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Tangible Interaction and Cultural Forms: Supporting Learning in Informal Environments

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Designers who create computer-based learning experiences for places like museums, out-of-school programs, and homes face a number of challenges related to the informal nature of such settings. Designs must generally function on their own without the support of teachers or curriculum while at the same time engaging a diverse audience, supporting productive social interaction, and activating appropriate prior knowledge and skills. In this article, I present an approach to the design of informal learning experiences based on tangible interaction. The term *tangible* refers to a variety of human–computer interaction techniques that move beyond computer screens and create opportunities for people to interact with digital systems using their bodies and physical artifacts. I argue that tangible interaction creates unique opportunities for designers to shape objects and situations to evoke cultural forms of literacy, learning, and play. In particular, I propose a class of cultural forms called *cueing forms* that can invite participation into patterned social activity while cueing cognitive, physical, and emotional resources on the part of individuals. To illustrate these arguments, I describe 3 design cases that colleagues and I have created to support learning in museums and homes.

Designers who create interactive learning experiences for places like museums, out-of-school programs, and homes face a number of challenges related to the informal nature of such settings. When a family visits a museum, for example, it has a large degree of freedom over what it chooses to see and do, with family members drifting in and out of activities according to individual interests and

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preferences (Falk & Dierking, 2000; Heath, Vom Lehn, & Osborne, 2005; Humphrey & Gutwill, 2005; Vom Lehn, Heath, & Hindmarsh, 2001). Engagement times tend to be short, and designs must stand on their own without the support of teachers and curriculum. Accordingly, designers strive to create experiences that appeal to a broad audience and that draw people into progressively deeper levels of engagement as they move from learning about how an interface works (at the level of usability) to learning about the underlying concepts that a design is attempting to convey (Allen, 2004; Davis et al., 2015; Heath et al., 2005; Hornecker, Marshall, & Rogers, 2007). For all of these challenges, seemingly small changes in a design can result in dramatic differences in the quality of experiences that people have with and around interactive artifacts (Block et al., 2015; Borun, Chambers, Dritsas, & Johnson, 1997; Eberbach & Crowley, 2005; Horn, Solovey, Crouser, & Jacob, 2009; Humphrey & Gutwill, 2005).

It is not surprising that digital technologies play a central role in many such learning experiences. Computers are increasingly inexpensive and reliable and can combine engaging multimedia content, sophisticated forms of interaction, and new means of audience participation (Louw & Crowley, 2013; Ma, Liao, Ma, & Frazier, 2012; Meisner et al., 2007; Roberts, Lyons, Cafaro, & Eydt, 2014; Simon, 2010; Snibbe & Raffle, 2009). Some examples common in museums include whole-body interaction (e.g., Lyons, Slattery, Jimenez, Lopez, & Moher, 2012; Roberts et al., 2014; Snibbe & Raffle, 2009), multitouch tabletops (e.g., Antle, Tanenbaum, Seaborn, Bevans, & Wang, 2011; Block et al., 2012; Horn, Leong, et al., 2012), augmented reality (Beheshti, Kim, Ecanow, & Horn, 2017; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012), and tangible interaction (Horn, Crouser, & Bers, 2012; Lyons et al., 2015; Ma, Sindorf, Liao, & Frazier, 2015; Oh et al., 2013). In the aid of crafting informal learning experiences that make use of such technologies, a number of frameworks, recommendations, and design principles have been proposed (Antle, Corness, & Droumeva, 2009; Hornecker et al., 2007; Humphrey & Gutwill, 2005; National Research Council, 2009; Snibbe & Raffle, 2009). However, much of the theoretical work in this area (like the technology itself) is still in formative stages of development.

In this article, I build on this existing work and offer an approach to the design of informal learning experiences based on tangible interaction techniques. Tangible interaction is an approach to human–computer interaction that attempts to move beyond computer screens by allowing people to use their bodies and physical artifacts to interact with digital systems (see Hornecker & Buur, 2006; Ishii & Ullmer, 1997). My central argument is that tangible interaction creates unique opportunities for designers to shape objects and situations to evoke existing cultural forms of literacy, learning, and play. In particular, I propose a class of cultural forms called *cueing forms* that can invite participation into patterned social activity while cueing cognitive, physical, and emotional resources on the part of individuals. I derive this approach from cultural-historical activity theory and from the work of Saxe (1991, 2012), Cole (1998), Stevens (2007), and Nasir (2005), among others. In the next section I provide a brief overview of tangible interaction and its theoretical foundations followed by a description of what I mean by cueing forms as they apply to interaction design. I then discuss three design cases that colleagues and I have created based on this perspective: a museum exhibit on computer programming and robotics; an interactive sticker book designed to support emerging computational literacy skills for young children; and a board game designed to help families think about tradeoffs related to energy consumption, comfort, and environmental sustainability. These design cases are meant to convey the breadth and potential of this space while highlighting different aspects of cueing forms and their impact on informal learning. I conclude with a summary of this design approach and broader considerations for the use of technology in informal environments.

TANGIBLE INTERACTION

Tangible interaction has roots in the ubiquitous computing movement of the late 1980s and early 1990s articulated by researchers at Xerox PARC. Among the hallmarks of this vision was the idea that machines would increasingly conform to human dimensions, capabilities, and activity structures rather than the other way around (Weiser, Gold, & Brown, 1999). Many aspects of ubiquitous computing have been realized over subsequent years, especially through the mass availability of smartphones, tablet computers, large interactive displays, and smart objects and infrastructures. Building on these ideas, Ishii and Ullmer (1997) coined the term *tangible* to describe a class of computer interfaces that used a variety of physical objects and surfaces as a means of both manipulating and representing digital information. For example, in the Urp project, urban planners could manipulate physical models of building to interact with digital simulations of wind, sunlight, and shadows in an urban environment (see Ullmer & Ishii, 2000). Their use of the term *tangible* to describe such systems was in part meant to capture the idea that much of the richness of human interaction with the physical world through the use of tools has been replaced by uniform interaction with narrow bandwidth input devices such as mice, keyboards, and touchscreens. Incorporating a variety of physical objects and multisensory feedback was seen as a way to recapture some of this richness and to humanize human–computer interaction. Similar ideas of blending digital and physical interaction were explored in the work of Papert (1980), Perlman (see McNerney, 2004), Resnick et al. (1998), Suzuki and Kato (1995), and Weiser et al. (1999), among others. The influence of Papert and his colleagues and students in particular was a substantial if underacknowledged force in the emergence of tangible interaction around the turn of the century.

Whereas early definitions of tangible user interfaces concerned the ability to couple physical object manipulation with digital information (Ullmer & Ishii, 2000), later definitions such as Dourish's (2001) notion of embodied interaction and Hornecker and Buur's (2006) tangible interaction emphasized the degree to which interactive systems could be meaningfully embedded in physical, social, and cultural contexts. In this sense, tangibility became less about the physical nature of the interface and more about the idea that interaction with digital systems could be entangled within material and social realities beyond that of an individual sitting in front of a computer screen. Dourish in particular attempted to capture the complex relationship among interaction, objects, and meaning as it is constructed through social and cultural practice: "The analytic exploration of embodied interaction has repeatedly uncovered the way that objects carry meaning on multiple levels: as entities in their own right, as signifiers of social meaning, as elements in systems of practice" (p. 166).

Similar research has argued that it is important to create computer systems that are responsive to social and cultural factors (Kafai, Searle, Martinez, & Brayboy, 2014; Kern, Hamilton, & Toups, 2012; Mackay, 2000; Suchman, 2007; Weiser et al., 1999). Lee's cultural modeling design framework, for example, advocates for the design of learning environments that are responsive to school students' socially constructed ways of knowing (Lee, 2003). She demonstrated the application of this framework in the design of a multimedia literacy environment that is responsive to linguistic and cultural traditions of students in schools. More recently, Kafai and colleagues (2014) have explored notions of culturally responsive computing that creates design tools based on cultural practices and resources. For example, they have developed computational literacy activities based on e-textiles for youth in indigenous communities in the U.S. Southwest.

Tangible Interaction and Learning

Since the idea of tangible interaction was first introduced, numerous tangible learning environments have been developed (see Shaer & Hornecker, 2010). These include systems such as digital manipulatives (Resnick et al., 1998), tangible programming languages (Fernaeus & Tholander, 2006; Horn, Crouser, et al., 2012; McNerney, 2004; Wyeth, 2008), physical/digital construction kits (Raffle, Parkes, & Ishii, 2004; Schweikardt & Gross, 2008; Zuckerman, Arida, & Resnick, 2005), literacy tools (Hengeveld, Hummels, & Overbeeke, 2009; Sylla, Branco, Gonçalves, Coutinho, & Brito, 2012), and science education environments (Moher, 2006). Although these designs are exciting and novel, the theoretical and empirical justification for their support of learning compared to more conventional digital environments is often tenuous (Clements, 1999; Marshall, 2007; Marshall, Cheng, & Luckin, 2010). Arguments in favor of tangible interaction appealed to pedagogical traditions of Fröbel and Montessori (Resnick et al., 1998; Zuckerman et al., 2005), Piagetian notions of learning through sensorimotor experiences with the physical world, and ideas of working with concrete versus abstract representations (see Clements, 1999; Marshall, 2007). Other motivations were more pragmatic in nature, such as offering better support for collaboration and improved accessibility for young children (Horn, Crouser, et al., 2012; Zuckerman et al., 2005) or children with cognitive impairments (Hengeveld et al., 2009; Piper, O'Brien, Morris, & Winograd, 2006). However, a prevalent assumption (often based more on intuition than evidence) is that physicality in its own right can lead to improved learning experiences (Marshall, 2007).

WHAT ARE CULTURAL FORMS?

Building on this prior work, I propose that a defining characteristic of tangible interaction is that it creates new opportunities for designers to shape objects and situations to evoke cultural forms of literacy, learning, and play. My use of the term *cultural forms* is derived from the work of Geoffrey Saxe (1991, 2012) and his form–function shift framework. Briefly, Saxe attempts to integrate individual cognitive development with changes that take place at the level of communities and cultures. His framework accounts for the ways in which individuals continually appropriate and adapt cultural forms in light of shifting goals and expectations and how modified forms then spread through communities and cultures (Saxe, 2012). Saxe's research with the Oksapmin people of Papua New Guinea provides a vivid example. These communities used a 27-digit counting system in which body parts were enumerated, starting with the thumb on one hand and ending with the little finger on the opposite hand. Saxe documented the adaptation of traditional counting forms to incorporate Western currency systems and mathematical operations such as addition and subtraction. The traditional forms were not eradicated or replaced but rather were restructured by individuals to incorporate new currency and number systems in light of emerging goals.

Saxe describes cultural forms as historically elaborated social constructions, conventions, and systems of representations, including counting systems, games, tools, and monetary currency. This definition has similarities to Cole's (1998) notion of artifact as "an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action" (p. 117). Artifacts in Cole's perspective are both material and conceptual, encompassing language, representation systems, physical artifacts, and social norms. Related perspectives similarly account for the interdependent nature of individual and cultural development and the role of cultural artifacts and symbol systems in mediating human activity (e.g., Bruner, 1990; Dourish, 2001; Engeström, 1993; Rogoff, 2003; Vygotsky, 1978). Central to all of these perspectives is the notion of human activity and practice. There is a mutual dependency between cultural forms and routinized patterns of social activity: Activity gives rise to cultural forms and enables them to persist and evolve over time (historical elaboration). Forms in turn facilitate and structure human activity and thought. The appropriation of forms by individuals and social groups leads to the transformation and evolution of both forms and activity in light of emergent goals and expectations (Saxe, 2012).

Cueing Forms

The definition of cultural forms that I have sketched so far is quite broad, encompassing everything from representation systems and social norms to tools and games. Other definitions commonly used in the learning sciences emphasize social constructs that mediate positioning and identity formation (e.g., Eisenhart, 2001; Holland & Leander, 2004). In this article, however, my interest is narrower. I propose a class of forms that I refer to as *cueing forms* with five properties of particular interest to designers of informal learning experiences (see Table 1). Specifically, I define *cueing forms* as cultural forms of literacy, learning, and play that invite participation into patterned social activity while cueing resources that individuals can bring to bear on novel learning experiences.

TABLE 1
Five Properties of Cueing Forms of Relevance to Designers of Informal Learning Experiences

Property	*Description*
Property 1	Cueing forms can be evoked through the use of physical artifacts, symbols, or situational cues. The *legibility* of a cueing form refers to how easy or difficult it is for participants to recognize a form in a given circumstance.
Property 2	Once recognized, cueing forms invite participation into patterned social activity while suggesting roles for various participants to play.
Property 3	Cueing forms involve situated resources that individuals can bring to bear on an activity.
Property 4	Cueing forms are malleable—designers can adapt and combine them with other forms in novel ways while preserving aspects of the original meaning.
Property 5	Cueing forms suggest a relationship between a learning domain, personal identity, and existing cultural expectations and norms about who can and should engage in a particular type of learning activity. As cultural forms, cueing forms will be interpreted differently by participants depending on their background, value systems, and goals for engaging in a particular learning activity. These differences in interpretation will also impact the resulting learning activity.

To better understand the concept of cueing forms, consider the game rock–paper–scissors. This is a simple hand game thought to date back at least 2,000 years to ancient China with variants played throughout the world. One might speculate about the success of this game. It requires no specialized equipment and can be played just about anywhere, it fulfills basic human needs such as resolving minor disputes and providing entertainment, and it has a certain mathematical elegance that makes it easy to teach and learn. The broader point is that rock–paper–scissors is a highly recognizable cultural form that has persisted over a long period of time and spread across a variety of cultural landscapes. And as a cueing form, the game has each of the five properties listed in Table 1.

Cueing forms can be evoked in various ways through the use of physical artifacts, symbols, situational cues, or other signifiers. For example, hand gestures such as a closed fist, an open palm, and index and middle fingers extended in a V shape readily call to mind rock–paper–scissors without the need for written or verbal descriptions. The idea is that designers can intentionally shape learning environments so that the intended cultural forms are recognizable to participants. The physical nature of tangible interaction opens up new possibilities for designers to evoke existing forms in ways that go beyond media limited entirely to on-screen representations afforded by traditional computer systems. If nothing else, tangibles allow for the incorporation of diverse materials that occupy physical space. The legibility of a particular form depends on many additional factors, including the background and experience of the audience, the context of use, and the fidelity of a given representation to its source form. I elaborate on this relationship between physical embodiment and the ability to evoke cultural forms in the three design cases below.

This first property of cueing forms is related to Norman's (2002) notion of perceived affordances as perceived or actual properties of an object that communicate how it might be used. But with cueing forms, my emphasis is different. The term *perceived affordance* places an emphasis on the object itself and how the object might be used while deemphasizing the elaborate patterns of social activity that can transpire around particular cultural artifacts. If I do not recognize a $20 bill as monetary currency, then it is just a piece of paper. That piece of paper has certain affordances: It affords writing, folding, crumpling, and so on. But as a $20 bill, the paper has meaning in terms of practices that involve the storing and exchange of currency for goods and services. More recently, Norman (2008) pointed out that the concept of perceived affordance fails to capture the full implications of these kinds of phenomena and instead proposed the term *social signifiers* to refer to physical or social indicators that cue social behavior.

This leads to the second property of cueing forms: They can invite participation into patterned social activity and shape expectations about the roles that various participants will assume. Rock–paper–scissors is a relatively simple example that involves the coordination of two people over short periods of time. Other forms can involve more people over longer periods in different configurations with more or less structure. This property of cueing forms is valuable to consider because in many informal learning situations the social activity that takes place around an interactive artifact is at least as important as the usability of the object itself. So, for example, when a parent and child read a storybook together, what is on the pages of the book is arguably less important than the interaction that takes place between the parent and child as they read together (Anderson, Anderson, Friedrich, & Kim, 2010; Bus, Van Ijzendoorn, & Pellegrini, 1995). This ability to support productive social interaction is a critical but often overlooked aspect of design.

A third property of cueing forms is that they help cue situated resources that individuals can bring to bear on novel learning activities. These resources are not limited to cognitive dimensions and can, for example, involve physical coordination or emotional dispositions toward an activity. Even for a simple game like rock–paper–scissors, these resources can be surprisingly sophisticated. Players have the ability to remember and reproduce various hand gestures and rhythmic verbal phrases, they can enact and negotiate the rules of the game with another person, they can perhaps imagine their opponent's mental state to anticipate their next action, and they can cheat or bend the rules ("Come on, how about best five out of seven?"). As designers set out to create interactive learning experiences, it is worth considering such situated resources in terms of both helping users understand how an interface works and activating relevant knowledge and skills to make sense of new concepts targeted by the design.

A fourth property of cueing forms is that, like all cultural forms, they are malleable—they can be adapted, appropriated, and combined with other forms in novel ways (a property that Saxe, 2012, referred to as *hybridity*). The implication for interaction design is that cultural forms can be remixed and repurposed to create new experiences. Engeström (1993) captured the dynamic and evolving nature of sociocultural activity systems: "An activity system always contains sediments of historical modes, as well as buds or shoots of its possible future" (p. 68). Taking up this metaphor, I argue that these buds and shoots are of particular interest to interaction designers, as they represent potentially novel activities that are nonetheless rooted in existing and familiar modes. Cueing forms could be a way to help designers ground activities in the familiar while at the same time opening novel possibilities.

Finally, cueing forms have the potential to suggest a relationship between activity, learning domain, personal identity, and existing cultural norms and expectations. Falk (2009) argued that much of the learning that takes place in museums is deeply influenced by interconnections between identity and narratives that visitors construct to explain the relationship between who they are and what they are doing on a particular day at a particular institution. These entry narratives are used to continually construct and maintain identity (or identities) as they emerge out of interactions with the social, cultural, and physical environment. As he put it, "Most museum visitors 'enact' a museum 'identity' during their visit" (Falk, 2006, p. 154). I propose that on a microlevel, when visitors encounter interactive artifacts in a museum (or any informal learning environment), a largely unconscious calculus spins out a relationship narrative between the artifact, the individual visitor, the social group, and broader cultural expectations and norms about just who can and should participate—"Oh that's something I would like to try" or "I would be embarrassed to try that with all my friends around" or "That seems boring." Excellent examples come from research and design work that incorporates computing and electronics with traditional crafting materials and pursuits (sewing, origami, textiles, scrapbooking, greeting cards) as a way to engage people who would not ordinarily self-identify as technology hackers (Buechley, Peppler, Eisenberg, & Kafai, 2013; Buechley & Perner-Wilson, 2012; Eisenberg, 2003; Kafai, Fields, & Searle, 2012; Kafai et al., 2014). DiSalvo's research on the face-saving strategies of African American youth who engage in computing clubs is another relevant example (DiSalvo, Guzdial, Bruckman, & McKlin, 2014). It is important to emphasize that cueing forms will be interpreted differently by participants depending on their background, culturally rooted value systems, and the activity itself. These differences in interpretation will have consequences for the resulting learning activity that takes place around an interactive artifact.

DESIGN CASES

In this section I describe three design cases meant to illustrate the potential of cueing forms for shaping real-world informal learning experiences. The first case is an exhibit on robotics and computer programming that was installed at the Museum of Science, Boston. We conducted research with both tangible and nontangible variants of the exhibit. I argue that the design variants affected the legibility of the underlying cueing form and in turn impacted visitors' social engagement and learning. The second design case involves an interactive digital experience embedded in a children's storybook. I use this example to illustrate some of the ways in which cultural forms can be malleable yet still cue valuable resources on the part of participants (in this case parent–child literacy practices). This case also provides an example of how people from different cultural and linguistic backgrounds might interpret cueing forms in subtly different ways. Finally, I share an example from the world of games. I show how a hybrid digital/physical family board game cued patterned social activity that provided structure for in-depth family discussion, negotiation, and learning.

Design Case 1: Tangibles and the Legibility of Cueing Forms

The first design case is a museum exhibit on computer programming and robotics called Robot Park that I developed with colleagues[1] at Tufts University and the Museum of Science, Boston. At the exhibit, visitors could build simple computer programs to control the movement of a robot that roamed around a platform. Unlike typical computer programming experiences that involve typing or arranging visual elements on a computer screen, visitors would instead build physical programs by connecting chains of wooden blocks (see Figure 1, left) shaped like jigsaw puzzle pieces. When visitors pressed a RUN button, a computer vision system would convert these tangible programs into digital instructions that controlled the actions of the robot.

To evaluate the efficacy of this approach compared to more conventional methods of programming, we conducted a study involving an equivalent graphical programming language (see Figure 1, right). With the graphical language, visitors created programs by dragging and connecting visual jigsaw puzzle blocks on a computer screen using a standard computer mouse. The same exhibit installation was used in both conditions, with the only difference being the input method (wooden blocks or computer mouse). For both conditions, we observed visitors from a distance as they interacted with the exhibit, keeping track of holding times, patterns of interaction, visitor group composition, and the number and complexity of visitor programs. We also kept track of all visitors who approached the exhibit and, of those, the number who stopped to try the exhibit (capture rate). Finally, we recruited a small number of families to participate in semistructured postinterviews. As part of this study, we observed a total of 260 individuals at the museum (108 for the graphical condition and 152 for the tangible condition) from late morning to mid-afternoon. Of these, 104 of the participants were children (47 tangible and 57 graphical).

Summary of Findings

A full account of this study is available in Horn et al. (2009). However, to briefly summarize the results, there were three areas in which we observed substantial differences in visitor interaction. First, with the exception of adult males, the number of visitors who stopped to try the exhibit increased dramatically when there were wooden blocks on the table as opposed to a computer mouse. For example, around one third of girls who approached the exhibit in the mouse condition stopped to try it. This increased to 85.7% of girls in the tangible condition (see Figure 2). Second, we noted a significantly larger proportion of active participants in visitor groups. In other words, if a visitor group stopped to

[1]Robert Jacob, Erin Solovey, Daniel Ozick, Dan Noren, Taleen Agulian, Lucy Kirshner, R. Jordan Crouser, and Bill Rogers contributed to the development of Robot Park.

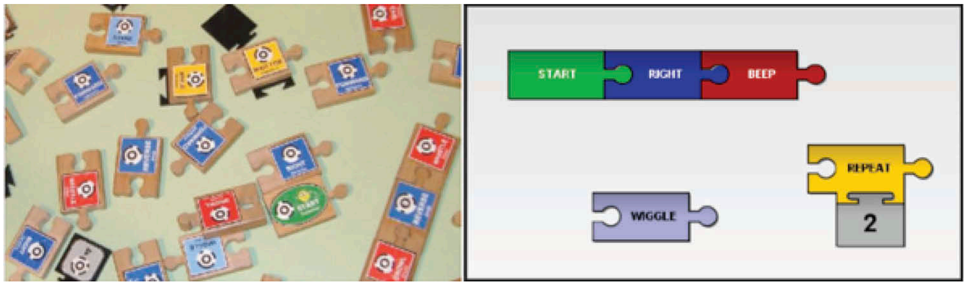

FIGURE 1 The Robot Park exhibit featured a tangible interface that museum visitors would use to construct physical computer programs out of wooden blocks shaped like jigsaw puzzle pieces (left). A study compared visitor interaction with the physical blocks to visitor interaction with graphical blocks displayed on a computer screen (right).

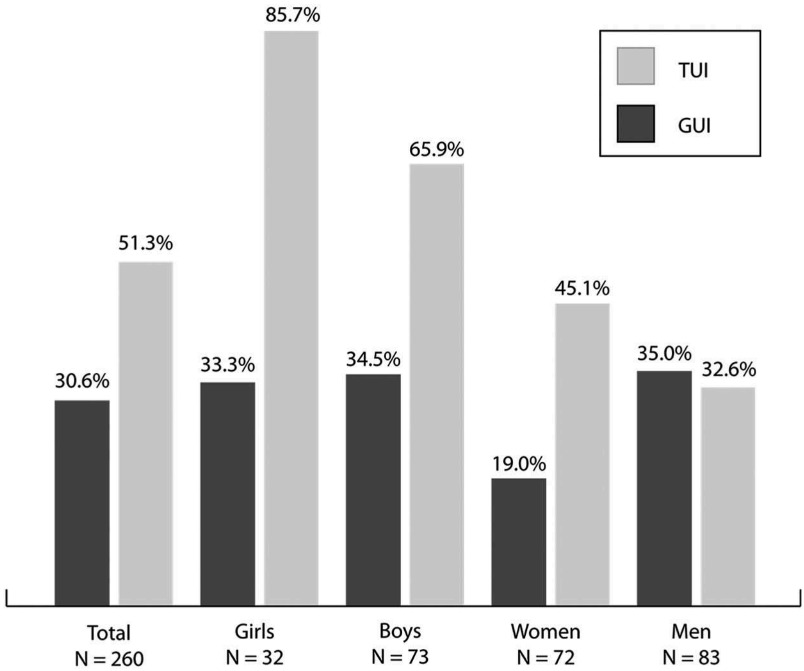

FIGURE 2 Percentages of museum visitors who stopped to interact with the Robot Park exhibit after noticing it. Dark gray bars represent visitors in the graphical, screen-based condition, and light gray bars represent visitors in the tangible condition. TUI = tangible user interface; GUI = graphical user interface.

try the exhibit, more family members were involved in physically interacting in the tangible condition than in the graphical condition. And third, we noted a qualitative shift in the ways in which parents and children worked together. In the tangible condition the activity appeared more child driven, with parents taking on more of a supportive role, whereas in the graphical condition parents often drove the activity and had control over the mouse. In one of our participant interviews, for example, we asked a father–daughter pair to complete a number of programming tasks using the mouse-based interface. For these tasks, the girl sat on her father's lap while he controlled the mouse to complete the tasks. Midway through the interview, we switched the interface to the wooden blocks. At this point, the daughter hopped off of her father's lap and took over the programming tasks for the rest of the session (see Horn et al., 2009, for a full account of these results).

Our results were somewhat unexpected. In particular, the increase in the voluntary engagement of boys and girls with the exhibit seemed in need of an explanation. It could be that the tangible blocks were more novel than the mouse—an argument that would carry more weight were the setting not a hands-on science museum full of whimsical objects to play with. It could also be that the blocks provided visitors with multiple objects that could be independently manipulated, thus supporting more side-by-side collaborative engagement. It is also plausible that the blocks were simply more appealing or child friendly than the mouse and the screen-based blocks. But this last explanation begs deeper questions: Why would the blocks be more appealing to visitors? And why would visitors perceive them as more collaborative or child friendly? My proposal is that the wooden blocks evoked a strong and recognizable cueing form (something akin to a jigsaw puzzle) that suggested particular patterns of engagement while appealing to a different segment of the potential audience. In contrast, the most salient aspects of the graphical system might have been the physical components, the computer mouse and monitor—entirely different (and more polymorphic) cultural forms with different associated resources. According to this theory, when visitors first encountered the exhibit, they made rapid value judgments based on personal identity, existing cultural expectations, and the artifact that they perceived as being on display. These judgments impacted their decisions to try the exhibit in the first place, their default patterns of social engagement (Is this something I let my child explore on her own, or is this something I demonstrate to her?), and the resources and strategies that they brought to bear on exploring the interface and its functionality. Here it is interesting to note that the graphical interface also presented a jigsaw puzzle as an on-screen representation. However, the legibility of the form on screen might have been degraded because of the relative salience of the physical components of the exhibit (namely, the computer mouse and monitor). In other words, in a crowded museum environment with many possible activities that visitors can engage in, the physical blocks were simply easier to notice and recognize than blocks on the computer screen.

This study was not designed to test or validate the notion of cueing forms. Rather, the empirical results highlighted the need for a theoretical explanation that ultimately led to the development of the idea of cueing forms. In terms of the five properties in Table 1, the exhibit interface could be understood as building on a cueing form that was evoked through the use of the block representation. The differences between the two conditions could be attributed to differences in the legibility of the form with visitor groups. Particularly in the tangible condition, the exhibit seemed to activate emotional, social, and physical resources associated with playing with blocks or assembling a jigsaw puzzle. It is possible that these resources helped participants understand how the interface was supposed to work. And the cueing form was malleable. Visitors could simultaneously interpret the wooden blocks both as toys and as a computer programming language. Finally, one explanation for the differences between the two conditions is that a relationship between the cueing forms and visitor identity helped make the activity appealing to a more diverse audience. Or, to put this a different way, children simply found the blocks-based exhibit more closely matched to the kinds of experiences they were looking for at the museum.

Design Case 2: Computational Literacy Sticker Book

For the second design case, we were interested in expanding our tangible programming technology to support simple computational literacy activities for preliterate and early-literate children (Horn, AlSulaiman, & Koh, 2013). We envisioned an out-of-school activity that parents and children would engage in together at home or in similar informal settings, but we were faced with a core design challenge that children with rapidly changing literacy skills would require the support of a parent or other caregiver to structure the activity and tailor it to their needs, abilities, and interests. At the same time, we recognized that many parents would have little or no computer programming experience that they could fall back on to support their children.

Thinking about this project from the point of view of cultural forms suggested several possible design approaches that we might have taken. One approach was inspired by diSessa's (2000) notion of computational literacy as a social, material, and cultural complex of practices and artifacts with direct parallels to other forms of literacy. This led to the idea that we might try to build on parents' existing language literacy practices (particularly those that supported children's acquisition of reading and writing skills) by embedding our activities within the cultural form of a children's storybook. Storybook reading activities have been shown to promote early literacy skills and reading achievement in elementary school (Anderson et al., 2010; Bus et al., 1995). These activities include making spontaneous connections between the text of the book and the world of the child, providing emotional encouragement, and dynamically adapting the reading session to the child's skill level (Bus, Leseman, & Keultjes, 2000; Bus et al., 1995). Through the use of a storybook, we hoped to cue such language literacy practices while providing a framework for parents to scaffold their children's emerging computational literacy skills.

Based on this review of the parent–child storybook reading literature, the children's storybook seemed like a good example of a cueing form. First, we anticipated that it could be evoked through the use of physical materials and graphical/textual conventions of children's picture books. The storybook genre, although diverse, has many well-established conventions that make it easily recognizable to a diverse audience. Second, research suggests that children's storybooks are deeply linked to joint parent–child reading, a patterned social activity associated with a delightful array of practice-linked resources that parents and children bring to bear on the activity (Anderson et al., 2010; Bus et al., 1995). Ideally the storybook makes the activity appealing to children, but, perhaps more important, it makes the activity more palatable and approachable for adults by grounding and scaffolding their involvement.

The book we created follows the adventures of a lonely boy named Roberto as he sets off across his city in search of new friends. Throughout the book are pages with sticker activity prompts (see Figure 3) that say things like "Use the stickers to help Roberto dance" or "Use the stickers to help Roberto do his dance three times." To complete the activities, children peel stickers from an attached sheet and adhere them to the pages of the book. Dashed sticker outlines on the pages indicate the structure of the programs that can be created as well as the types of stickers that can be used. Once the stickers are placed on the page, parents and children take a picture of their sticker program using a smartphone or tablet computer and can then watch a digital animation of Roberto acting out their programs. As the story continues, the activities become more sophisticated, following a progression of computer programming concepts such as sequences of actions, infinite repeat loops, counting loops, and sensor logic.

To evaluate our prototype, we were interested in whether the storybook was a good starting point for our design. In other words, was it effective in cueing parents to provide structure and support for their children in the programming activities? We were especially interested in whether and how practices of joint storybook reading would translate into computer programming activities.

Because we were also interested in differences in interpretation of the storybook form, we recruited families from two distinct linguistic and cultural regions: English-speaking families from the U.S. Midwest and Arabic-speaking families from Riyadh, Saudi Arabia. Eight caretaker–child dyads participated in the study in the United States, including four boys and four girls between the ages of 4 and 10 (average age = 6.63, *SD* = 2.0), all of whom spoke English during the study. Six dyads participated in the study in Saudi Arabia, including three boys and three girls between the ages of 4 and 8 (average age = 6.0, *SD* = 1.41), all of whom spoke Arabic. For the Arabic-speaking families, we translated the storybook, stickers, and app to Arabic. We also reversed the direction in which programs were assembled (right to left rather than left to right) in order to be consistent with written Arabic.

Summary of Findings

We presented participants with the storybook, sticker sheets, and a mobile device, and we then invited them to read the story and do the activities together. The full results are presented in Horn et al. (2013); however, a few of our findings are worth mentioning here. Many of the parental support strategies for the activity seemed closely related to strategies for general language literacy, and it was

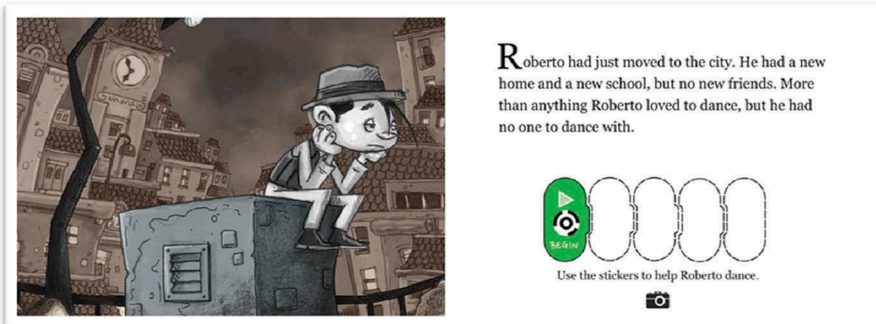

FIGURE 3 A page from the Roberto computational literacy sticker book. Parents and children can create simple computer programs by adhering stickers to the pages of the book along the dashed sticker outlines (bottom right). They can then run this program by taking a picture of the page using a companion app on a smartphone or tablet computer.

difficult to draw sharp distinctions between technical support, language learning, and reasoning about computer programming concepts. For example, the following excerpt comes from a 4-year-old girl and her mother in the United States. The pair was working on a programming activity, and the mother used the opportunity to help familiarize her daughter with the programming stickers:

Mom: So what, what different things can he do in the dance?
Daughter: Uh, that one, and I mean. That one, and that one, and that one [referring to stickers].
Mom: What about these?
Daughter: Well actually, this one.
Mom: Which one is this? What's the word?
Daughter: Spin
Mom: Spin. So what, if we use this sticker, what will he do?
Daughter: Uh, spin.
Mom: This one?
Daughter: Walk.
Mom: Walk.
Mom: [Pointing other stickers in turn]
Daughter: Stand.
Daughter: Run.
Daughter: Spin [inaudible] ah ha ha
Mom: That will be a fun one.

In analyzing the video of the parent–child sessions, diSessa's notion of computational literacy as a sociotechnical system of practice was a productive frame. The mother began this excerpt by elaborating on the programming prompt: "Use the stickers to help Roberto dance." By asking her daughter what "different things can he do," she was orienting her daughter to the physical materials needed for the programming activity—in the video she had positioned the stickers in front of the storybook and was pointing to individual stickers in turn. Throughout the session, the mother positioned the various pieces of equipment for her daughter to notice and identify.

The mother appeared to take advantage of the activity not only to familiarize her daughter with the range of possible programming stickers but also to practice reading skills—the girl at age 4 was just able to read the words on the stickers. The mother pointed to each sticker in turn and waited for her daughter to say the word out loud, after which the mother repeated the word. And by asking her daughter to predict the effect of stickers ("If we use this sticker, what will [Roberto] do?"), she assessed her daughter's understanding of the words on the stickers as well as the ways in which the system would function to control the digital character. The mother in this dyad (like many of the parents in our study) provided a range of technical support to her daughter. This included things like helping her daughter to peel stickers off the sheet, helping her hold and position the tablet computer when it was time to take pictures of the program, and identifying elements of the user interface (such as buttons on the screen) for her daughter to press. Throughout the session, the mother seemed to continually reassess her daughter's ability to manipulate elements of the system, allowing her to perform the tasks on her own when she was capable. On another level, the mother seemed to be emotionally framing the activity for her daughter by saying things like "That will be a fun one." In other words, she was setting up the activity as something that would be enjoyable to participate in.

There were also pronounced differences between the reading activities of families in Saudi Arabia and the United States. Prior research comparing parent–child reading practices of Dutch, Turkish-Dutch, and Surinamese-Dutch families found cultural differences in the ways in which parents supported their children during storybook reading sessions (Bus et al., 2000). In our study, Saudi parents made use of significantly more direct instructions and assistance with the stickers than U.S. parents. They also provided more frequent explanations of the programming tasks and system. For example, this excerpt comes from a Saudi mother reading with her son (age 8):

Mom: Tap … Forever [reading]. Can we use these now? [question directed to researcher]
Researcher: What do you think?
Mom: [Pasting sticker] … gets repeated over and over
Son: Run
Mom: This is jump here [correcting son]
Son: Jump, sleep … so he could get some rest.
Mom: Okay, what next?
Son: Sleep, so he could get some rest.
Mom: Sleep?
Son: Yes, to get rest.
Mom: Umm, no. Jump and then directly sleep? I don't think it is appropriate.
Son: He plays a lot
Mom: Yes [laughs]

We saw similar instances of parents directing and gently correcting their children's choices in the activity. It is important to emphasize that our sample in this study was small and not representative of Saudi or U.S. parents. Other factors beyond region and language might have contributed to these results (e.g., income and education levels). However, from a cultural forms perspective, the more interesting finding from this study is that the purpose of the sticker book seemed to be interpreted in slightly different ways by parents from different backgrounds. In other words, parents brought subtly different but recognizable value systems into the activity based on assumptions about the purpose of a storybook. These differences in interpretation in turn seemed to subtly but substantially shape the activity.

Discussion of Case 2

The point of this example is not to prove that the sticker book cued a more productive learning experience than some other comparable activity. Rather, stepping back into the design perspective, it is meant to demonstrate how design teams might use a cultural forms perspective both to generate design ideas and to orient evaluations around how people use such designs in real-life settings. A reasonable question to ask is this: Why not simply use a tablet computer to encapsulate the entire design, including the storybook and programming activities? Why is a paper storybook needed at all? In some ways, this is an empirical question best answered through a controlled study. However, a theoretically driven hypothesis is that the physical book presented a more legible and less polymorphic cultural form that would be more effective in cueing the kinds of parent–child reading practices we were targeting. Here again, I see the legibility of the form as critical to the success of a design, particularly in informal environments. Results from existing research comparing parent–child storybook reading with traditional and electronic media are mixed (De Jong & Bus, 2002; Lauricella, Barr, & Calvert, 2014). However, a recent study suggested that there are subtle but significant differences in the way in which parents and children read together with digital versus print media (Lauricella et al., 2014). Further research would be needed to understand this issue as it relates to our sticker book design.

Design Case 3: Turn Up the Heat

One rich source of cultural forms comes from the study of games and play. The use of games to support learning in formal and informal environments alike has received sustained attention from the learning sciences community (e.g., Cole, 1998; Gee, 2007; Guberman & Saxe, 2000; Habgood & Ainsworth, 2011; Holbert, 2013; Nasir, 2005; Saxe, 1992; Steinkuehler, Squire, & Barab, 2012; Stevens, Satwicz, & McCarthy, 2007). Although much of the focus on games (particularly video games) has involved understanding elements of design that facilitate learning (e.g., Gee, 2007; Habgood & Ainsworth, 2011; Holbert, 2013), other work has broadened the scope to consider social activity that transpires in and around game worlds. For example, Stevens et al.'s (2007) study of kids playing console video games in living rooms provides a detailed account of children's self-organized learning arrangements and the ways in which game activity is entangled with the rest of kids' lives. Other examples involve nondigital games such as board games and dominoes (Berland & Lee, 2011; Guberman & Saxe, 2000; Nasir, 2005; Saxe, 1992). In these studies, games are treated more as cultural artifacts around which patterns of social activity are enacted and through which participants bring a variety of practice-linked resources to bear on cognitive activities such as mathematics or computational thinking (Berland & Lee, 2011; Guberman & Saxe, 2000; Saxe, 1992). With tangible interaction there are new opportunities to blend physical and digital media as a means of building on a variety of game-related practices that go beyond those of video games while still preserving the power and interactivity of digital media (e.g., Horn, 2014; Kern et al., 2012). In this vein, thinking about games as cueing forms can create new opportunities for their use in informal learning environments to purposefully shape social experiences.

FIGURE 4 Turn Up the Heat is a family board game about energy, comfort, money, and environmental sustainability. Players must work together to make it through a full year while earning 20 Green Points, earning 20 Comfort Points, and staying out of debt. A companion app on a tablet computer (top right) simulates temperature and weather conditions.

In the final example in this article, I describe a board game called Turn Up the Heat that colleagues[2] and I created to encourage families to reflect on tradeoffs related to energy, money, comfort, and environmental sustainability (see Figure 4). The game playfully confronts power dynamics associated with the use of residential thermostats to control heating and cooling systems while addressing common misconceptions about how thermostats work (Kempton, 1986) and how they can be used to save energy and money. Our game incorporates traditional elements such as a board, dice, cards, and tokens, but it also includes a tablet computer app as a central feature of play. The app allows us to simulate a home's heating and cooling system to give each player (parents and children alike) an opportunity to adjust the thermostat on his or her turn. We were careful to balance the purely digital aspects of the app with the physical components of the game to maintain the legibility of the source cultural form that we thought was most important—namely, the board game rather than the video game.

The game was inspired by a series of interviews that we conducted with families in the U.S. Midwest about how family members think about and use resources such as electricity, natural gas, and water. As part of our interviews we asked questions about how families used residential thermostats to control their heating and cooling systems. Through these questions, it quickly became apparent that the use of thermostats is an adult-only activity in many homes (see Horn, Leong, Greenberg, & Stevens, 2015). Based on these findings, we set out to design a new thermostat activity meant to carve out culturally acceptable modes of participation for young people. Our initial direction was to create a game for a tablet computer that involved simulating a home's heating and cooling systems. However, we soon recognized that the tablet game on its own would be unlikely to cue the sorts of whole-family participation and discussion we were targeting. This led us to reconceptualize the activity as a family board game, the idea being that the cultural form of the board game would create space for social activities akin to family game nights. Specifically, we anticipated that it would be possible to evoke a board games form through the use of common cultural artifacts such as dice, spinners, pawns, cards, and game boards. And because board games are often played together with family and friends (e.g., family game night), we expected that a board game would invite participation into patterned social activity. Prior research has clearly documented that board game play brings elaborate situated resources (cognitive, physical, social, and emotional) that players use to engage in the activity together (see, e.g., Guberman & Saxe, 2000; Nasir, 2005). Finally, board games, and games in general, are a class of

[2]Reed Stevens, Amartya Banerjee, Laurel Schrementi, Pei-Yi Kuo, Pryce Davis, Zeina Leong, and Andreas Wadum.

cultural forms that are fantastically malleable. They are continuously remixed and adapted to create new forms of play.

Turn Up the Heat features a cooperative style of play, which means that players must work together on the same team to survive for one full year while staying out of debt and earning Green Points and Comfort Points. Team members take turns moving a single token around a game board representing the four seasons of the year. Using the tablet computer, players then enter the month of the year shown on the board and spin for random weather conditions that simulate the climate of the U.S. Midwest. For example, in January a player might spin a high temperature of 30°F (–1°C) and a low temperature of 12°F (–11°C). Players must then set the thermostat based on their character's comfort profile, after which the tablet computer simulates the home's indoor temperature over the course of the day. Players earn Comfort Points when the indoor temperature is within their comfort zone and Green Points when energy consumption is minimized.

To evaluate our game, we visited nine families in their homes to conduct playtesting sessions. Participants included 13 parents (nine mothers, four fathers) and 18 children (ages 6–16). The families came from a range of social and economic backgrounds, including two families that earned less than $25,000 a year, four families that earned between $25,000 and $50,000 a year, and three families that earned more than $90,000 a year. The families all controlled their own heating (and sometimes cooling) systems and lived in a variety of building types, including apartments (two families), standalone homes (five families), and condominiums or duplexes (two families). The focus of these sessions was to understand whether and how the board game would cue family practices such as sustained collaborative play; strategy development; and discussions around trade-offs of energy, money, and comfort.

Summary of Findings

One of the most striking aspects of family play took place in the first few minutes of the sessions. It was common for families to sit together and read the rules of the game out loud and discuss how they should be enacted. Perhaps this is not a surprising thing for a family to do when playing a board game together for the first time. But this is exactly the point—it is not a surprising activity for a board game. However, to us researchers accustomed to observing families in museums, the sustained and focused attention that families devoted to this task was surprising.

Beyond the first few minutes of play, as we had hoped, there were many instances of family discussion around game strategy and the meanings of the temperature graph and thermostat interfaces. These discussions also led to instances in which family members drew connections between the game and various aspects of their real-world circumstances. For example, in the following excerpt a family is confronted with an unusually high energy bill:

Boy15: I gained Comfort Points, but I lost … [Green Points]
Dad: Huh. See what your bill is.
Boy13: [Looks over Boy15 shoulder] Four hundred dollars!
Boy15: Four hundred dollars, how is that even possible?
Dad: How did you have a $400 bill? What did you do?
Mom: Yeah, what did you do?
Boy15: I put on the heat.
[…]
Dad: Well, you got to put the heat on in the winters.
Boy15: Well, that's all I did.
Dad: Well, it's expensive, isn't it?
Boy15: Yeah, it is expensive.

To interpret this episode, it is important to note that we decided to have the game start on Earth Day (April 22) after realizing that late spring and early summer tend to be much easier than winter and late fall. This gives families who have never played the game before a low-risk opportunity to experiment with the thermostat interface and the basic game mechanics. However, it also means that winter comes as something of a shock. As families round the board into December and January they are confronted with more extreme (and expensive) weather conditions, and they realize that they should have been more frugal. In the previous excerpt, the surprise of a high energy bill is an excuse for the father to share aspects of his experience managing the family heating system. The excerpt also highlights one of the ways in which traditional thermostat roles were inverted or tweaked through game play. Because the son was the one controlling the thermostat, it gave the father an opportunity to draw a parallel with his real-world experience. From the perspective of cueing forms, it is notable that game play seemed to set a structure within which family discussion and lighthearted debate could play out. Families, in other words, were able to make such connections between energy concepts in the game and their everyday lives because the pace and format of gameplay did not have to be taught or enforced by game rules but was conveyed through broad familiarity with the board game genre.

Moments of financial pressure in the game also led to strategic breakthroughs. For example, in the following excerpts the father interprets strategy decisions of the family as they make progress around the board:

[Timestamp: 34:50]

Boy10: [Tries turning the thermostat off and running the simulator]
Dad: Kid, you got us 4 energy points. Way to go.
Boy10: I used no energy! Because I used my chocolate [reference to a resource card that makes the game easier] and I turned off the thermostat. I used no energy, Mom.
[Timestamp: 36:45]
Dad: I don't need to be that warm. If I go in the mid-60s maybe it'll not be in my total comfort zone, but it'll be in my neutral zone, so I wouldn't spend as much money. [Sets thermostat to 66]
Boy10: I'd rather spend less money and use less electricity.
[Timestamp: 1:00:00]
Dad: That was an interesting strategy. You set it as low as you could.
Mom: Like safety … safety instead of comfort.
Dad: It wasn't super expensive …
[Timestamp: 1:06:00]
Dad: Now that we know how this works, I'll set the thermostat a lot lower because my goal wouldn't necessarily be to stay within the orange band, but just don't go below the negative. I didn't have that in mind when we started.
Boy10: And don't manage your energy in the game as you do in real life.

This example illustrates how game strategies emerged over time as a result of discussion among family members. We see this first in the breakthrough from the son (age 10), who realizes that it is possible to use no energy on a turn (and thus earn Green Points). This is followed by the father's turn, in which he interprets the temperature/comfort zone graph (see Figure 4) and expands on a strategy of giving up on absolute comfort to save energy. Later in the game, the mother then echoes this strategy further by using an approach that she calls "safety instead of comfort." Through this play the son comments on his father's real-world energy management ("don't manage your energy in the game as you do in real life"). It is difficult to interpret exactly what the son means by this comment, but he seems to be playfully critiquing some aspect of the family's heating situation, perhaps implying that the home is uncomfortably cold or that the energy bill is too expensive. From an informal learning perspective, these fleeting moments of reflection seemed quite valuable as they arose not out of explicit prompting or intervention from a teacher or researcher but rather out of spontaneous discussion and debate. By *spontaneous* I do not mean to imply that this would happen in ordinary day-to-day conversation. If anything, our preliminary interview study suggests that families rarely have energy discussion on this level. However, the game did appear to invite participation into patterned social activity that opened space for this otherwise unusual dialogue.

Discussion of Case 3

Interpreting this design case from a cultural forms perspective, I argue that the family game routine cued by the board game form seemed to provide structure to make this activity work in a quasi-informal environment. The structure set expectations for slow pacing, social engagement, collaborative strategy development and debate, and even reflection on the relationship between the game world and everyday life. It would still be necessary to test the game in more naturalistic settings (without the artificial aspects of a playtesting session), but our preliminary findings are encouraging. This example is meant to hint at some of the richness of games as cueing forms, particularly games that break out of the predominant video game mold. The strategies used in game play were constructed and negotiated between players over the course of the session. This type of interaction, although not foreign to video games (Stevens et al., 2007), seemed to follow from the particular style of play cued by collaborative board games—reading rules out loud and systematic turn taking. Thinking broadly about games from the perspective of cultural forms can also suggest new possibilities for merging digital media into more diverse and traditional game forms (such as playground games, sports, word games, and so on). There is a subtle shift here. From their inception, video games have integrated and remixed traditional game forms and genres into screen-based interaction. Tangible interaction implies the opposite: a merging of digital media back into the physical, potentially supporting richer collaborative learning experiences (Banerjee & Horn, 2014; Kern et al., 2012).

GENERAL DISCUSSION

> Consider the things that a screen-based transitional object, of any sort, cannot be: it cannot be large and inhabitable; or collectible; or huggable; or something that you give to your parents; or something that you miss when you take a trip and leave it at home; or furry; or a million other things. (Eisenberg, 2003, p. 35)

With the three above design cases, I have tried to sketch the relationship between tangible interaction and the role of cultural forms in shaping informal learning experiences. My central argument is that tangible interaction creates new opportunities for designers to build on cultural foundations by shaping objects and situations to evoke cueing forms. This perspective is distinct from other research on tangible learning environments, which has tended to focus on features such as multimodality, affordances and constraints, the strengths of concrete representations, or the relationship between physical interaction and embodied metaphor. In contrast, I propose that the relationship between artifact and culturally situated activity and resources is a critically undertheorized aspect of tangible interaction. In this regard, I have used the three cases to elaborate on a class of cultural forms that I refer to as *cueing forms.*

One value of conceptualizing tangible interaction in terms of cultural forms is its generative potential for design. It is not uncommon for publications involving design-based research projects to underplay the role of creativity and instinct in the design process. As much as one would like to believe that project teams follow orderly processes guided by principles and theories, the creative spark or inspiration for projects often comes from designers following their gut instincts first and then reconstructing how their ideas were shaped by theory afterward. There is nothing necessarily wrong with this approach, especially when designers' instincts are well honed—steeped in theories of learning and backed by practical experience. But what cut-and-dried research reports almost always fail to convey is the vastness of the design space for a particular domain and how narrowly explored that space actually is. Especially when one starts to consider physical/digital hybrid systems (in which the designers' palette has expanded beyond pixels on a flat display to encompass the universe of physical objects, bodily movements, and cultural artifacts) it can be overwhelming to move from open-ended ideation to concerted implementation efforts. Thus, for tangibles in particular, I would argue that there is a strong need for additional design frameworks that help narrow or scope down the ideation stage of design.

The notion of cueing forms can be a step in this direction. A design process that considers cueing forms might first ask questions such as the following: What are the desired learning outcomes? What kinds of social activity structures do we hope to foster? What are productive roles for people with diverse experiences and backgrounds? And what existing cognitive, emotional, and physical resources would be valuable to help people learn novel concepts? After thinking about these questions, the team might then brainstorm existing cultural forms that could lead to these outcomes. Based on a list of potential forms some ingenuity is then required to craft objects, situations, and interactions in such a way as to evoke these desired forms. Last, designers might observe ways in which diverse audiences interpret or reinterpret these forms in light of novel activities and concepts embedded in the systems. Does the design support a variety of engagement patterns, or is it limited to one or two? Do diverse interpretations enrich the learning experience or diminish it? This design process is, of course, a caricature of the way a real design team might function—the individual steps are never so well defined, nor are they executed in a precise order. However, I argue that considering cueing forms has the potential to enhance creativity and reveal productive avenues for design.

My focus has, to this point, been on design—how can cueing forms inspire the design of informal learning experiences while helping to attract and engage participants in productive ways? A reasonable question, however, is this: Beyond attracting and engaging audiences, what do cueing forms have to do with learning? In other words, do cueing forms actually help lead to more effective informal learning experiences? One obvious answer is that for informal environments, if people are not engaged or never initiate an activity in the first place, then learning will not happen, at least not in the ways the designers intended. Thinking about target learning objectives does not make much sense if the intended audience never uses an exhibit, for example. But there is a deeper answer to this question as well. Associated with many cultural forms are elaborate practices of teaching and learning. Cultural forms, by definition, persist in societies and cultures over time—they pass from peer to peer or from one generation to the next. But for this to be true, there must be a corresponding mechanism through which people can teach and learn from one another—the forms reproduce and evolve (using the biological metaphors of cultural-historical theory) because people continuously learn from one another and reinterpret meaning from forms. An excellent example of this is described Nasir's (2005) study of African American children and adults engaged in playing the game of dominoes. Nasir documented a variety of subtle strategies that players use to both seek and offer help in the course of game play that seem entangled in the activity itself. In many ways, for Nasir's players, dominoes is as much about helping opponents or teammates become better players as it is about trying to win the game itself. Children's storybooks are another good example wherein it is arguable that a substantial purpose of the form itself is to support children's acquisition of language literacy. Storybook reading, in this respect, is a cultural form of learning. There are many such cultural forms of literacy, learning, and play wherein the cultural value system underlying the form emphasizes the learning of particular skills or values. This aspect of cultural forms is interesting to consider when the goal is to create experiences in which people learn from one another as much as they do from the interactive artifact in front of them. For designers, understanding these forms and their corresponding value systems seems particularly important in the effort to craft productive informal learning experiences.

Before concluding, I would like to contrast these ideas (rooted in social and cultural perspectives on learning) with another popular take on tangible interaction that builds on theories of embodied cognition and conceptual metaphor theory (Lakoff & Johnson, 1999, 2003). This approach suggests that everyday sensorimotor experiences, starting in infancy, form the metaphorical foundation through which people understand a wide variety of abstract concepts. Much of the appeal of this perspective comes from the idea that one can take advantage of emerging interactive technology to design more intuitive mappings between abstract concepts and things like bodily movement, actions performed with objects, and attributes of physical materials (Antle et al., 2009; Bakker, Antle, & Van Den Hoven, 2012; Hurtienne & Israel, 2007; Hurtienne, Stößel, & Weber, 2009; Macaranas, Antle, & Riecke, 2012). However, there has been a tendency in much of this work to focus on universal aspects of human experience that cut across cultural contexts. For example, Hurtienne and Israel (2007) proposed a continuum of preexisting knowledge that includes innate, sensorimotor, cultural, and domain expertise. And while acknowledging the role of culture, they explicitly emphasized the sensorimotor end of the continuum in an effort to be more universally applicable: “The further we rise towards the top level of the continuum, the higher the degree of specialization of knowledge and the smaller the potential number of users possessing this knowledge gets” (p. 128). Continuing in this direction, more recent research has attempted to identify metaphor population stereotypes (Hurtienne et al., 2009; Macaranas et al., 2012), or embodied metaphors that are reliably and consistently recognized by a given language group. For example, in one such study, English-speaking participants reliably and consistently mapped surfaces with smooth and rough textures onto concepts such as dangerous/safe and unpleasant/pleasant (Macaranas et al., 2012). Similar design frameworks dealing with natural and intuitive interaction have focused on universal (or near-universal) aspects of human experience largely by elaborating on metaphors derived from interaction with the physical world (Jacob et al., 2008).

Although a focus on universality might have value for creating broadly applicable designs, it also risks underplaying the profound role of culture in shaping people’s engagement with the world around them at a physical and social level (Dourish, 2001; Kern et al., 2012; Suchman, 2007; Weiser et al., 1999). Bruner’s (1990) critique of a computationally oriented cognitive science in search of “transcendent human universals” could be leveled against much of the current research in human–computer interaction (p. 20). Particularly troubling is the sense in which cultural factors seem to be actively avoided in the design of novel interactive systems, a tendency that not only risks stifling creativity by excluding many starting points for design but also treats cultural differences almost like bugs in the system that need to be fixed rather than opportunities to invite differences in interpretation. There is a further danger that through this stance designers will not consciously consider the cultural nature of their own designs, nor will they critically interrogate the cultural implications of their design choices with their target audience.

CONCLUSION

In this article, I propose an approach to the design of computer-based learning environments for informal settings such as museums and homes. My emphasis is on cueing productive patterns of social engagement along with valuable cognitive, physical, and emotional resources that individuals can bring to bear on an activity. My approach is based on the use of tangible interaction as a means of shaping objects and situations so as to evoke existing cultural forms. My definition of cultural form is based on the work of Saxe (2012) and his form–function shift framework. Building on this work, I propose a class of cultural forms that I refer to as *cueing forms*. Cueing forms are of particular interest to interaction designers because they can help shape the social interaction that takes place around an interactive learning experience. Above I presented three examples that illustrate the use of tangible interaction and cueing forms in practice.

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