mapping between channel number and sensor type is given in the following table.

Channel Number	Sensor
0	resistance-D
1	resistance –C
2	resistance –B
3	Button
4	resistance –A
5	Light
6	Sound
7	Slider
15	firmware-id (currently 0x04)

In response to a poll request, the Scratch Sensor Board first sends the firmware-id (channel 15), followed by channels 0 through 7 of sensor values.

Scratch maps the 10-bit sensor data onto a 0 – 100 scale using a mapping that is different for each sensor type. Users can access the "raw" 10-bit values by right-clicking a ____ sensor value block, selecting "show ScratchBoard watcher," then shift-clicking on

the ScratchBoard Watcher and selecting "report raw data". Doing so will show sensor values in the range 0 - 1023.

Most of the sensors use a generic linear conversion to report scaled values between 0 - 100. Light and sound sensors use piecewise linear functions that take into account the idiosyncrasies of those sensors. (Note that readings for light are reversed so that more light gives larger values.) Code for scaling functions is shown below.

```
generic(n)
      return round ((100 * n) / 1023)
light(n)
      if n < 25 return 100 - n
      else return round((1023 - n) * (75 / 998))
sound(n)
      //empirically tested noise sensor floor
      n = max(0, n - 18)
      if (n < 50) return n / 2
      //noise ceiling
      return 25 + min(75, round((n - 50) * (75 / 580)))
//noise floor and ceiling values might vary for different parts
```

Additional Technical Information Documents Online
You can find additional documents containing technical information about the Scratch Sensor Board at http://info.scratch.mit.edu/Sensor_Board.

There, you will find:

Bill of Materials	ScratchBoardBOM.pdf
Firmware (Intel-format hex file)	ScratchBoardFirmwareR1.hex
Gerber files for the PCB	ScratchBoardGerberR1.zip
Scratch Board License	ScratchBoardLicense.txt
Schematic	ScratchBoardSchematicR1.pdf
Technical information overview	ScratchBoard_Tech_InfoR2.pdf