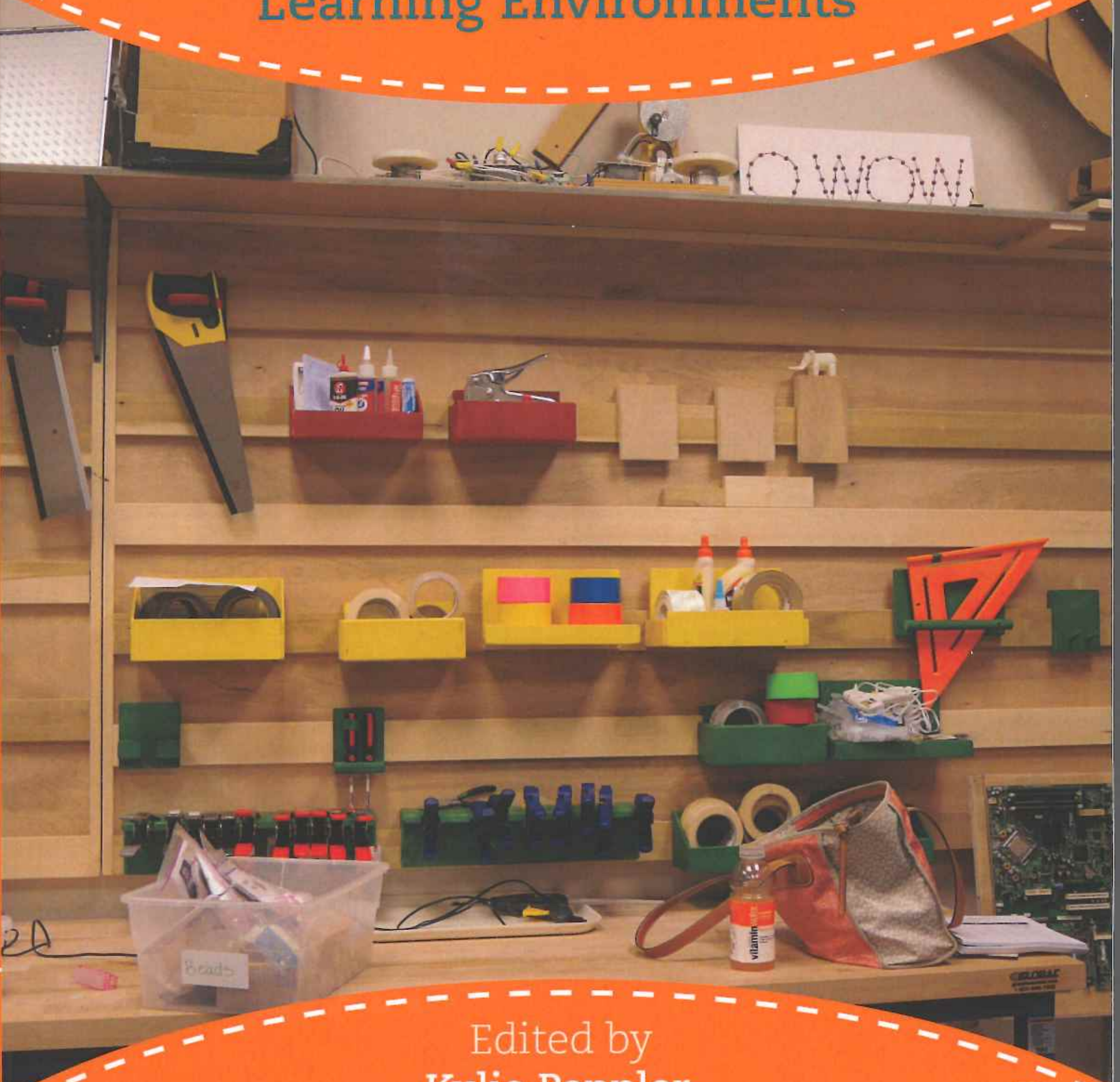
VOLUME 1

Makeology

Makerspaces as Learning Environments



Edited by
Kylie Peppler,
Erica Rosenfeld Halverson,

CHAPTER 6

DESIGN PLAYSHOP

Preschoolers Making, Playing, and Learning With Squishy Circuits

KAREN E. WOHLWEND, ANNA KEUNE, AND KYLIE PEPPLER

In the hum of activity in a sunny preschool classroom, young children bend intently over their projects on the small table strewn with Squishy Circuit kits: maker kits for crafting working electric circuits with playdough "wires," battery packs, and LEDs, fans, or buzzers. As they busily stick small white plastic light bulbs into playdough caterpillars, spaceships, and pancakes, the children squeal "It's red!" or "I made a yellow one!" as each bulb lights up to reveal its hidden color. One 5-year-old boy, Nate, leans across the table to offer helpful advice to a younger girl whose circuit is not working. "I want to tell you one thing. If you put one [battery lead] into one [playdough] ball, it won't work. You have to make two balls, and put one [lead] into one ball and other [lead] into another ball." However, the child with the nonworking circuit wants to instead flatten her playdough ball into a pancake. Suparna, a 5-year-old girl whose caterpillar glows with colorful lights, chimes in, "I know! You have to have two. So make a big pancake and then put into two [halves] and then put that battery pack into both of them."

This vignette provides a glimpse of the interactions that occur when children play together with electronics and craft materials. In this chapter, we describe a preschool maker project that illustrates the potential of Design Playshop, a model we developed to support playful and expanded learning in makerspaces, communities of makers creating with materials in a physical place (Peppler & Bender, 2013). Using Squishy Circuits kits (Johnson & Thomas, 2010), we created a preschool makerspace where children play, craft, collaborate, and experiment with electronics materials typically reserved for older youth in intermediate elementary grades. This allowed us to explore how intentionally merging play and open-ended crafting

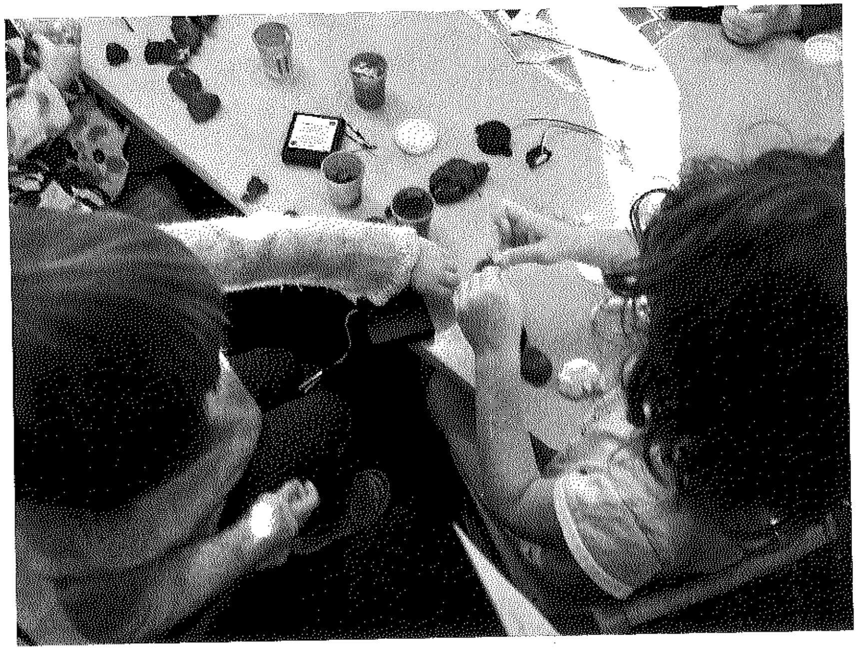


Figure 6.1 Photograph by Anna Keune.

possibilities with a circuitry challenge through the Design Playshop model expands learning and participation in makerspaces (see Figure 6.1).

BACKGROUND

One clear educational goal for makerspaces is to develop participants' technology skills and conceptual knowledge in electronics (Blikstein & Krannich, 2013) through exploratory tinkering, collaboration, and aesthetic design (Peppler & Bender, 2013) with 3D printing, puppet making, digital fabrication, book binding, woodworking, interactive toy design, deconstructing everyday electronic appliances—in short, making almost anything. However, in early childhood classrooms, this kind of technological tinkering is rare. While children often have opportunities to play and make with arts and crafts materials as core components in early childhood curricula, they typically have few opportunities in schools to produce their own content with mobile technologies or electronic tool kits (Darling-Hammond et al., 2011), despite the recent explosion of early childhood products in the software and app market (Gutnick, Robb, Takeuchi, & Kotler, 2011; Shuler, 2012). According to a survey (NAEYC & Fred Rogers, 2012), if preschoolers engage technology in their early schooling, it will most likely be through television viewing, e-book listening, or skills practice on computers (Herold, 2015). Furthermore, the lack of creative technology experiences at preschool exacerbates an "app gap" at home, where affluent children have 24/7 access to mobile technologies on robust networks while children in poverty "do not know what an app is" (Rideout, 2013). By contrast, making offers children active hands-on opportunities to, for instance, record their own play with animation tools (Wohlwend, Buchholz, Wessel-Powell, Coggin, & Husbye, 2013) or to design their own e-puppets, opening more equitable chances for young children to imagine, innovate, and identify as technology producers (Burnett & Merchant, 2013; Marsh, 2010).

We see the Maker Movement as an opportunity to infuse technology into early childhood curricula through teachers' expertise in familiar staples of early childhood education: dramatic play and exploratory design with art materials. Recent additions to the established body of early childhood research on play and hands-on crafts reveal these developmentally appropriate curricular tools for learning also facilitate equitable participation for diverse learners (Genishi & Dyson, 2009; Marsh, 2010). Making presents a fresh opportunity for meaningful technology integration that encourages not only children's imaginative wondering through playing and crafting, but also productive innovation with new technologies. New child-friendly toolkits are emerging (Kafai & Peppler, 2014; see also chapter 14 of this volume and Peppler, 2016, in volume 2 of this series) that encourage invention and tinkering, but also make visible and actionable the inner workings of new technologies (e.g., e-puppet circuitry, stop-action animation, digital painting, and music).

In celebration of making and its multifaceted opportunities for young children to engage and learn, we recognize that access to developmentally appropriate and innovative technologies is only a first step toward realizing the learning potential of early childhood making. The promise of maker curricula will be unrealized if making simply reinscribes technology divides across class, gender, race, and ethnicity. The Maker Movement, while valuing broad participation and free-ranging exploratory learning, has grown in spaces serving adolescents and adults—more male than female—and narrowly focused goals in order to complete a product within a workshop. New curricular models for understanding and facilitating making are needed that improve the quality and inclusivity of participants' learning experiences, two goals that are also core foundations for early childhood developmentally appropriate curriculum and instruction. Toward that end, we ask:

- What is needed in an early childhood curricular model that not only equally facilitates play, design, inclusivity, and new technologies but also integrates these areas in meaningful ways?

- How does working from children's varied interest-driven orientations affect their individual participation and learning experience: length and depth of their learning engagement, the quality of their interactions, imaginings, collaborations, and innovations?

DESIGNING AN EARLY CHILDHOOD MAKER MODEL: THE SQUISHY CIRCUITS PROJECT

We undertook a qualitative study to understand how a maker model might support technology-integrated learning in early childhood. To develop and refine a model where playful making with technology supports learning, we sought out preschool classrooms where 3- to 5-year olds freely play, create, and imagine together. Over a period of two weeks, we studied how 40 preschool children in these classrooms played, experimented, crafted, and collaborated with Squishy Circuits batteries (Johnson & Thomas, 2010; Thomas, 2011), a commercially available electronic toolkit with light-emitting diodes (LEDs), a motor, buzzers, and a battery pack with two AA batteries (Figure 6.2). When connected properly, these components create working electronic circuits, using the conductive properties of salt in ordinary playdough.

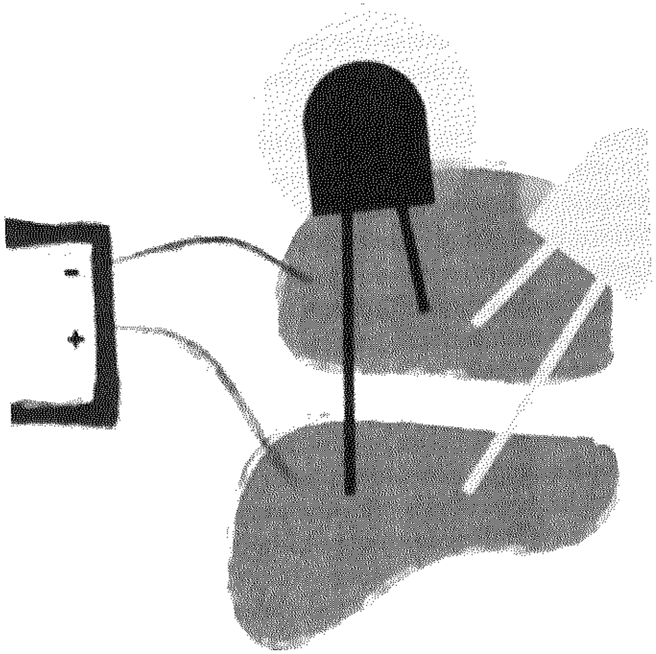


Figure 6.2 A working Squishy Circuit (diagram). Graphic by Anna Keune.

We iteratively developed the maker model over a sequence of seven 1-hour sessions to support young children in mediating advanced electronics concepts by allowing them to design a personalized pathway in and through the project.

We analyzed 23.5 hours of video data of children's interactions with Squishy Circuits, systematically looking at their making using four prominent activities as lenses: play, crafting, collaboration, and circuitry. For example, analyzing data through the lens of the circuitry activity revealed changes in children's stated and enacted conceptualizations of circuitry concepts (connections, polarity, and current flow) (Thompson, Tan, Peppler, Wohlwend, & Thomas, 2016).

We also studied how the emerging data informed our decisions as facilitators as we developed and refined the model. Following recursive processes of design-based research, we analyzed children's responses to the Squishy Circuits materials to see how the model accommodated differences among children's individual orientations—that is, their focus and sets of practices for using the materials on 1) playing or animating materials as toys, 2) designing or crafting artifacts with art materials, 3) collaborating with friends, or 4) solving circuitry technology problems with Squishy Circuit materials (Wohlwend & Peppler, 2015).

Focal Children

Using nexus of practice framing in mediated discourse analysis (Scollon, 2001), we first identified children who engaged deeply (i.e., chose to stay at the table for at least 30 minutes on one or more occasion and returned for at least three sessions) and who produced working playdough circuits. We then analyzed 54 hours of video-recorded activity to identify high-frequency practices, generating four sets of maker practices: play, design, collaboration, and technology. We identified four focal children (two boys and two girls) with high-frequency practices for each set. We then identified nexus of maker practices that created mutually beneficial mergers of two sets (e.g., a technology practice—successfully connecting a circuit—enhanced design practices by enabling decoration because the white LEDs only revealed their color when lit). Comparisons of cases in Table 6.1 showed that children who merged practices participated more often and longer and had more elaborate products and processes (e.g., more detailed aesthetic designs, more cooperative instances with other children). Looking across learners, we found that encouraging a range of orientations expanded the entry points to the making activity, attracting different makers when new crafting tools and materials were added or when new dolls and toys were added (Wohlwend & Peppler, 2015).

Table 6.1 Making orientations, engagement, and outcomes

	Orientation to Making	*Sustained Engagement*	*Elaborated Outcomes*
Suparna (girl)	*Design:* Crafted and decorated playdough	Extended innovative production	Complex use of components and design concepts
Aamir (boy)	*Play:* Animated and turned playdough into toys	Invent meanings and energize participation	Playful fluid improvisation
Lisa (girl)	*Collaboration:* Helped other children make projects	Extended reach and access to multiple projects and problems	Collaborative distributed problem-solving
Nate (boy)	*Technology:* Focused on getting circuit to work	Intense but brief problem-solving	Circuitry hypotheses and explanations

Across cases, we found that opportunities to play, craft, collaborate, and make circuits attracted and held the interest of children who approached the project from different *orientations to making* (e.g., a technology orientation: children like Nate who primarily experimented with electronics materials; a design orientation: children like Suparna who primarily crafted and decorated necklaces or other artifacts out of playdough). While children began from a particular orientation, most children in the study progressed to integrate two or more sets of practices by the last session. The degree to which each child integrated practices and the complexity of their products related to their overall engagement with the materials. For example, circuitry-focused Nate stayed the shortest time and made the least-elaborated projects (left side of Figure 6.3), while Suparna who integrated crafting and circuitry stayed longer, participated in more sessions, explored more circuitry concepts, and created artifacts with more components (right side of Figure 6.3). The difference in their *sustained engagement* meant Suparna had more time to explore and develop technological concepts, but also to develop design concepts and playful improvisation. Important to the goal of promoting inclusivity to work against gender disparity in technology disciplines, girls' and boys' participation in the project were fairly equal in both elaborated outcomes and sustained engagement or time spent at the table.

In the following sections, we share vignettes of two focal cases to provide a glimpse into the learning potential of playful making; Nate represents a technology orientation and Suparna represents a design orientation.

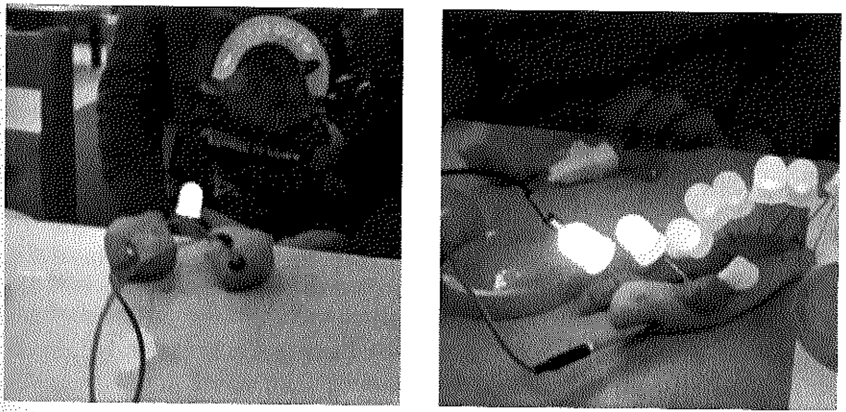


Figure 6.3 Two playdough lumps light an LED (left); a crafted electronic caterpillar (right). Photographs by Verily Tan.

Nate: Focusing on Circuitry

Nate, a blond 5-year-old boy, worked intently to connect circuits and light LEDs. His teachers named him "our circuitry expert." Nate's most productive engagement with the Squishy Circuit materials was on his first day, when he stayed for the entire session. He first attempted a circuit by sticking two battery leads and several LEDs into one lump of playdough. Nate debugged his circuit, noting that the LED turned on when the playdough balls were farther apart and off when they were closer together. Inferring that components must be separated to make the circuit work, he separated the connector wires connected to the LED bulb. He soon discovered the importance of positioning the LED connectors so that current could flow from the negative lead into the bulb and out the positive lead. Nate worked independently but often spontaneously described and explained his experimentation to passing adults: "the LED lights up when it is spread apart and turned the right way." As Nate worked to explore, debug, and adjust this setup, he eventually separated the playdough into two balls, separated the LEDs' connectors, and stuck many LEDs into each ball. An LED lit briefly, but with many components clustered together, tight and durable connection was difficult. Undeterred, Nate systematically removed all but one LED, and then experimented by spreading the playdough pieces farther apart, until finally the LED lit. This accomplished, he played briefly, pretending his playdough and circuitry components were a spaceship ready to take off.

He repeatedly made successful connections, lighting nine LEDs. He paused when finished, advising another child on how to construct a working circuit:

> Oh, and let me tell you one thing. If you do it . . . you have to make two balls and stick one [LED] in one ball and the other in another ball. It won't work if you put it into one ball.—Let me show you something. [He demonstrates with the other child's materials as he explains]. You have to make these little balls and then stick them in. You do that and make another ball and put that in. . . . Oh, and when you put it very close—I didn't explain this–it will turn off [creating a short in the circuit]. And when you take it apart, it will light up.

Finally, he noted the value of persistence to experimentation: "I just kept on trying, and trying, and trying."

Although Nate explored circuitry practices in depth, when compared to the practices of other children who integrated circuitry practices with other quadrants, Nate's sustained engagement was intense but short-lived, beginning and ending on the same day. When his circuit was successfully completed and he had shown his parents his accomplishments, his interest faded quickly, forestalling further elaboration of his hypotheses and explanations.

Suparna: Copying to Innovation

Suparna, a 5-year-old girl, warmed up slowly, her large brown eyes carefully watching the noisy circuit making of other children, finally asking the researcher, "How did you make that?" After much encouragement, she molded a simple snowman with playdough and circuitry components, turning two unlit LED lights into the eyes of her snowman. By the end of the project, Suparna was moving confidently around the room gathering ideas and improvising with materials, finally making a motorized fan that allowed her to explore the color-mixing effects of spinning fan blades.

Suparna participated for 6 out of 7 days; typically, she came to the table as soon as she arrived for the day and remained until the activity ended. Suparna's projects grew in complexity as her skill with circuitry and crafting practices increased: from an unlit snowman to an LED-studded electric caterpillar, a beaded necklace, and a motorized fan. Unlike Nate's trial-and-error approach to circuitry, Suparna copied others' projects to quickly learn to build a working circuit and light an LED. After the LEDs were lit, their colors became visible and Suparna's attention turned to carefully arranging colors (i.e., blue, yellow, red, or green) to decorate her playdough creations. "I have all different colors," she said, pointing to her four LEDs and calling out to others. "Look at the colors that I have. Look at the matching colors I have."

Two days later, Suparna actively explored the aesthetic effects of various crafting tools: cookie cutters and a playdough press. Firmly pressing two cookie cutters into a mound of playdough, she picked up an LED and paused, considering. She divided the playdough into two mounds with a cookie cutter in each, and then tried to insert one LED across the two cookie cutters, but it could not span the center holes of the two cookie cutters. A researcher at the table noted, "We need LEDs with longer legs, don't we?" Suparna tried several strategies to debug her project, first turning the battery pack on and off, then adjusting the LED's position, and finally switching LEDs, "I guess I'll try another one." She finally poked the LED's two connectors into the playdough sticking out at the base of each cookie cutter, and the LED lit (Figure 6.4). Suparna smiled proudly and immediately turned her attention to the playdough press.

On the fifth day, Suparna created her most innovative artifact, a color-mixing fan, made from a motor and colored craft foam. After starting the motor by sticking its leads into two balls of playdough that were connected to a battery pack, Suparna stuck foam shapes on the spinning rotor to create fan blades, watching intently as the yellow and pink bits of foam spun into an orangish circular blur.

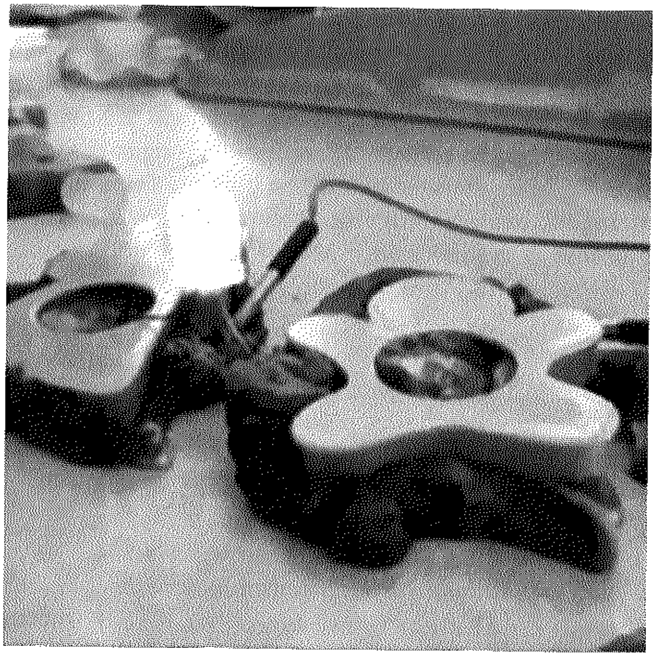


Figure 6.4 Suparna's cookie cutter project. Photograph by Verily Tan.

Suparna's sustained engagement was continuous and progressive, providing the time to watch and copy others, to integrate her circuitry observations with crafting goals, and to innovate with tools and create elaborated artifacts that no one at the table had thought of before, including the adults.

THE DESIGN PLAYSHOP MODEL

We organized our maker model by the four leading domains or quadrants that we observed in the children's approaches to making: *Play, Design, Collaboration,* and *Technology* (Figure 6.5). Making expands design (e.g., visual arts, crafting), play, and collaboration, already valued in preschool education, to include new technologies. The playdough maker kits presented in this chapter featured crafting in the design domain and circuitry in the technology domain. Each domain circulates and values particular social practices (e.g., molding and blending in crafting, connecting, and debugging in circuitry) made up of dispositions, knowledge, and skills gained through mediated experience with others.

Play: Inventing Meanings and Energizing Discoveries

A play orientation provides animated pretense and fluid invention that attracts and holds the attention of players and audiences. Children pretended with the Squishy Circuits materials by inventing meanings for playdough objects, so that a playdough lump became a snowman that could be talked to, sung to, and joked about. Nate used play to entertain himself between discoveries: launching a blob of playdough and turning it into a spaceship kept him at the table for a few minutes longer. His play appeared to be a temporary diversion, useful in keeping him at the table but not in generating new ideas or hypotheses. By contrast, playful Aamir invented toys and characters continually while experimenting with circuits and sharing his discoveries with friends.

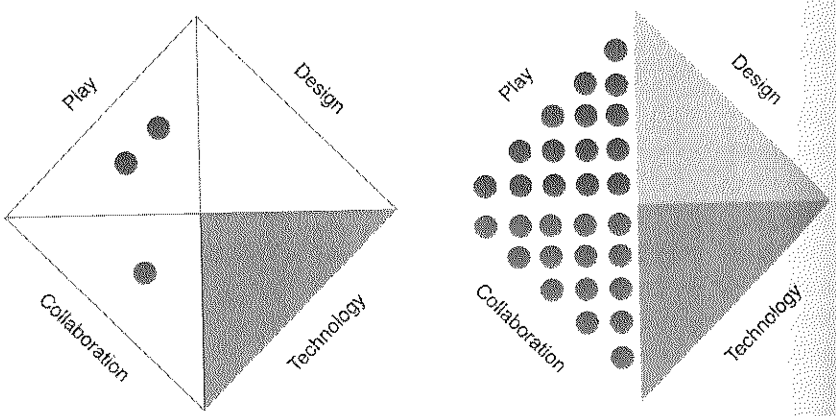


Figure 6.5 Design Playshop orientations for Nate (left) and Suparna (right). Graphic by Anna Keune.

Design: Assembling Innovation Across Artifacts

A crafting orientation values aesthetic decision making, design abilities, and innovation. Through her sustained engagement with the Squishy Circuits materials, Suparna's crafting became more complex throughout the project as she integrated circuitry with crafting to produce more elaborate artifacts. Each artifact was an assemblage of materials, practices, and design abilities that grew with each project, producing a sequence of progressive innovation. Suparna started by crafting a simple playdough snowman and familiarized herself with electronic components by using unlit LEDs as its eyes. Her next craft project was a copy of a sample product provided by the research team—a playdough caterpillar that included several lit LEDs—and her final project was her own working electronic innovation. By contrast, Nate's limited use of design kept him focused on problem-solving one goal in a single project: lighting an LED in two lumps of playdough.

Collaboration: Extended Reach and Growing Expertise

A collaborative orientation supports shared knowledge production and distribution; helping and showing others are valued as ways to spread knowledge among makers. Nate shared and explained how to connect a circuit for others as demonstrations of his independent problem-solving and emerging circuitry knowledge. However, a collaboration lens reveals the value of Suparna's copying and attentive watching of peers and adults that enabled her to quickly develop more sophisticated designs and explorations, ending in an innovative experiment: mixing colors through motion using a motorized fan in her playdough circuit.

Technology: Efficient and Effective Problem-Solving

A technology orientation values trial and error and efficient debugging that produces a working circuit. Nate engaged predominantly in circuitry experimentation, hypothesizing and explaining his findings. After Nate successfully completed the challenge of creating a working circuit with LEDs, he quickly lost interest. Contrasting this to Suparna's rich and sustained engagement, we wonder how much more he might have achieved with circuitry if his engagement had included more integration of play, design, or collaboration.

As we expanded the curricular model to encompass four orientations to making, we found we also needed to expand our research orientation to children's learning, challenging our own familiar patterns of focused curricular implementation. Through systematic daily researcher debriefings and review of video data, the research team realized early in the project that we had inadvertently privileged a technology orientation by tending to encourage children to engage in problem-solving with circuitry and ignoring the other orientations, at times even unthinkingly interrupting and redirecting children's play, collaboration, or crafting. We quickly adjusted the provision of materials and our own researcher facilitation to support exploration and encourage children's use of other quadrants. For example, to increase the potential for design, we intentionally commented on and modeled ways of combining colors and molding shapes and added additional colors of playdough, decorative beads, plastic figurines, and a Fun Factory Play-Doh press.

Each quadrant contributes a key process for making. *Play* and *design* mediate artifacts and environments. Pretend play attaches new meanings to everyday objects while design creates and emphasizes new forms. When combined, play and design enhance and strengthen their shared effects: Play fluidly creates shared meanings through playful innovation that are made stable, durable, and portable through design practices that realize, elaborate, and emphasize the essence of new meanings. In other words, design makes pretend meanings concrete by turning a mercurial play idea into an anchoring artifact (Wohlwend, 2011). Similarly, *technology* practices materialize and test hypotheses or concepts (e.g., through circuitry practices, children manipulate components to test their ideas about working circuits [Glauert, 2005, 2009]). Finally, *collaboration* amplifies this productive transformation, allowing ideas and practices to travel and spread, or at times bringing children together to pool resources and solve problems (Wohlwend et al., 2013).

The Design Playshop model has relevance to the design and study of makerspaces programming beyond this preschool. This study of collaborative playful design and technology learning illuminates the educational potential of play for expanding learning environments. How might makerspaces, such as facilitated workshops or informal museum spaces, expand to intentionally design for play and collaboration? The interest-driven, equitable, and engaged learning that a play-based model facilitates is particularly relevant to makerspaces that merge rigorous science, technology, engineering, and mathematics (STEM) learning with creative innovation in the arts (STEAM), such as mergers of electronics and e-textile crafting in digital puppetry or fashion design. Finally, the study points to the need for further theorization and empirical research for play-based, technology-integrated curricula that provide opportunities for children to play and collaborate while designing with new technologies.

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"*Makeology* is the first broad and comprehensive examination of the Maker Movement as a catalytic force for young people's learning. Practitioners and scholars interested in implementing and studying making as a force for creative expression and student-centered learning will find in this two-volume collection a wealth of thoughtful and significant information."
—Margaret Honey, President & CEO, New York Hall of Science, USA

"Our goal should be helping children see themselves as good learners, as lifelong learners. The impact of what they create, design, shape, and build will be known in the future, but the time for making it happen is now. This book can increase the opportunities for making in educational settings by sharing the insights of many leading practitioners."
—Dale Dougherty, Founder & Executive Chairman, Maker Media, Inc., USA, from the foreword

"One thing we have in common is our commitment to putting more power in the hands of people from all backgrounds, enabling everyone to develop their voice and express themselves. There's a special opportunity right now. But that moment could also slip away, so it is all the more important to make connections and join forces with other communities with shared values, to make sure that all children have the opportunity to grow up as full and active participants in tomorrow's society."
—Mitchel Resnick, LEGO Papert Professor of Learning Research and head of the Lifelong Kindergarten group at the Media Laboratory at Massachusetts Institute of Technology, USA, from Volume 2

Makeology introduces the emerging landscape of the Maker Movement and its connection to interest-driven learning. While the movement is fueled in part by new tools, technologies, and online communities available to today's makers, its simultaneous emphasis on engaging the world through design and sharing with others harkens back to early educational predecessors including Froebel, Dewey, Montessori, and Papert. *Makerspaces as Learning Environments (Volume 1)* focuses on making in a variety of educational ecosystems, spanning nursery schools, K–12 environments, higher education, museums, and after-school spaces. Each chapter closes with a set of practical takeaways for educators, researchers, and parents.

Kylie Peppler is Associate Professor of Learning Sciences at Indiana University.

Erica Rosenfeld Halverson is Associate Professor of Digital Media and Literacy in the Department of Curriculum & Instruction at the University of Wisconsin–Madison.

Yasmin B. Kafai is Professor of Learning Sciences at the University of Pennsylvania.

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