International Journal *of* Designs for Learning
2020 | Volume 11, Issue 2 | Pages 118-129

FIGHT THE POWER! GAMES, THERMOSTATS, AND THE ENERGY PATRIARCHY

Michael Horn[1], Pryce Davis[2], Amartya Banerjee[1], & Reed Stevens[1]
[1]*Northwestern University;* [2]*University of Nottingham*

Confronting issues of global climate change will require creative approaches to energy consumption across a range of human activities. This design case looks at the evolution of a physical/digital hybrid board game that we created to encourage families to reflect on household energy consumption and environmental sustainability. Design in this context was particularly challenging due to the nature of household heating and cooling systems, which tend to be opaque and difficult to understand. Our challenge was to employ game mechanics to help build up interest, awareness, and understanding of heating and cooling systems, while at the same time providing an enjoyable and engaging activity. Through many rounds of playtesting and interviews, we converged on the design presented here. We start with a conceptual framework describing modern energy practices, after which we describe the game design and reflect on its strengths and weaknesses.

Michael Horn is an Associate Professor of Computer Science and Learning Sciences. He studies the design of playful technology-based learning experiences.

Pryce Davis is an Assistant Professor in Learning Sciences at the University of Nottingham. His research interests include learning in informal settings, public engagement with science, and the design of learning environments.

Amartya Banerjee is a Research Associate in Computer Science at Northwestern University.

Reed Stevens is a Professor of Learning Sciences in the School of Education and Social Policy at Northwestern University. His research interests include ethnographic and interactional studies of learning and designs for learning that support creativity, agency, and the exploration of interests. He leads the FUSE Studios project.

INTRODUCTION

Confronting issues of global climate change will require creative approaches to energy consumption across a range of human activities. In this design case, we are concerned with the management of household energy systems and the ways in which families might become more conscientious and knowledgeable energy consumers. This is not a trivial concern. The urgency of climate change and associated environmental issues will require dramatic changes in the way we produce and consume energy across all aspects of life. Residential energy consumption—power used in homes for lighting, cooking, heating, cooling, and other appliances and electronics—accounts for more than 20% of the United States' overall energy expenditure (US EIA, 2016) with similar levels in other developed countries. Even though reducing waste and increasing efficiency in the residential energy sector is a worthwhile goal, the knowledge and skills needed for households to become more competent energy consumers seem elusive. Modern energy infrastructures have done a remarkable job making energy consumption invisible—something we almost never have to think about or reflect on. Not surprisingly, research shows that people lack a basic understanding of how energy is produced and transmitted, the basic units of consumption, and the implications of many day-to-day actions (Chetty, et al., 2008; Karjalainen & Koistinen, 2006; Meier et al., 2011).

This design case looks at the evolution of a board game called *Turn Up the Heat!* that we created to encourage families to reflect on household energy consumption and environmental sustainability. Our goal was to foreground not

https://doi.org/10.14434/ijdl.v11i2.26100

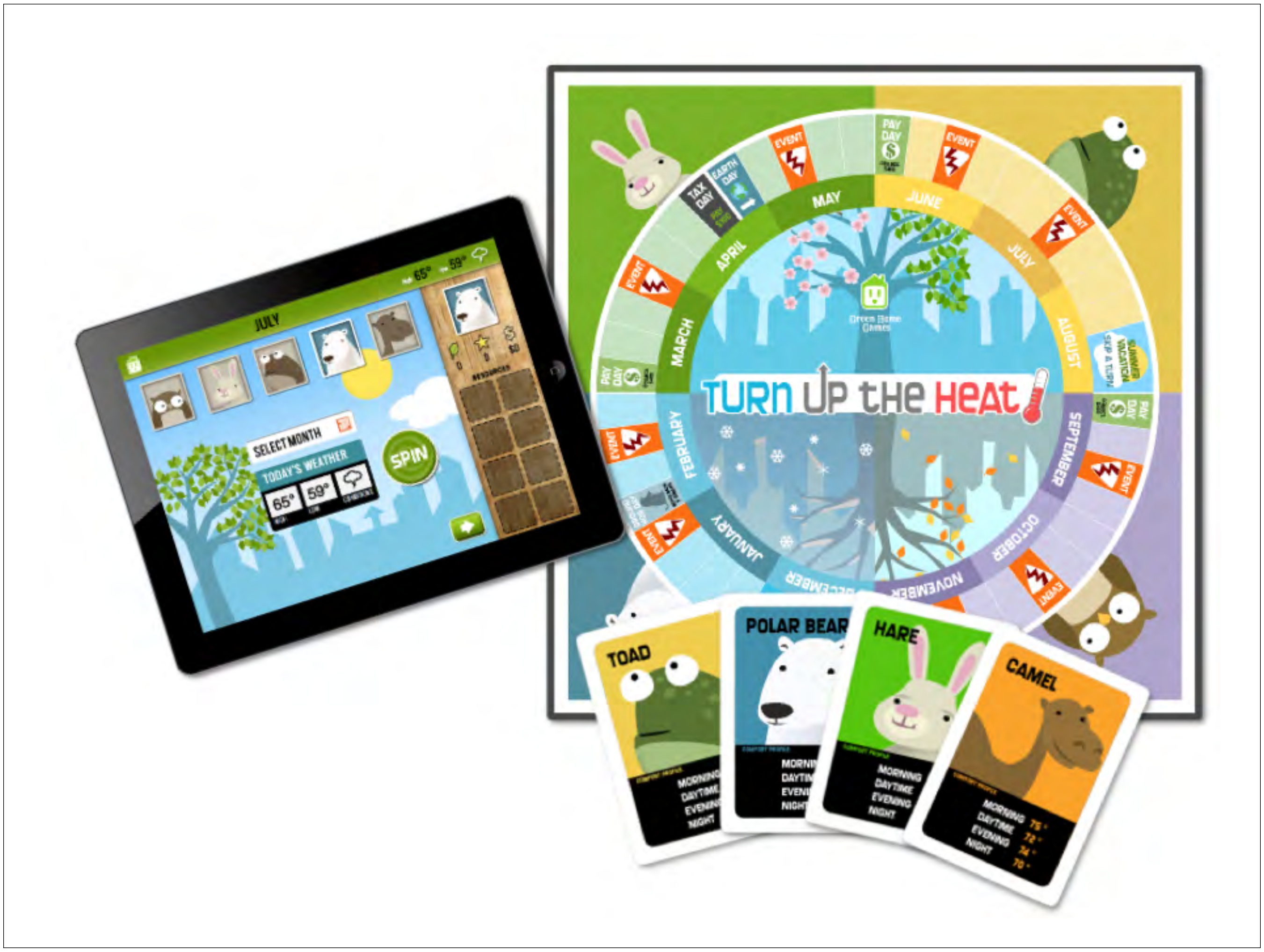

FIGURE 1. *Turn Up the Heat!* is a family board game about thermostats, energy, money, and environmental sustainability. Players collaborate to earn 20 Green Points and 20 Comfort Points while staying out of debt as they move a single token around a board representing the seasons of the year. Players have a profile card that shows their temperature comfort zone. The game includes an iPad app that simulates weather conditions and the effects of different thermostat settings

only energy technology but also the day-to-day practices involved in managing household heating and cooling systems. In this way, we hoped to provide a context for families to reflect on energy consumption and reducing waste.

In a prior research study, we conducted a series of interviews with families around issues of domestic water and energy consumption (Horn et al., 2015). Topics of the interviews included knowledge of energy and water infrastructures, the quantity of resources consumed, costs, and units associated with those resources, and the roles of various family members in managing consumption. One notable finding from these interviews was that children had little voice in family energy decisions. For example, when we asked families about how they used household heating and cooling systems, we found that youth rarely, if ever, touched the thermostat(s) in their home and had a minimal understanding of how heating and cooling systems worked. Notably, unlike other important household activities like cooking and cleaning, there appeared to be less of an opportunity for youth to get involved as they got older. Parents often expressed concern that children would simply over-adjust for comfort without understanding reasonable temperature ranges, without considering alternative like "putting on a sweater", and without considering the broader impact on family finances.

Given this state of affairs, we began our design process with two questions: How might we begin to reconfigure household energy management practices to be more inclusive and to offer better opportunities for learning? And, could we imagine ways to scaffold the involvement of children and adolescents in what would otherwise be adult-only energy activities? Precipitated by our interview data around family thermostats, we started to develop a conceptual framework and a related set of design principles to create an experience that we hoped would encourage families to reflect on tradeoffs related to energy, money, and comfort related to household heating and cooling systems. We intentionally treated parents and children as equal partners in strategy development, while attempting to blur the line between the game world and the real world to provoke discussions about energy use.

RELATED DESIGNS AND RESEARCH

A growing body of research has also explored the use of gamification and "eco-feedback" technologies as a way to help families become more mindful of the implications of their daily behaviors and habits (Chetty et al., 2008; DiSalvo et al., 2010; Fitzpatrick & Smith, 2009; Froehlich et al., 2012; Froehlich et al., 2010; Gustafsson & Gyllenswärd, 2005; Kuznetsov & Paulos, 2010). Such eco-feedback displays are used to visualize otherwise invisible consumption so as to make energy use more salient in terms of scale and impact (Chetty et al., 2008; DiSalvo et al., 2010; Gustafsson & Gyllenswärd, 2005). For example, an in-home energy display might show the rate and accumulated amount of electricity used in real-time. These displays are often coupled gamification elements such as a green leaf to indicate eco-friendly settings or a red stoplight to represent high-intensity use. There are numerous other examples of research along these lines (for some examples, see DiSalvo et al., 2018; Froehlich et al., 2010) that both design innovative energy displays and study the impact of such technologies on family behavior.

Since thermostats control a significant proportion of total energy consumption in an American homes, "smart" devices such as the Nest thermostat have started to incorporate subtle eco-feedback cues to potentially reduce a home's energy footprint. In the case of the Nest, a small green leaf appears on the display when families select energy-efficient settings. However, research on families' use of the Nest has also shown that while the Nest did impact users' pattern of HVAC control, it did so for only a short period of time (Yang et al., 2014). This outcome highlights an important limitation of the eco-feedback approach. According to Strengers (2011), current eco-feedback systems cast householders as "micro-resource managers" making rational choices; they do not consider social or familial dynamics that can affect rationality. Similarly, Pierce et al. (2010) found that interactions with technology in the home are performed unconsciously, habitually, and are mostly irrational. Designing for domestic sustainability, therefore, involves not just improving the visibility of resource consumption, but also addressing social dynamics of households, and working towards a shift in social and cultural value systems.

In this project, we build on a tradition of research on the use of games (not just gamification) to foster engagement with environmental issues (Antle et al., 2014; Banerjee & Horn, 2014; Bell-Gawne et al., 2013; Lee et al., 2012; Horn et al., 2016; Horn et al., 2014). In these projects, games create a playful alternative reality in which family members can take on different roles and new responsibilities. Games simultaneously highlight the longer-term implications of everyday actions. Some examples include the work of Antle et al. (2014), who created a game called Youtopia that allows children to share their values around sustainable development, and Banerjee and Horn (2014), who created an interactive system that engages parents and children in seeking out hidden sources of energy consumption in their homes. One appeal of games around these topics is that by creating a challenging play experience, they provide a context for families to step back and reflect on how they use energy on a day-to-day basis.

DESIGN CHALLENGE: RECONFIGURING HOUSEHOLD ENERGY PRACTICES

We adopt a perspective on learning as a process through which value systems, personal identity, and practices of a community shift over time as new participants take on meaningful roles (Nasir & Hand, 2008; Lave & Wenger, 1991; Rogoff, 2003). Thinking about learning in this way also highlights the idea that some activities and practices provide more fertile grounds for learning and engagement than others. The management of household energy consumption would seem, at first blush, to be an excellent fit for children to learn by participating with adults in consequential activities under varying degrees of supervision. Unfortunately, however, based on our prior interview study and other research, energy practices seem surprisingly sterile in many homes (Pierce et al., 2010). By "sterile" we mean to capture the reality that new participants (especially children) have a difficult time getting involved in practices in the first place and then expanding their role over time. Our claim is not that this universally describes *all* energy management activities in *all* homes. Rather, there appear to be characteristics of modern energy infrastructures that lead to this state of affairs. In particular, we see seven interrelated properties that characterize modern energy management practices in homes.

1. Lack of Expertise

First, energy practices are marked by limited expertise at all levels. Communities of practice depend on experts who have more experience and skills in the target practice. However, within home energy management, the people who play this role seem less obvious. An expert would have a functional understanding of how energy works, how to use the tools that regulate energy, and how to balance comfort, convenience, and expense. Yet, research suggests widespread confusion around energy consumption, particularly with respect to thermostats (Karjalainen & Koistinen, 2006; Kempton, 1986; Meier et al., 2011; Peffer et al., 2011). Of course, most parents aren't gourmet chefs either, but there is usually a baseline level of competence that clearly separates a novice from an expert in common household activities. In energy management, we see the gap between expert and novice as much less recognizable.

2. Diminished Visibility of Practice

The *visibility* of expert activity also plays a central role in learning (e.g., Rogoff, 2003). In other words, for kids to get interested and start engaging in an adult activity, it helps to be able to see those activities in action. Energy practices, however, are characterized by diminished visibility. By this, we mean that the locus of activity is decentralized, minimal, or infrequent. Families with programmable thermostats, for example, might "set it and forget it" (Yang et al., 2014). Even for families with other types of thermostats, contact with devices might be subtle, infrequent, or even invisible to kids. Contrast this with activities like cooking or cleaning in which there are a wide array of highly visible activities that play out over relatively long amounts of time. For example, it might take 30-45 minutes of focused activity to prepare a simple meal, compared to a second to adjust a thermostat.

3. Impoverished Artifacts of Practice

Many everyday practices are defined to a large extent by the artifacts and tools that shape and facilitate that activity. This is perhaps most obvious for cooking, which entails the use of dozens and dozens of implements for all manner of tasks and subtasks—spatulas, knives, pots, pans, and so on. But this is no less obvious in other activities like cleaning, gardening, and household repairs. For other practices, the array of artifacts is small. In the management of central heating and cooling systems, there is often only one visible artifact: the thermostat. And, this particular artifact is intentionally designed to blend in rather than stand out (Horn et al., 2015). Thermostats are mounted on the wall at adult height and are usually beige or white in color with tiny controls that are uniform in appearance.

4. Limited Divisibility

Related to impoverished artifacts comes limited divisibility. Complex cognitive activities are often (if not always) distributed across multiple participants, artifacts, and spaces (Latour, 2000; Nasir & Hand, 2008). This distribution invites a division of labor that can create opportunities for the involvement of newcomers as they become more active participants and learn aspects of the practice as a whole. Children are able to participate in many household activities through a division of labor. In doing so, the child becomes an active participant and, over time, learning many aspects of the practice as a whole. Just as there is an array of physical artifacts used to prepare a meal, so too are there a wide variety of ways in which parents can delegate small yet productive tasks while preparing a meal. Perhaps a parent might ask a child to gather certain ingredients, set the table, or chop vegetables. In contrast, for many aspects of home energy management, there are a few obvious ways to divide tasks into smaller jobs that can be delegated to children. There are fewer obvious toeholds to support children's initial or ongoing involvement.

5. Participation is Discouraged

One of the most striking findings from our family interview study was the degree to which children's participation in the management of central heating and air-conditioning systems was both actively and passively discouraged. Some parents said they had explicit rules or hands-off policies, while other parents discouraged involvement by suggesting alternative means to achieve thermal comfort when kids complained about being hot or cold ("put on a sweater"). There were some parents who said they wouldn't mind if kids adjusted the thermostat, but these kids reported rarely doing so, with some even claiming that their parents wouldn't allow it. Building on these findings, a defining characteristic of energy practices is that the involvement of children and adolescents is discouraged, possibly because the activity is perceived to be dangerous or costly, possibly because parents themselves feel uncertain about the activity (lack of expertise), and partly because there are few ways to meaningfully divide the tasks into smaller activities that could be delegated to a child (limited divisibility).

6. Invisible Outcomes

With many family practices, there is a tangible (and often satisfying) outcome of group activity. When families cook a traditional meal, the outcome is the food that is enjoyed by everyone. Other activities, such as cleaning, gardening, and household repair, have similar visible or perceptible outcomes. In the case of energy practices, not only is the practice itself largely invisible, but the outcomes of the activity are difficult to perceive as well. With heating and cooling systems, an outcome might be that the house becomes more comfortable, but this effect is delayed in time and influenced by many other factors such as the outdoor weather conditions, clothing taken on or off, windows opened or shut, and ceiling fans turned on or off. Outcomes such as financial savings are delayed by even longer periods of time and almost entirely invisible except to the person paying the bills.

7. No Room for Self-Expression

More recent research on the development of identity in relation to participation in practices has highlighted the importance of self-expression and the ability to make unique contributions to a group in service of a larger goal or effort. Identity grows out of what individuals see as their specialized abilities and roles (Nasir & Hand, 2008). These self-expressive avenues seem obvious for practices such as training with a basketball team or cooking a meal. Energy management again proves lacking in comparison, with limited opportunities for specialized roles and self-expression.

DESIGN CONTEXT

The game was an outcome of a multi-year design-based research study (Barab & Squire, 2004; Easterday et al., 2014). In our case this meant that both the game itself and the theories of learning that informed it were tested, clarified, and refined over time. A design becomes an embodiment of the learning theories, while testing in the real world with real people puts the theories into "harm's way" (Cobb et al., 2003). Just as we expect a design to fail (often gratuitously) the first time we test it, so too do we expect theory to need substantial refinement over time. By "theory of learning", we refer to small but functional hypotheses about how and why an activity should work in a specific context and with specific topic areas. These theories took the form of design principles that guided our work.

During the design process, the core project team consisted of the four authors of this paper, who were, at the time, two university faculty members, postdoctoral research, and a doctoral student. All members have a background in either or both Learning Sciences and Computer Science, with particular expertise in informal learning and the design of learning environments. All members had direct input in design decisions, which we all made through consensus-building discussion in team meetings.

All team members were also directly involved in design testing. The testing process usually began with design decisions being quickly translated into low-fidelity prototypes. The lo-fi prototypes were "tested" in informal reviews with the core team members, as well as playtesting with friends and colleagues with varying degrees of knowledge in the Learning Sciences, home energy management, and games. Through iterative cycles of this sort of testing and redesign, we gradually created medium-fidelity and high-fidelity designs. This specific process is described in the following section.

DESIGN PROCESS

As mentioned earlier, two questions drove our initial design process: How might we begin to reconfigure household energy management practices to be more inclusive and to offer better opportunities for learning? And, could we imagine ways to scaffold the involvement of children and adolescents in what would otherwise be adult-only energy activities?

Our first concern was narrowing the scope. Household energy management involves a large number of interrelated practices, so we decided to limit our focus to household heating and cooling systems. Not only do these systems make up close to 50% of residential energy consumption in the United States (US EIA, 2016), but they are also one of the most extreme examples of sterile energy practices in homes.

Once this was decided, we focused on how we could reconfigure practices around household heating and cooling to involve whole families. An obvious approach to this would be designing a thermostat for whole family use. However, fundamentally altering the artifacts of home energy, in order to build new practices almost from the bottom up is a daunting task. Therefore, in our discussions, we thought about how we might leverage existing family practices, to scaffold family home energy management. One match that seemed obvious to us was board games. Many board games are designed specifically for whole family play, and many families have experience playing board games together. Expertise in board game content is built during play, which can close the expert/novice gap. Rules and artifacts of gameplay can be simple and clear but rich in feedback. Family board games can also encourage participation, have clear outcomes, and allow expression through gameplay decisions.

Board games have become a topic of interest for researchers in the Learning Sciences in their own right. For example, Berland and Lee (2011) analyzed college students playing the cooperative board game, *Pandemic*, and found evidence that players made use of sophisticated computational thinking skills in the course of gameplay. Nasir (2005) studied children and adults from African American communities playing dominoes. Her analysis focused on the nuanced ways in which players sought and offered help as a way to improve the game experience. As a final example, Guberman and Saxe (2000) developed a game called *Treasure Hunt* for use in elementary school mathematics instruction. They found that children created thematic divisions of labor as they took on various roles in the game. These divisions of labor enabled children to accomplish mathematical problems that were beyond their independent ability. We focus on board games for all of these reasons but, most importantly, because they invite participation in social activity in which families sit together to play, argue, collaborate, and learn (Horn, 2018).

Once we decided on created a board game, we struggled with how to represent both more tangible elements (such as money, weather conditions, and thermostat settings) with intangible elements (such as character comfort, energy consumption, and the passage of time). Elements such as weather conditions have inherent randomness tempered by seasonal variability and daily cycles. We also struggled to decide on our core game mechanics. The act of setting the thermostat seemed like an obvious strategic decision point but understanding how to integrate that act into a broader game structure was more elusive.

Our early paper prototypes experimented with a wide variety of representations and game mechanics. We worked through popular cooperative and competitive-style games to find ideas or inspiration. We experimented with individual player mats representing comfort and expense levels, and

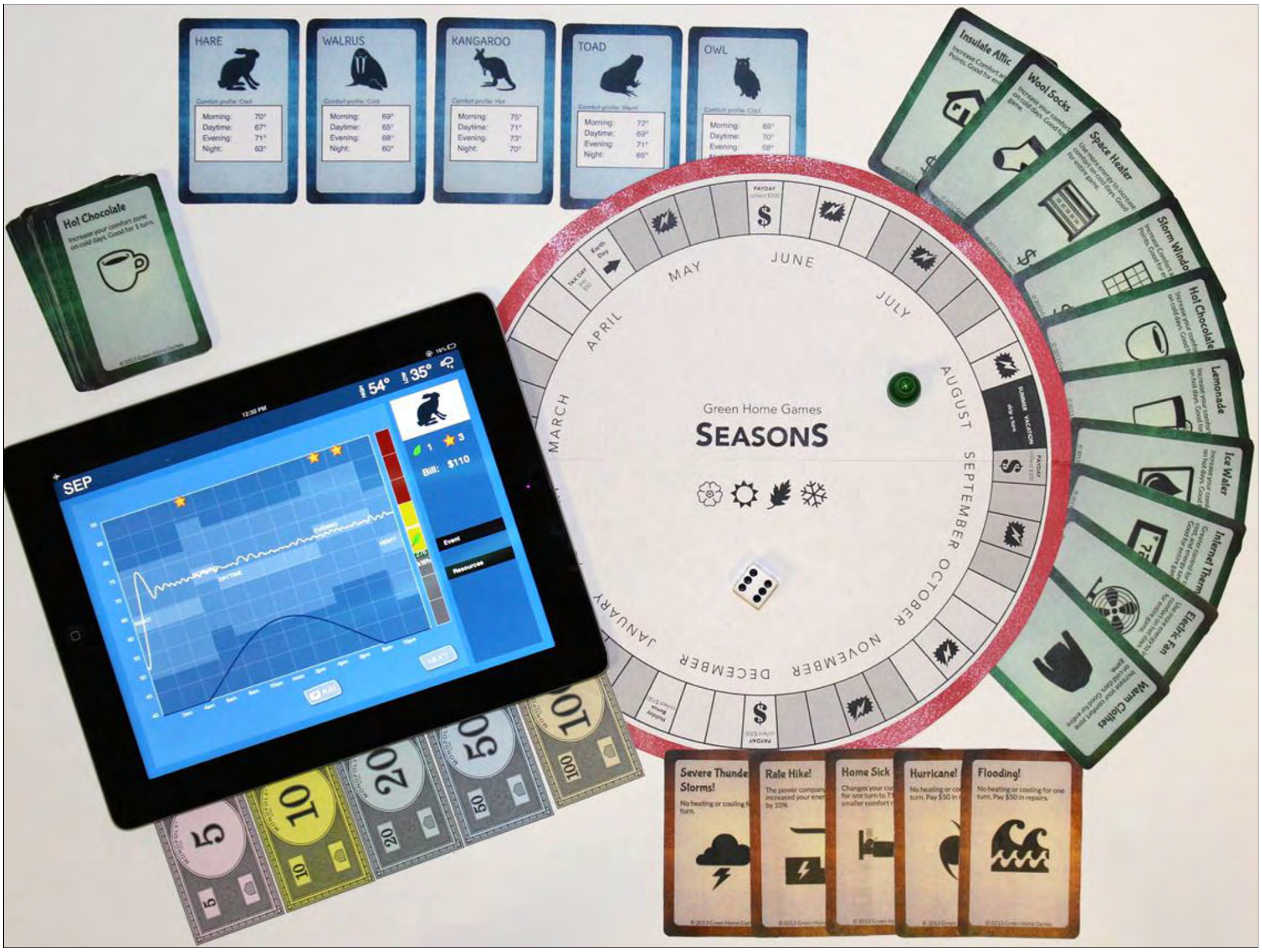

FIGURE 2. A medium-fidelity paper prototype developed after we had settled on the idea of moving a game token around the seasons of a year.

we explored many different options to generate random weather conditions. Eventually, we hit on the idea of representing the passage of time as the physical movement of a character token around a game board. This move also helped us settle on the "win" condition for the game—families needed to make it through one full year (365 days and four seasons), while staying reasonably comfortable and out of debt (see Figure 2).

We debated using more cooperative versus more competitive styles of play. Our playtesting sessions strongly suggested that families expected and enjoyed competitive modes of play—possibly due to familiarity with common commercial board games. In these games, characters each have their own game tokens, and players compete to accomplish the game goals first. However, our testing also suggested that cooperative games afforded richer discussions and strategy development around heating and cooling—exactly the kinds of learning activities we were hoping to see. Likewise, cooperative games afford more ability to divide tasks across all players. To help strike a balance, we eventually settled on a nemesis character (a greedy energy executive) that families would collectively compete against.

Finally, we explored many possible analog representations and game mechanics. For example, slider made out of cardboard and a paperclip to indicate temperature. However, all of these approaches were cumbersome and slowed down gameplay. Plus, they didn't really map closely enough to the real-world home energy management. Therefore, we eventually decided to bring a companion tablet computer app back into the gameplay (see Figures 2 and 3). There were a few motivators for this. First, we felt that it was important to provide a dynamic simulation of temperature variation inside the home, along with associated energy consumption and costs. It would have been difficult to capture these dynamics with physical/analog elements alone (see Figure 4 for the design that we ultimately implemented). Second, we wanted to provide a reasonably realistic experience of setting a thermostat, both manual and programmable (see Figure 3). The tablet app was a convenient way to provide this experience. Lastly, we wanted to build a system that might eventually be able to connect to a home's actual energy infrastructure. For example, smart thermostats like the Radio Thermostat now have APIs that allow for third-party apps to connect and provide services. The eventual goal would have been to show actual household energy consumption alongside the gameplay consumption to help families make connections to the real world.

Individual players would also have characters that they would take on in gameplay. We wanted to make sure to capture the mini-conflicts that families have around thermal comfort. Some family members like it cooler, while others like it warmer. We used animal characters to try to make this idea more obvious (e.g., the polar bear likes it cold, and the camel likes it hot). We also decided that players would take turns setting the thermostat to play up strategy discussions and subtly challenge household power dynamics wherein adults are generally more active actors than children.

FINAL GAME DESIGN

Turn Up the Heat! is a thermostat board game in which players must work together to earn at least 20 Green Points and 20 Comfort Points over the course of one full year while staying out of debt (see Figure 1). At the beginning of the game, each player draws a Character Card that determines their *comfort profile*. This profile affects how difficult and costly it will be to earn Comfort Points under different weather conditions. To play, team members take turns moving a single token around a game board representing the four seasons of the year. After moving, players use a tablet app to *spin* for random weather conditions that simulate the climate of the United States Midwest (see Figure 3, top). 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 then set the thermostat based on their character's comfort profile. The game begins with a manual thermostat that can be upgraded to a smart thermostat in the course of gameplay (see Figures 3, middle and Figure 3, bottom). The manual thermostat allows players to set only one temperature for the entire day, while the smart thermostat allows players to set individual temperatures for each of four time periods (sleep, wake, day, and evening).

The tablet computer simulates indoor temperatures (white oscillating line in Figure 4) over the course of the day based on the thermostat settings (horizontal green line), and the outdoor temperature (blue line). These are shown as a temperature over time graphs (see Figure 4) that animates as the simulation runs. Players earn Comfort Points when the indoor temperature is within their comfort zone (orange area) and lose points when the temperature is outside of the "neutral zone" (a light grey area). Of course, running the heating or A/C uses energy and costs money. An indicator to the right animates the energy consumed over the course of the day. Players earn Green Points by using less energy, and,

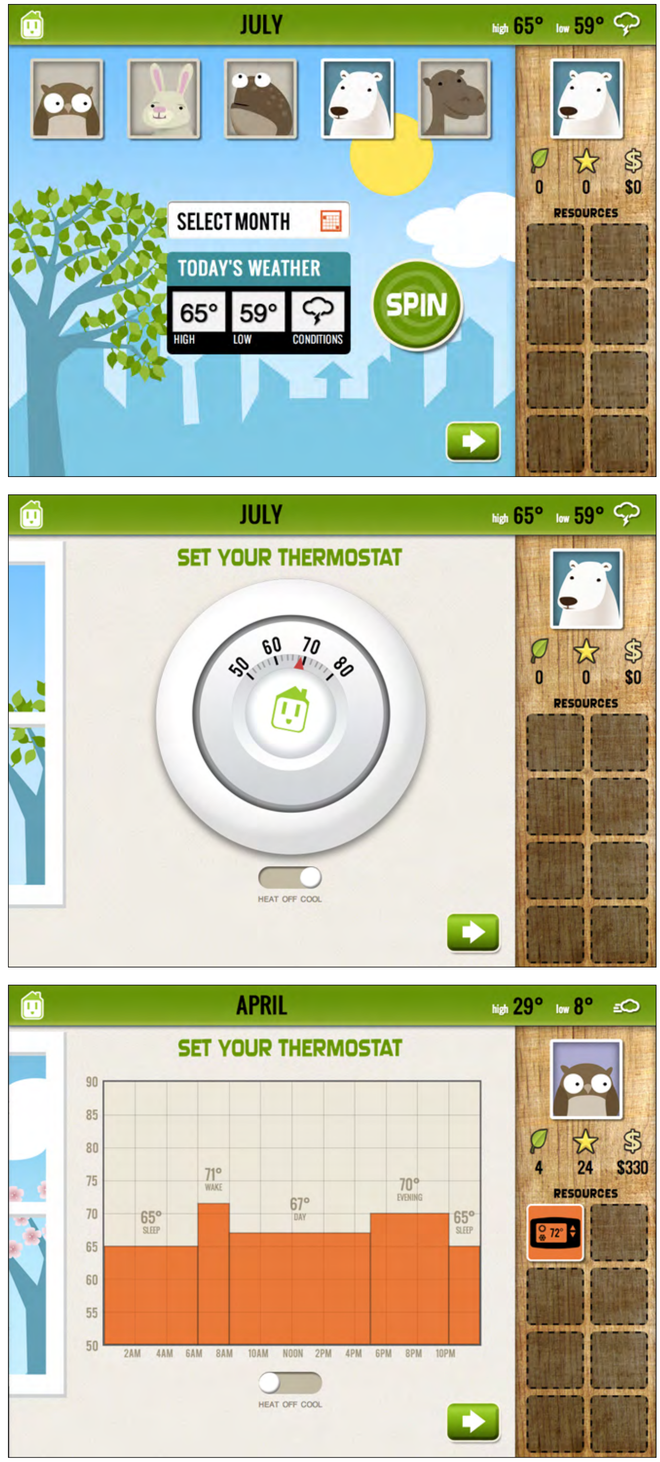

FIGURE 3. (top) Your character determines your comfort profile; spin for seasonal weather conditions; (middle) Conventional thermostat interface sets one temperature for the entire day; (bottom) Smart thermostat unlocked with a Resource card lets players set different temperatures for different periods of the day. Artwork by Maisa Morin.

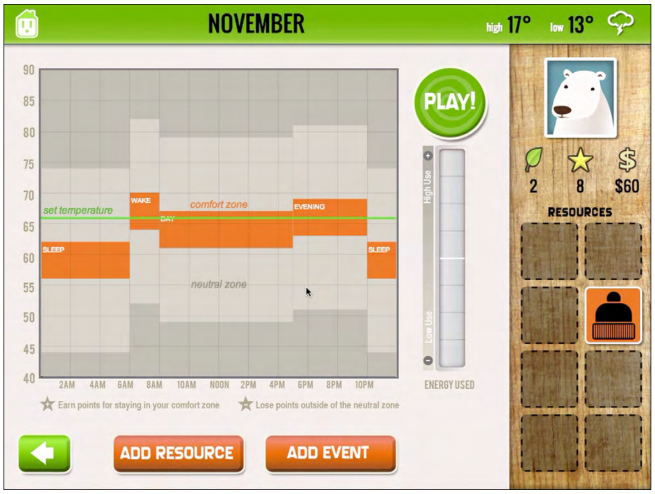

FIGURE 4. Simulator screen showing comfort zone (orange area), neutral zone (a light grey area), energy use, and the indoor and outdoor temperature over time. When the temperature falls within a character's comfort range, they earn comfort points represented as stars. The blue line at the bottom shows outdoor temperatures over time. When the player presses the green Play button, the graph is animated out from left to right to show the change in temperature over time along with the energy consumption levels (right side). If the ultimate energy level is below 400 kWh, players earn green points (represented as green leaves).

correspondingly, lose points by using more energy. Resource Cards (such as warm clothes, hot chocolate, and ice water) can be used to expand an individual player's comfort zone, making it easier to earn Comfort Points while using less energy. Other resources (such as insulation, storm windows, and a smart thermostat) improve the home's infrastructure, making the game easier for all players. These infrastructure cards cost money, so team members must decide together if a particular upgrade is worth the investment.

At the end of each players' turn, there is an energy bill screen. Players have the option of paying the bill in full, paying a minimum amount, or paying zero. This screen was by far the most emotionally intense part of the game, prompting heated debates between parents and children about whether it was ok not to pay the bill in full or to spend down savings too aggressively. By giving all players (children and adults) a chance to set the thermostat on their turn, we hoped to subtly draw attention to power dynamics around heating and cooling systems. We also intended to confront usability issues and misconceptions around thermostat use.

The game ends when players advance their token all the way around the board (representing the traversal of one full year). The game is won by staying out of debt while earning a total of 20 green points and 20 comfort points.

PLAYTESTING THE DESIGN CHALLENGES

As part of our design process that led to the final product just described, we undertook many rounds of playtesting. In this section, we present some examples from playtesting to show how our conjectural plans to overcome the design challenges discussed earlier were implemented in actual gameplay. We do this to illustrate our design decisions and inform other designers interested in similar spaces.

Participants

In playtesting, we visited fourteen families in their homes (see Figure 5). Participants included 20 parents and 26 children (ages 6 to 16). Several of these families were visited on multiple occasions to test different design iterations of the game. Families came from a range of social and economic backgrounds, including families who earned less than $25,000 a year, families who earned between $25,000 and $50,000 a year, and families who 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, standalone homes, and condominiums or duplexes. We began the first session with each family with a brief interview about family practices around board gameplay, thermostat use, and environmental attitudes. After the interview, we invited the families to play one of our game prototypes.

All interviews and gameplay sessions were video recorded. To understand whether and how our game was working, we reviewed these videos with several guiding questions:

> *How did game strategy develop and evolve over the course of the play? What role did children and adolescents play in this strategy development? How did families learn to make sense of the relatively sophisticated representations in the games (e.g., Figures 3 & 4)? Did families make connections between gameplay and their everyday circumstances, and, if so, what did these connections look like?*

In order to begin the process of answering these questions, we adopted the methodological approach of interaction analysis (Jordan & Henderson, 1995). Interaction analysis uses video as a primary data source and involves repeated viewing in order to provide an in-depth analysis of the interactions that shape thought and behavior through talk, nonverbal cues, and artifacts. Here we share excerpts from playtesting that illustrated both the strengths and weaknesses of the game along with the seven characteristics of modern energy practices that we described earlier.

Visibility of Practice and Tangibility of Artifacts

We intentionally designed the game rules to make energy management practices visible. This included choosing cooperative play styles that promoted discussions of strategy (see also Berland & Lee, 2011) as well as making the artifacts of energy management central features of the play. For example, *Turn Up the Heat!* emphasizes the relative affordances of manual thermostats (familiarity and ease-of-use) and programmable thermostats (flexibility and savings). In our play sessions, we saw numerous instances in which players shared strategies and offered advice to their families.

It was common to see all family members intently watching the temperature simulation and arguing over the thermostat settings, especially when money was tight (see Figure 5). Beyond thermostat adjustments, financial practices also came into view as players confronted costly energy bills. Players could choose whether to pay their entire bill in full, to pay a minimum amount, or to pay nothing and incur a fine. The example next is from a family of five with father, mother, daughter, and two sons. This excerpt shows the younger son's second turn when he receives an energy bill, but decides only to pay the minimum amount:

Boy 13: *Only $60 [the minimum payment amount].*

Dad: *$60?*

Boy 13: *Yeah.*

Mom: *Face me.*

Boy 13: *I paid minimum. So now you've got the big bill*

FIGURE 5. Two family playtesting sessions with different versions of the game prototype.

When his turn is over, the younger son chooses to "grief" his mother (who had the next turn) by paying the minimum bill despite the family having enough to pay the bill in full. As he does so, he smiles and says his mother will now have to pay the "big bill." Essentially, the younger son's strategy is to minimize his own hardship while passing responsibility onto the rest of his family. Of course, this goes against the cooperative nature of the game since finances are shared by all players. As the round continues, we see the ramifications of this decision. Due to the younger son paying the minimum, the mother (after setting the thermostat too high) receives a bill too high for the family to afford. She, therefore, also chooses to only pay part of the bill. Around six minutes following the previous exchange, the father takes his second turn. At the end of this turn, the father receives a bill of $800. At this point, the following exchange occurs:

Boy 15: *Eight hundred dollars!?*

Boy 13: *I like this game. It's like real life you prolong paying something and it gets bigger and bigger*

Boy 15: *And at least we have the comfort still.*

Boy 13: *Yeah. We're nice and comfortable.*

When the father says how much the bill is, the older brother responds with incredulity. Then the younger son smiles, leans toward his mother, and says that he likes that the game is similar to real-life in that expenses mount on unpaid bills. This is an example of a participant connecting the game to real life, but it also shows how player strategies evolved over successive rounds. In the remainder of the game, the younger son, who had initially griefed his mother, took a more fiscally prudent strategy and was vocal in promoting energy savings through lower thermostat settings.

Emergent and Distributed Expertise

Modern energy practices are notable for their lack of expertise and the limited ways in which roles can be distributed and specialized among family members. This also makes it difficult for personal self-expression and practice-linked identity formation (Nasir & Hand, 2008). Building on the previous excerpt, it was common for families to develop specialized roles and expertise in the context of gameplay. One common role, also prevalent in commercial board games, was the financial manager. Interestingly, this role was often taken on by younger siblings who not only managed simple accounting (addition, subtraction, and making change), but also acted as fiscal enforcers, insisting that families pay the full energy bill after every turn. This enforcement would often break down in the winter months when the energy bills got higher, forcing arguments and negotiations about how and when to pay bills.

Beyond financial roles, we also saw expertise around energy management begin to emerge and distribute across family members. In many instances, kids took leading roles in developing expertise around energy management, including interpreting the interface and representations. In this excerpt, the son (playing with his mom and dad) interpreted the temperature over time graph. As the vignette begins, the son is the first to take his second turn.

Mom: *Go ahead. Roll the die mister polar boy bear boy.*

Dad: *I wonder if you lose stars if we go outside our comfort zone.*

Son: *I'm the only one who gets—*

Dad: *We— So we're going for green so do you want to—land on events.*

Son: *Oh, there's a payday.*

Mom: *Whee.*

Dad: *So we could—*

Son: *Four hundred.*

Dad: *—keep going lot longer in our comfort zone and still be [inaudible].*

Son: *Here, I'll take 400.*

Mom: *Give us our payday.*

Son: *No, dad. If we're not in our comfort zone but we're not out of our neutral zone, you don't lose any stars. But we don't gain any stars.*

Dad: *Right.*

Mom: *Say that again.*

Son: *Why?*

Mom: *Because I didn't understand [laughter].*

Son: *Okay. If we are in our comfort zone—*

Mom: *It's amazing that I'm the one who controls the thermostat [laughs]. Okay. Did you select your guy?*

Son: *Yeah.*

The turn begins with the mother telling the son to roll the die by referring to him by his game character ("polar bear boy"). While the son starts his turn, the father wonders aloud about the stars that appeared on the graph at the end of the previous turn. He questions whether they go away if you leave the comfort zone. This conversation is intertwined with players advancing the token and collecting "payday" money. The son eventually responds that you do not gain or lose stars if you are in your "neutral" zone. This exchange demonstrates the beginning of a distributed expertise among the players. The father asks an open question about the game rules, but the son feels free to voice his opinion. As the exchange continues, the mother looks to the son to clarify rules, further cementing his role as the interface expert, if not the energy saving expert, with her even saying that "it's amazing that I'm the one who controls the thermostat."

In another example of distributed expertise, two boys are playing with their mother.

Boy1: *How much did you cost us mom?*

Mom: *Two hundred and sixty dollars.*

Boy1: *What the heck.*

Boy2: *Oh my gosh.*

Boy1: *Jeez we have [inaudible]. So, put pay in full.*

Mom: *Yep because we did pay in full. As long as we're not in debt I don't care.*

Boy1: *Mom you have 29 comfort points. So, you're over already.*

Mom: *I shouldn't have points?*

Boy1: *No mom you need them, you need to have 20 and you have 29 so it's like extra credit. And you just got above what you need it's not bad. But you need 10 more green points.*

Unlike the previous example where the father and son seemed to be working out a strategy collaboratively, the mother in this family seems to have a harder time interpreting the game interface. Over successive turns the sons chide their mother for a strategy that focuses too heavily on Comfort Points to the detriment of Green Points. The mother increasingly looked to her sons for strategy advice, especially when setting the thermostat on her turn. This led to relatively rich discussions about fine-tuning thermostat temperature settings to balance out personal comfort with lower energy use. Often times, families would debate the differences between small ranges (1-2 degrees) in temperatures. Families discovered through these discussions that turning the thermostat off entirely was a good way to save energy even if it meant being a little uncomfortable.

DISCUSSION

Modern energy infrastructures have done a remarkable job making the production, transport, and consumption of energy largely invisible to consumers. Energy infrastructures literally surround us (in the air, underground, and in our walls). Yet, for the most part, we only notice these massive systems when things go wrong. In this design case study, we have argued that these "black box" infrastructures have set the stage for what we call sterile energy practices in homes. For children, these practices are hard to see, but even when they are noticed, there is a perception that they not appropriate for kids. For adults, there is a lack of expertise and a few ways for tasks to be divided up and delegated to kids to help them learn. With the increasing adoption of smart home technologies (such as smart thermostats and digital smart meters), are there new opportunities to reconfigure such practices?

To help answer this question, we explored the use of board games to provide a context in which families can think about how they use energy and to talk about how they can be more sustainable. In this sense, the game world seemed to carve out a safe space that creates room for the emergence of new forms of participation. There is a delicate balance in the design of such games—we want to preserve the enjoyable cultural form of the family board game because it provides a unique context for discussion and collaborative strategy development. At the same time, we want to create a suspenseful, even stressful, play experience that challenges families with very real tradeoff around energy, money, and comfort. Of all of our game design features, possibly the most successful was simply making it so that everyone in the family gets a chance to set the thermostat on their turn. Especially in winter months, when money was tight, families would get into heated debates in which strong advice was offered (but not always taken up) about how to optimally set the thermostat. Since two of our most important objectives were to draw attention to this hidden aspect of energy consumption and to encourage families to reflect on energy practices, this was an important mechanism to at least opening families to the possibility that heating and cooling system management might be distributed or shared. Beyond that, we saw numerous examples of families making connections to their everyday circumstances while having living debates and discussions over the best ways to balance energy consumption, and comfort in the game.

Of course, the real question here is whether or not this game (or similar games) will ultimately make any difference. Once the game is over, do families simply move back to their day-to-day, business-as-usual routines? Or, could such games catalyze even small-scale changes in the ways that families use energy. It's difficult to answer this question, especially with our limited dataset. We speculate that, yes, games like *Turn Up the Heat!* can help. However, they will also be most effective when combined with larger, systemic changes such as public information campaigns, policy-based financial incentives to conserve, and widespread availability of eco-feedback devices that let families see household energy consumption on a continuous basis. Our conceptualization of sterile energy practices might inform these greater efforts in terms of promoting the active involvement of children and adolescents as partners in a more sustainable future.

ACKNOWLEDGMENTS

Aleata Hubbard, Mallessa James, Danielle Kiefert, Izabel Duarte Olson, and Laurel Schrementi contributed to this work. Our research was supported by the Institute for Sustainability and Energy at Northwestern (ISEN) and the National Science Foundation (grant IIS-1123574). Any opinions, findings or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Foundation.

REFERENCES

Antle, A. N., Warren, J. L., May, A., Fan, M., & Wise, A. F. (2014, June). Emergent dialogue: eliciting values during children's collaboration with a tabletop game for change. In *Proceedings of the 2014 conference on Interaction design and children* (pp. 37-46). ACM. https://doi.org/10.1145/2593968.2593971

Banerjee, A., & Horn, M. S. (2014, February). Ghost hunter: Parents and children playing together to learn about energy consumption. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (pp. 267-274). ACM. https://doi.org/10.1145/2540930.2540964

Barab, S. & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1-14. https://doi.org/10.1207/s15327809jls1301_1

Bell-Gawne, K., Stenerson, M., Shapiro, B., & Squire, K. (2013). Meaningful play: The intersection of video games and environmental policy. *World Future Review*, *5*(3), 244-250. https://doi.org/10.1177/1946756713497472

Berland, M. & Lee, V.R.. (2011). Collaborative strategic board games as a site for distributed computational thinking. *International Journal of Game-Based Learning, 1*(2), 65. https://doi.org/10.4018/ijgbl.2011040105

Chetty, M., Tran, D., & Grinter, R. E. (2008, September). Getting to green: understanding resource consumption in the home. In *Proceedings of the 10th international conference on Ubiquitous computing* (pp. 242-251). ACM. https://doi.org/10.1145/1409635.1409668

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational researcher*, *32*(1), 9-13. https://doi.org/10.3102/0013189x032001009

DiSalvo, C., Sengers, P., & Brynjarsdóttir, H. (2010, April). Mapping the landscape of sustainable HCI. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1975-1984). ACM. https://doi.org/10.1145/1753326.1753625

Easterday, M. W., Lewis, D. R., & Gerber, E. M. (2014). Design-based research process: Problems, phases, and applications. Boulder, CO: International Society of the Learning Sciences. https://doi.dx.org/10.22318/icls2014.317

Fitzpatrick, G. & Smith, S. (2009). Technology-enabled feedback on domestic energy consumption: Articulating a set of design concerns. *Pervasive Computing*, 8,1: 37-44. https://doi.org/10.1109/mprv.2009.17

Froehlich, J., Findlater, L., Ostergren, M., Ramanathan, S., Peterson, J., Wragg, I., ... & Landay, J. A. (2012, May). The design and evaluation of prototype eco-feedback displays for fixture-level water usage data. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2367-2376). ACM. https://doi.org/10.1145/2207676.2208397

Froehlich, J., Findlater, L., & Landay, J. (2010, April). The design of eco-feedback technology. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1999-2008). ACM. https://doi.org/10.1145/1753326.1753629

Guberman, S.R. & Saxe, G.B. (2000). Mathematical problems and goals in children's play of an educational game. *Mind, Culture, and Activity 7*(3), 201-216. https://doi.org/10.1207/s15327884mca0703_08

Gustafsson, A., & Gyllenswärd, M. (2005, April). The power-aware cord: energy awareness through ambient information display. In *CHI'05 extended abstracts on Human factors in computing systems* (pp. 1423-1426). ACM. https://doi.org/10.1145/1056808.1056932

Horn, M. S., Banerjee, A., D'Angelo, S., Kuo, P. Y., Pollock, D. H., & Stevens, R. (2014). Turn Up the Heat! Board games, environmental sustainability, and cultural forms. *Proceedings Games, Learning, and Society, GLS*, *14*. https://doi.org/10.1145/1999030.1999051

Horn, M. S., Leong, Z. A., Greenberg, M. D., & Stevens, R. (2015). Kids and thermostats: Understanding children's involvement with household energy systems. *International Journal of Child-Computer Interaction*, *3*, 14-22. http://54.186.10.128/media/files/pubs/heat-gls-2014.pdf

Horn, M. S., Banerjee, A., Davis, P., & Stevens, R. (2016). Invasion of the Energy Monsters: A Spooky Game About Saving Energy. In *Games+ Learning+ Society Conference 12*. https://pdfs.semanticscholar.org/ca2c/765c604090145a33a4b2228f-2ba4dd075dbf.pdf

Horn, M. S. (2018). Tangible Interaction and Cultural Forms: Supporting Learning in Informal Environments. *Journal of the Learning Sciences*, 1-34. https://doi.org/10.1080/10508406.2018.1468259

Jordan, B. & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, 4(1), 39-103. https://doi.org/10.1207/s15327809jls0401_2

Karjalainen, S & Koistinen, O. (2006). User problems with individual temperature control in offices. *Building and Environment*, *42*, 2880-2887. https://doi.org/10.1016/j.buildenv.2006.10.031

Kempton, W. (1986). Two theories of home heat control. *Cognitive Science, 10*, 75-90. https://doi.org/10.1207/s15516709cog1001_3

Kuznetsov, S., & Paulos, E. (2010, April). UpStream: motivating water conservation with low-cost water flow sensing and persuasive displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1851-1860). ACM. https://doi.org/10.1145/1753326.1753604

Latour, B. (2000). Where are the missing masses? The sociology of a few mundane artefacts. In Bijker, W. E. & Law J. (Eds), *Shaping Technology/Building Society: Studies in Sociotechnical Change*. MIT Press.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press. https://doi.org/10.1017/cbo9780511815355

Lee, J. J., Ceyhan, P., Jordan-Cooley, W., & Sung, W. (2012). Greenify: Real-World Missions for Climate Change Education, In *Games Learning and Society* 2012. http://web.cs.wpi.edu/~rich/courses/imgd4600-c13/Greenify.pdf

Meier, A., Aragon, C., Peffer, T., Perry, D., & Pritoni, M. (2011). Usability of residential thermostats: Preliminary investigations. *Building and Environment*, *46*(10), 1891-1898. https://doi.org/10.1016/j.buildenv.2011.03.009

Nasir, N.S. (2005). Individual cognitive structuring and the sociocultural context: Strategy shifts in the game of dominoes. *Journal of the Learning Sciences, 14*, 5-34. https://doi.org/10.1207/s15327809jls1401_2

Nasir, N. I. S., & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *The Journal of the Learning Sciences, 17*(2), 143-179. https://doi.org/10.1080/10508400801986108

Peffer, T., Pritoni, M., Meier, A., Aragon, C., & Perry, D. (2011). How people use thermostats in homes: A review. Building and Environment, 46(12), 2529-2541. https://doi.org/10.1016/j.buildenv.2011.06.002

Pierce, J., Schiano, D. J., & Paulos, E. (2010, April). Home, habits, and energy: examining domestic interactions and energy consumption. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1985-1994). https://doi.org/10.1145/1753326.175362

Rogoff, B. (2003). The cultural nature of human development. Oxford university press. https://doi.org/10.1111/j.1548-1352.2011.01177.x

Strengers, Y. A. (2011). Designing eco-feedback systems for everyday life. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 2135-2144). https://doi.org/10.1145/1978942.1979252

U.S. Energy Information Administration - EIA - Independent Statistics and Analysis. (n.d.). Retrieved August 26, 2016, from http://www.eia.gov/totalenergy/data/monthly/

Yang, R., Newman, M. W., & Forlizzi, J. (2014). Making sustainability sustainable: challenges in the design of eco-interaction technologies. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 823-832). https://doi.org/10.1145/2556288.2557380