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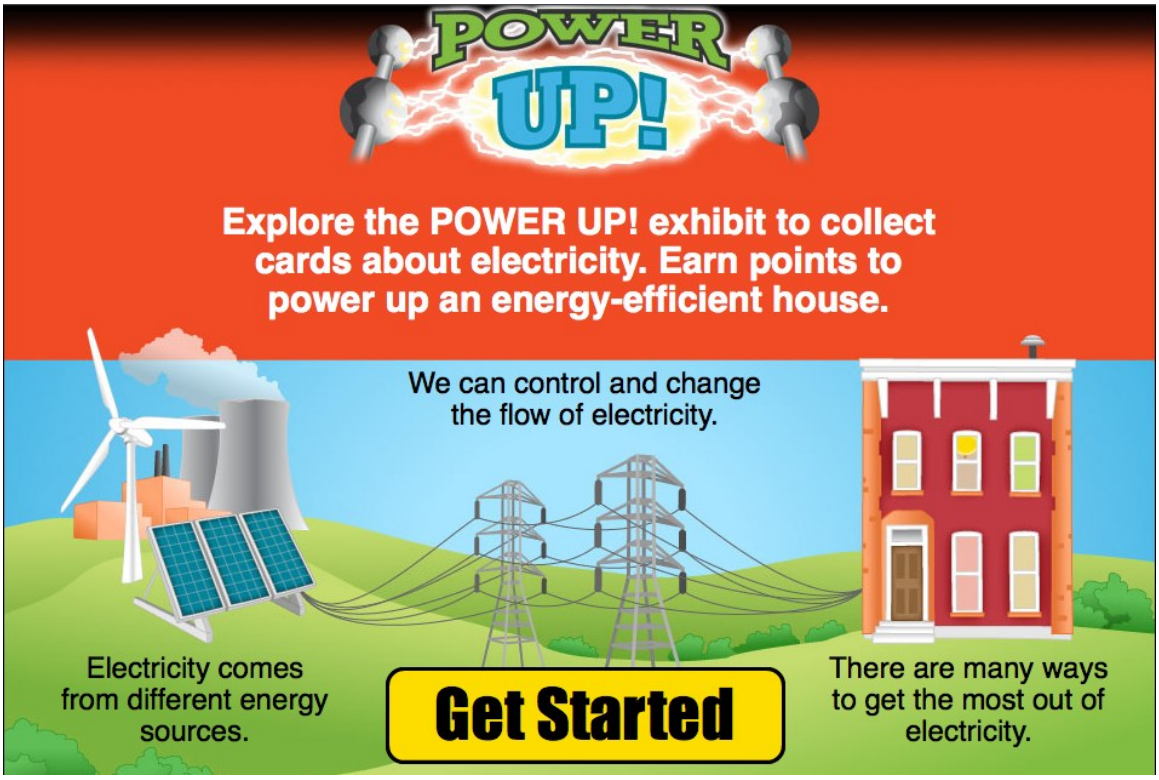
Summative Evaluation of *Power Up!* *A* Mobile Game for Maryland Science Center's *Power Up!* Exhibit



Report for
Maryland Science Center
by
Barbara N. Flagg, Ed.D. and Ilona E. Holland, Ed.D.
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EXECUTIVE SUMMARY

At the Maryland Science Center, a new permanent exhibition with a companion mobile game is focused on electricity. Multimedia Research, an independent evaluation firm, implemented a summative evaluation to assess how using the *PowerUp!* game in the exhibition influences engagement and knowledge acquisition. The evaluation collected timing and tracking observations and pre- and post-interview data from 18 ten-year-olds who used the game within the *Power Up!* exhibition area and 16 ten-year-olds who did not use the game.

Game players experienced the *Power Up!* exhibition area differently from non-gamers

The *Power Up!* game utilizes a two-part design: a question and answer section that encourages use of individual floor exhibits and a subsequent "mobile exhibit" that independently reinforces content through informative card playing and powering up an energy-efficient house. The "mobile exhibit" of the game acted as an additional meaningful exhibit and was competitive with the floor exhibits in holding gamers' attention and interest. Game players were more likely than non-gamers to visit non-interactive exhibits that presented game keycodes and more likely to skip exhibits that did not have keycodes. Game players remained in the exhibition area significantly longer than non-gamers; but due to their focus on the "mobile exhibit" activity, they visited floor exhibits for significantly shorter times on average; interacted physically with significantly fewer exhibits; and were observed significantly less often repeating activity rounds at exhibits, returning to exhibits, and observing other's actions with exhibits.

Game players enjoyed their experience as much as non-gamers and valued the game

On average, gamers and non-gamers rated equally the appeal of their experience in the exhibition area. Three-quarters of game players liked most the question and answer feature, half liked powering up their house, and one-third noted the appeal of the card playing feature. Participants felt that the *Power Up!* game helped them learn more about electricity, increased their attention to the exhibits and increased their activity in the exhibition area.

Game players learned as much, and more, about electricity as non-gamers

Gamers and non-gamers demonstrated statistically equivalent gains in their recall of new information about electricity overall and in their more specific recall of energy sources that generate electricity and methods that move, control or change electricity. With respect to the content area about ways to use less electricity, for which the game presented more information than the exhibits, gamers significantly outperformed non-gamers in acquiring new knowledge.

Overall, using the *Power Up!* game within the *Power Up!* exhibition has clear value in promoting appealing engagement and learning.

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INTRODUCTION

In the Spring of 2014, the Maryland Science Center (MSC) opened a new permanent exhibit focused on electricity, with a companion mobile game. Multimedia Research carried out a summative evaluation, reported here, to assess what value, if any, the *PowerUp!* game adds to the exhibit experience in engagement and knowledge acquisition.

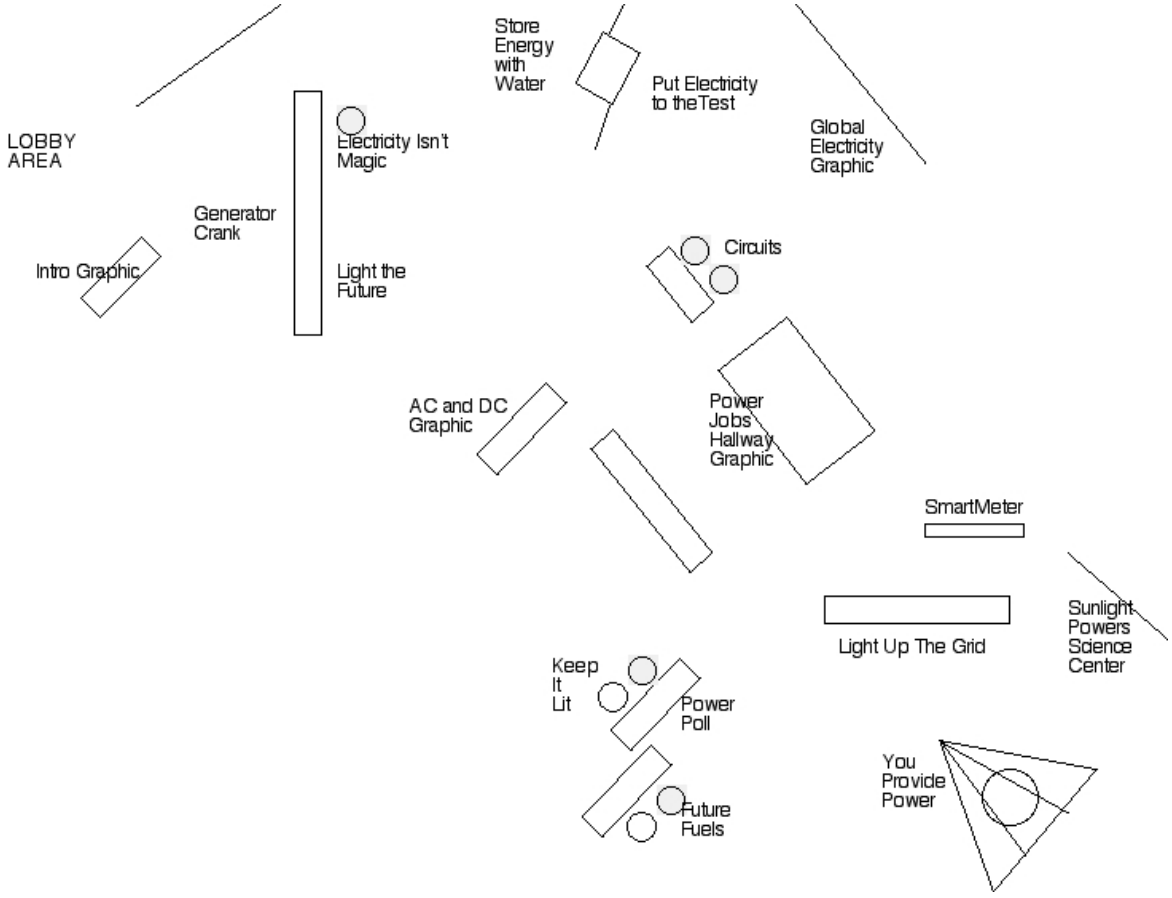
The Exhibit *Power Up!*

Sponsored by energy supplier Constellation and parent company Exelon, and designed by Hands On! Inc. and Maryland Science Center, the *Power Up!* installation presents visitors with 16 exhibits focused on four messages:

- Electricity isn't magic. I can understand how it works and how I can put it to work.
- It's fun to experiment with electricity because it can do so many things.
- Electricity can come from many different sources, each with advantages and disadvantages.
- Because we depend on electricity so much, the scale or the system is massive. It requires many people and many technologies that are all interconnected.

The photo below shows a portion of the 4,000 square foot exhibit area.

The 4,000 square-foot area as sketched below features 16 discrete exhibits beyond the Introductory graphic, including interactive stations for visitors to generate, measure, monitor, distribute and use electricity.



Visitors learn about different energy sources for generating electricity via five interactive stations - *Generator Crank, Electricity Isn't Magic, Store Energy with Water, Future Fuels, You Provide Power*. Also the exhibit *Sunlight Powers Science Center* presents solar information.

The *AC and DC Graphic*[1] along with three interactives - *Circuits, Keep It Lit*, and *Light Up the Grid* - address measuring, monitoring and distributing the flow of electricity.

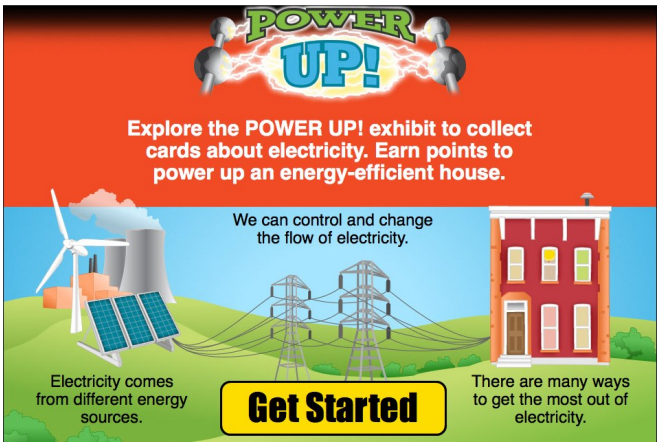
Energy efficiency is the focus of three interactives - *Light the Future, Put Electricity to the Test* and *SmartMeter*.

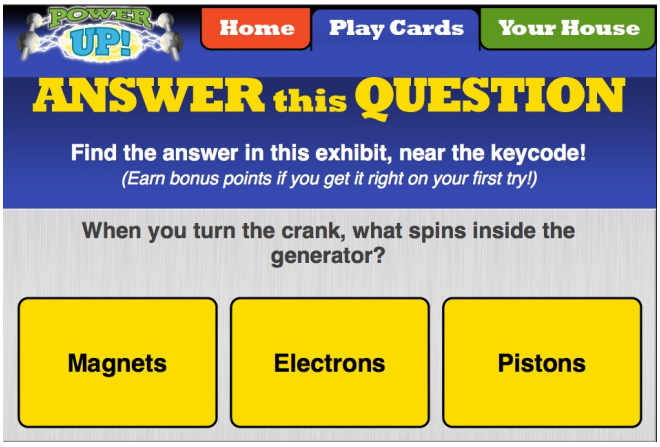
Along with the above mentioned *Electricity Isn't Magic*, the remaining three exhibits are not referenced in the *Power Up!* game activity: *Power Poll* is an interactive opinion poll asking what visitors would want most to power in their house. Two wall graphics – *Global Electricity* and *Power Jobs* – present images with minimal text.

[1] An AC/DC interactive associated with the graphic was not available during the evaluation period.

The Game *Power Up!*

To accompany the exhibit, MSC in conjunction with developer Eduweb produced a mobile game application that helps visitors explore the generation, control, and use of electricity while interacting with the exhibits. The *Power Up!* app offers young visitors (~ 8-12 yrs) an on-site game intended to enhance their exhibit visit.





Intro. The *Power Up!* app presents an interactive quiz and card game designed to be used in the *Power Up!* exhibition area. An introductory screen (top screen) presents three statements that summarize the app's main messages, which also reflect the exhibit messages. <Get Started> brings up a How to Play screen (middle screen).

How to play. A round of the game comprises (1) locating a keycode associated with an individual exhibit; (2) answering a multiple-choice question using the exhibit; (3) playing a card game matching content cards to one of the three game messages in order to (4) earn points that can be spent to outfit an energy-efficient house with an electricity power source, electricity control mechanisms and energy-efficient appliances.

Keycodes. Keycode labels are posted at strategic spots on each of 12 of the 16 *Power Up!* exhibits (See keycode #319 in ① of the How to Play screen). Each round of play involves one keycode and its exhibit-related multiple-choice question.

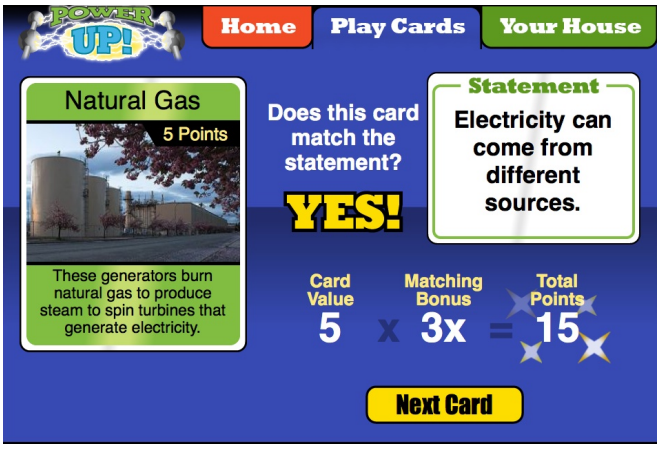
Q&A. With each keycode entered via a dedicated number keypad, a player receives a multiple-choice question and is encouraged to discover the answer by interacting with the exhibit or reading the exhibit panels (bottom screen). If an incorrect answer is touched, players are encouraged again to look in the exhibit near the keycode.

Message Statements. The top screen shows answer feedback for a correct answer and a transition sentence pertinent to the exhibit and multiple choice question (e.g., "*A generator uses magnetism to create…*"). The transition leads into one of the three message statements (in this case "*Electricity can come from different sources*."). The Generation message, "Electricity can come from different sources" is associated with five exhibits. The Control statement, "We can control and change the flow of electricity," relates to four exhibits. The Usage statement, "There are many ways to get the most out of electricity," goes with three exhibits.

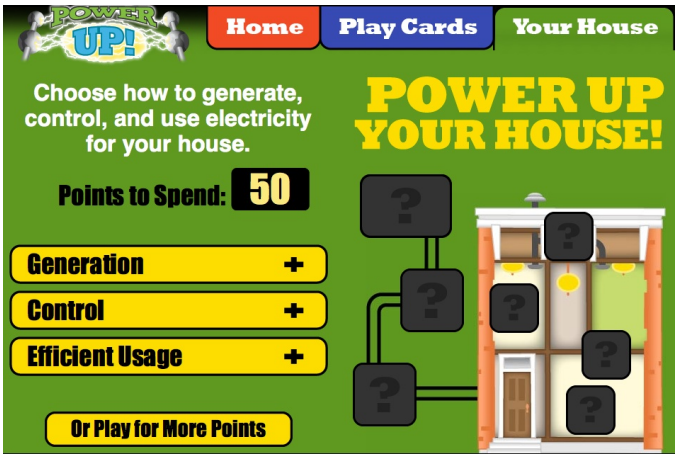
Card Playing. With presentation of the statement, randomly drawn content cards are displayed, as shown in the middle screen. The app draws on three types of content cards that players must match to the three message statements. Each card presents a title, a still or animated image, a sentence description and a point value (see the Natural Gas card).

- 9 Generation cards illustrate how different energy sources generate electricity.
- 8 Control cards show methods, techniques and devices that we use to control, move and change electricity.
- 9 Usage cards exemplify ways that we can use less electricity.

With consecutive cards, the player decides by touching <yes> or <no> whether or not a content card matches the statement presented. After each yes/no choice, a new card appears. The statement remains the same for each card drawn. When two cards receive a <yes> response and appear in the player's "hand," the player receives feedback and scoring points related to their correct or incorrect match choice for the card (see bottom screen). Bonus points are given for correctly answering the multiple-choice exhibit question and matching cards to the statement.



Power Up Your House. After acquiring points, a player plays for more points or spends points to "power up" a Baltimore row house (see top screen).



With sufficient points, players can choose one type of power plant to generate electricity for their house; two types of control mechanisms as the electricity moves to the house; and four types of efficient electrical appliances or devices (see middle screen). Players drag a choice to one of the question mark boxes. Players may also replace their choice by spending more points. Players can also skip powering up their house and continue to play for more points.

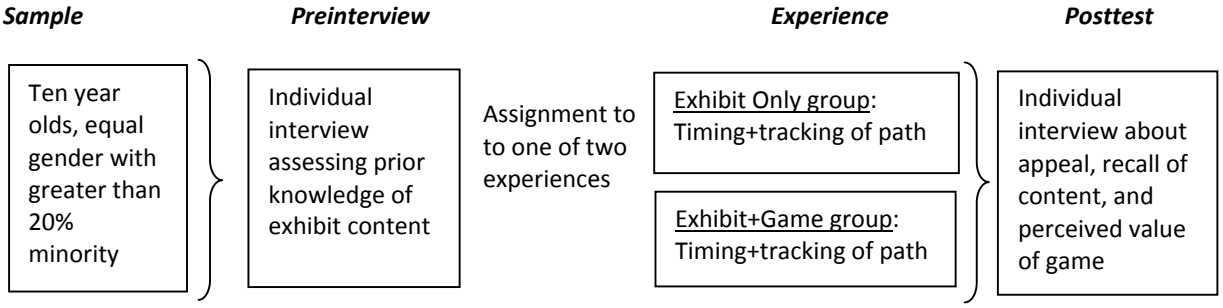
Upon completion of fully powering their house, players can take a picture, keep playing for more points or unpower their house and start over (see bottom screen).

While the Q&A section of the game is tied to individual floor exhibits via the keycodes and multiple-choice questions, the Card Playing and Powering Up section of the game presents content and interaction related to the exhibition content but independent of the individual floor exhibits. Thus, part of the game could be considered a "mobile exhibit" to be experienced anywhere in the exhibition area as contrasted with the "permanent exhibits" on the floor.

METHOD

Summative Evaluation Design

The *Power Up!* game is intended to engage youngsters with individual exhibits and increase their knowledge about electricity. Thus, the main goal of the summative evaluation is to assess what value, if any, the *Power Up!* game adds to the exhibit experience in engagement and knowledge acquisition. An experimental evaluation design was applied, as outlined below, in which ten year olds were assigned either to experience the exhibit only or to experience the exhibit with the game. Participants were interviewed prior to and after their experience as well as observed during their exposure to the exhibit, with or without using the game. The evaluation focuses on holding power, appeal, and learning for both groups and on appeal and perceived value of the game for the Exhibit+Game group.



The evaluation compares the two groups (Exhibit Only; Exhibit+Game) for the outcomes below:

- Are there differences in holding power? Do groups differ in…
  - time spent in the exhibition area?
  - time spent with exhibits overall and with individual exhibits?
  - number of exhibits visited and repeat exhibit visits?
  - reading and interacting with exhibits?
  - playing more than one round of exhibit activity?

- Are there differences in appeal? Do groups differ in…
  - how much they enjoy their 20-minute experience?
  - what they like about the exhibit?
  - what they do not like about the exhibit?

- Are there differences in learning? Do groups differ in…
  - how much they felt they learned?
  - their understanding of how electricity is generated?
  - their understanding of how electricity moves and is controlled or changed from generation to entering homes and businesses?
  - their understanding of how people can use less electricity?

Additional research questions addressed for only the Exhibit+Game group included:

- How many keycodes were entered and questions answered?
- How long players spent in the "mobile exhibit" sections of card playing and powering up the house?
- What is liked about the game?
- What is not liked about the game?
- How the game affected enjoyment of the exhibit?
- How the game affected perception of learning about electricity?

Sample

Exhibit+Game sample. One month before the summative evaluation, a formative evaluation procedure gathered contact information for science center members with ten-year-olds who were experienced with mobile app devices and willing to provide feedback using the prototype game in the exhibit.[2] This sample acquisition procedure ensured that we had children who were experienced in app use. Many more parents and children volunteered than could be included in the formative evaluation, so these parents and children were invited to participate in the summative evaluation in the Exhibit+Game group via an email, as follows.

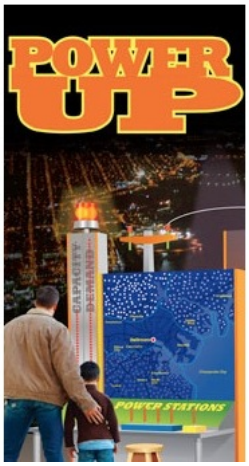
> *We are inviting children who are 10 years old to experience Maryland Science Center's new exhibit, Power Up, with a companion mobile app. If your child has seen the new exhibit, please do not respond to this invitation. If your child has not yet seen the new exhibit, then perhaps s/he would be interested in participating in a one-on-one evaluation session. During the session, s/he will be provided with an iPod Touch device to use the app with the exhibit. During and after the app use, s/he will answer some questions about appeal and content of the exhibit and app. Your child's feedback will be audio recorded but no names are attached to the recording. In recognition of participation, each child will receive upon completion of the session 4 vouchers (for exhibits and IMAX), which you can redeem at MSC's ticket counter within six months.*

[2] Flagg, B.N. (2014 March 3). Formative Evaluation of PowerUp Mobile App. Report for Maryland Science Center. Research Report No. 14-001. Multimedia Research.

Exhibit Only sample. A separate invitation was prepared to recruit the Exhibit Only sample in order to include children who were not aware of the accompanying game. The *Power Up!* app was not publicly available at the time of the evaluation. Invitations were emailed to science center members requesting ten-year-olds to participate in a one-hour session to explore and give their opinions about the *Power Up!* exhibit.

Help Us Evaluate a New Exhibit!

Power Up! is the Maryland Science Center's newest exhibit. The Science Center is seeking 10 year olds to explore the exhibit and give us their opinions. Join us for a one-hour session on any day from Friday, April 11 through Tuesday, April 15. Each 10 year old participant will receive four IMAX vouchers in appreciation. For more details, please email your child's gender and age to Barbara Flagg at powerup@marylandsciencecenter.org.



Those who responded to their respective invitation signed up for an individual one-hour time slot during a Friday-Tuesday period, which included two public school holidays. Prior to participation, parents and children read and signed consent forms. Children recruited for both groups confirmed that they had not visited the exhibit previously and that they were familiar with mobile games, so that all children are representative of visitors who might be likely to download the exhibit app.

Complete data sets of exhibit tracking and timing and pre- and post-interviews were obtained for 34 children, including 16 for the Exhibit Only group and 18 for the Exhibit+Game group. Of the Exhibit Only participants, 38% are girls and 31% are minorities. Of the Exhibit+Game participants, 50% are girls and 22% are minorities. The distribution of participants by group, gender and minority status is shown in the table below.

Power Up! Sample (N =34)

	Exhibit Only (n = 16)	Exhibit+Game (n = 18)
Gender	6 girls, 10 boys	9 girls, 9 boys
Minority (Asian, Black, Hispanic)	3 girls, 2 boys	3 girls, 1 boy

Procedure

Each of the two evaluators worked with half of the participants, distributed equally by group and gender. Sessions required 45 – 60 minutes. After signing the consent form in the lobby at the front of the exhibition area, participants were walked quickly through the exhibition area from front to back, with evaluators pointing out the extent of the *Power Up!* exhibition area. Interviews occurred in a quiet room off the back of the exhibition area.

Pre-experience interview. Each session began with background questions about age and mobile game experience followed by open-ended questions assessing prior knowledge about (1) energy sources used to generate electricity; (2) methods that move, control or change electricity as it comes to their house; and (3) what people can do to use less electricity.

Evaluators then introduced the children to the evaluation procedure, as follows. Additional instructions for the Exhibit+Game group appear in brackets:

> *In a minute, we are going into the Power Up exhibit [and I will give you the Power Up game to use on an iPodTouch]. I'll be available in the exhibit area but I won't interfere with whatever you want to look at or do there. You can explore the exhibit as much as you want [and use the game as much as you want]. When you have finished exploring, we will return here and I'll ask about your experience.*

Exhibit and game exposure. To maintain a total session duration of less than one hour for the children, participants were permitted up to 20 minutes in the exhibition area; however, they could stop at any time prior to that 20 minute limit. Participants were not informed of the time limit prior to entering the exhibition area. The 20 minute limit was used in a previous summative evaluation of Maryland Science Center's *PlanetMania* mobile game,[3] and this time limit initially was chosen because a review of tracking and timing studies indicated that average and median times spent by uncued adult visitors in most exhibitions are less than 20 minutes.[4] Participants of the two evaluators were offset in their session starting times by about 15 minutes so few participating children overlapped in their time in the exhibition area.

To ensure coverage of the whole exhibition in the data set, half of the participants in each group, balanced for gender and evaluator, entered the area starting in the front near the *Generator Crank* exhibit and half entered the area starting in the back near the *You Provide Power* exhibit (see map on p. 2). Over the course of their sessions, 78% of the Exhibit+Game group and 88% of the Exhibit Only group visited both sections of the exhibition area.

Tracking and Timing. Prior to data collection, the evaluators trained to become reliably consistent using TrackNTime™ tablet software with the exhibit and game. The software was used to assess holding power by recording participants' time with individual exhibits and the game components. Also recorded was the presence (not duration) of certain behaviors, described below. Evaluators observed from a distance of approximately 10 feet, moving with the child as s/he moved through the exhibit; thus, the evaluators were not unobtrusive but neither were they intrusive. In order to promote as natural exploration as possible, children were not informed that their activity would be recorded, but they were aware of the evaluator's presence in the exhibition area.

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[3] http://informalscience.org/evaluation/ic-000-000-003-551/_Summative_Evaluation_of_PlanetMania_Mobile_App_in_Maryland_Science_Center_s_Life_Beyond_Earth_Exhibit_

[4] Serrell, B. (1998). *Paying attention: Visitors and museum exhibits*. Washington, DC.: American Association of Museums. p. 36. Note that our child visitors were cued, likely yielding longer visit durations than for uncued visitors.

The following are variables obtained for both the Exhibit Only and the Exhibit+Game groups:

1. Total time spent in the exhibition area, parsed into (a) time in incidental activity such as walking around; (b) time involved with exhibits including the game Q&A; and (c) for the Exhibit+Game group only, time involved with the "mobile exhibit" of playing cards and powering up the house.
2. Time spent at individual exhibits. For the Exhibit+Game group, this variable includes the game question and answer (Q&A) time associated with individual exhibits. Evaluators did not distinguish Q&A activity from exhibit use since the questions encouraged exhibit engagement and players could quickly go back and forth between the game and the exhibit.
3. Number of exhibits visited. Stops of 3 seconds or less were not counted as an "exhibit visit."
4. Number of exhibits at which participants stood or sat to interact by cranking handles, flipping switches, pushing buttons, connecting components or listening to audio.
5. Number of exhibits for which looking at text was observed. This behavior is not coded as "reading" because actual reading could not be reliably observed. However, to be coded in this category, participants needed to be close enough to read exhibit text.
6. Number of exhibits returned to after visiting a different exhibit.
7. Number of exhibits for which participants completed more than one round of activity. A round of activity is defined as completing the intended interaction of the exhibit. For example, a round for *Light Up the Grid* involves connecting a series of electromagnetic chains to light up houses at the end of a circuit. Eleven (11) of the 12 interactive exhibits were defined as having a discrete round of activity.
8. Number of exhibits at which participants observed other visitors' verbal or physical interactions with the exhibit.
9. Number of exhibits at which participants verbally or physically interacted with others with respect to an exhibit.

Recorded for the Exhibit+Game group only were

1. Number of keycodes entered.
2. Time spent with the "mobile exhibit" content in the activity of matching cards to statements and powering up the house. Completion of this activity is independent of the "permanent exhibits" on the floor and could be observed reliably as it occurred typically between visits to the "permanent exhibits."

Two situational variables also were recorded for each participant's session:

1. Crowd level (Low (n = 14); Medium (n = 14); High (n = 6)
2. Time of day (Morning (n = 11); Midday (n = 14), Late day (n = 9).

Crowd level and Time of day were not correlated over the Friday – Tuesday collection period.

Post-experience interview. After their 20 minute exposure to the exhibits with or without the game, participants answered a series of structured interview questions focused on appeal and learning outcomes.

Regarding appeal outcomes, evaluators asked participants how much they liked or did not like their experience as well as what they liked and did not like about the exhibit. Evaluators also asked the Exhibit+Game participants what they liked and did not like about playing the game.

Regarding learning outcomes, evaluators asked participants how much they felt they learned from their experience, asked what they learned about electricity, and asked again the more specific three pre-experience knowledge questions (see p. 6-7).

Regarding perceived value of the game, evaluators asked the Exhibit+Game participants how using the game in the exhibit affected their experience and affected their learning about electricity.

Data Analysis

Appropriate statistical tests were implemented for all quantitative data, looking at group differences and relationships with gender, ethnicity, crowd level, time of day, and front or back entrance to the exhibition area. In this report, footnotes present a definition of a statistic when first used in the report and also present the statistical test results. A statistical test that gives a p-value, or probability value, lower than .05 is reported as "statistically significant" in the text. This means that a difference between groups is noted as significant only if it has a 5% or smaller likelihood of occurring by coincidence or chance.

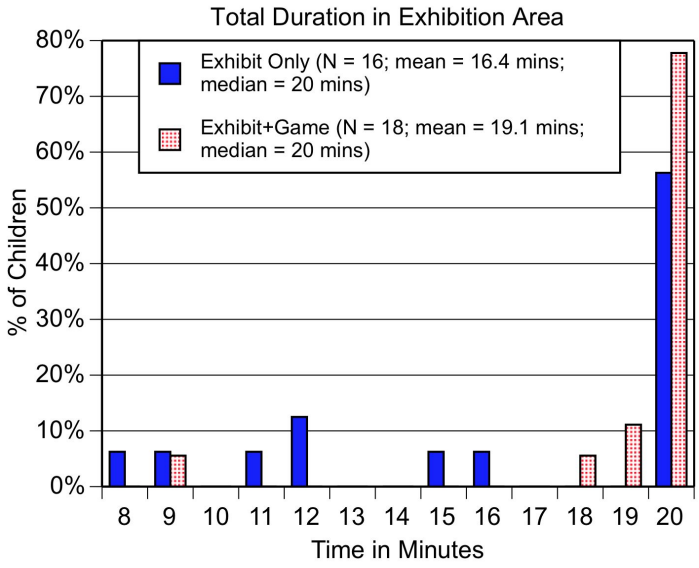
Qualitative data from interviews were sorted into categories by keyword and theme in relation to the evaluation issues of appeal, learning and perceived value of the game. Categories are presented as frequencies in the text, and verbatim quotes from participants are presented to illustrate each category and enrich the quantitative data set.

RESULTS: HOLDING POWER

The Exhibit Only and Exhibit+Game groups visited similar numbers of exhibits, but Exhibit Only children interacted physically with significantly more exhibits than Exhibit+Game children. Also, significantly more Exhibit Only children than game players were observed returning to exhibits; repeating a round at an interactive exhibit; and watching other visitors' actions with the exhibits. Children using the *Power Up!* game remained in the exhibition area significantly longer than those not using the game; however, game players attended to the exhibits for a significantly shorter average duration because of time they allotted to the "mobile exhibit" activity of card matching and powering up their house. On average, game players spent about the same amount of time with the exhibits and Q&A game activity as they spent with the card matching and powering up activities. Playing the game increased the likelihood that children would visit non-interactive exhibits that presented game keycodes but also skip exhibits that did not present keycodes.

- **A majority of children stayed in the exhibition area for the 20 minutes permitted, but game players remained significantly longer on average than those not using the game.**

Prior to entering the exhibition, instructions to participants were intentionally non-directive: *you can explore the exhibit as much as you want* [*and use the game as much as you want*]*;* however, researchers ended visits at 20 minutes to maintain the promised one-hour session limit. The chart shows that duration in the exhibition area ranged from a short 8-9 minutes up to the full 20 minutes. For the Exhibit Only group, this variable includes both time spent with exhibits and incidental time such as walking around or watching activity in adjacent areas. Added to this variable for the Exhibit+Game group is time spent playing the game. A majority of both groups stayed in the exhibition area for 20 minutes; however, the Exhibit+Game group averaged a significantly longer duration of 19.1 minutes compared to the Exhibit Only group duration of 16.4 minutes.[5]

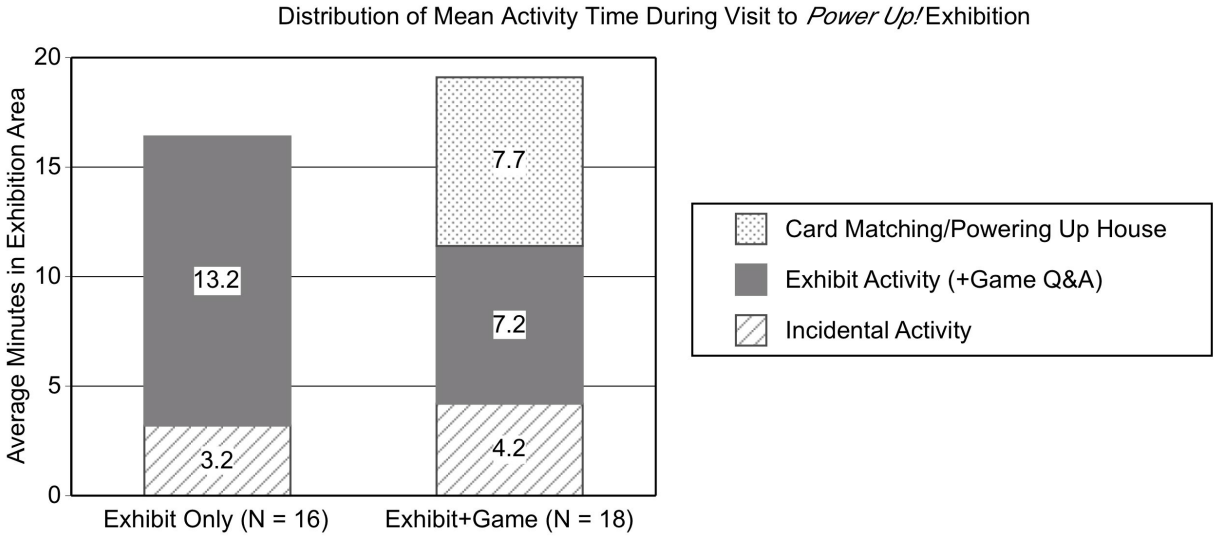


[5] $t(23) = 2.11$ $p = 0.04$. t-tests applied to two independent samples assess the difference between means, in this case the mean duration of the two groups in the exhibition area.

- **On average, time attending to exhibits was significantly longer for the Exhibit Only group compared with the Exhibit+Game group.**

As displayed in the chart below, the Exhibit Only group's mean total duration of 16.4 minutes in the exhibition area included an average of 3.2 minutes in incidental activity and an average of 13.2 minutes looking at text and interacting with the exhibits.

Also illustrated in the chart below, the Exhibit+Game group's mean total duration of 19.1 minutes included an average of 4.2 minutes in incidental activity and 7.2 minutes reading and interacting with exhibits as well as entering exhibit keycode numbers and using the exhibit to determine answers to the questions posed by the game Q&A. The two groups' incidental times did not differ significantly, but the game players interacted with the exhibits for a significantly shorter average time than those not using the game (7.2 mins. vs. 13.2 mins.)[6]. Players would tend to locate the keycode on an exhibit, read the game question, interact with the exhibit to determine the answer (or guess), and then move on to completing the game by matching cards to a statement and optionally powering up their house.



- **On average, game players spent about the same amount of time with the exhibits and Q&A game activity, which used the exhibits, as they spent with the subsequent card matching and powering up game activities.**

The chart above also shows that the Exhibit+Game group spent an average of 7.7 minutes of their time matching cards to the three message statements and powering up their house. The game activities of card matching and powering up produce a "mobile exhibit" alternative to those exhibits permanently on the floor. On average, players spent about the same amount of time with the "mobile exhibit" (7.7 mins) as with the "permanent exhibits" (7.2 mins).

[6] $t(26) = 3.98$ $p = 0.0005$.

The table below explores these same data, presenting the distribution of total time in percents across the three activity types for the two groups. Again, the proportion of time spent in incidental activity was the same for the two groups (19.5% vs. 21.7%), and game players split the remainder of their time equally between attending to exhibits with the Q&A part of the game (37.8%) and attending to the "mobile exhibit" of matching content cards to message statements and powering up their house (40.5%). Exhibit+Game participants explained:

The game was very fun and I still learned a lot. I liked how they would ask you a question and you would answer the question. I usually got it right on the first try and I got a lot of bonus points. I liked the cards and matching the statement. I also liked that you put things in your house.

I liked how it had a reading part and then the hands-on stuff, like how you could work it out for yourself and not have somebody teach it to you. You can mess around with it and figure it out for yourself. You learned something at each station. You got to test what you learned and you had to answer a question and you had to read a little bit and answer more questions and you got points for the stuff you got right. It was very understandable.

Distribution of Total Time During Visit to *Power Up!* Exhibition

	Exhibit Only (n = 16)	Exhibit+Game (n = 18)
Incidental Activity	19.5%	21.7%
Exhibit Activity (+Game Q&A)	80.5%	37.8%
Card Matching/Powering Up House		40.5%
	100%	100%

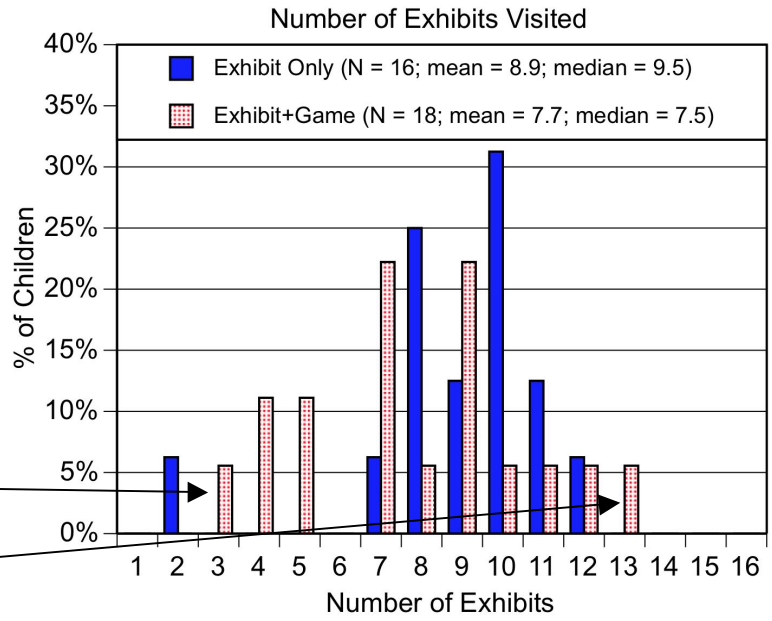
- **Groups with and without the game visited on average a similar number of exhibits.**

Groups did not differ significantly in their average number of exhibits visited. Exhibit Only participants visited an average of 8.9 exhibits vs. 7.7 exhibits visited by the Exhibit+Game participants.

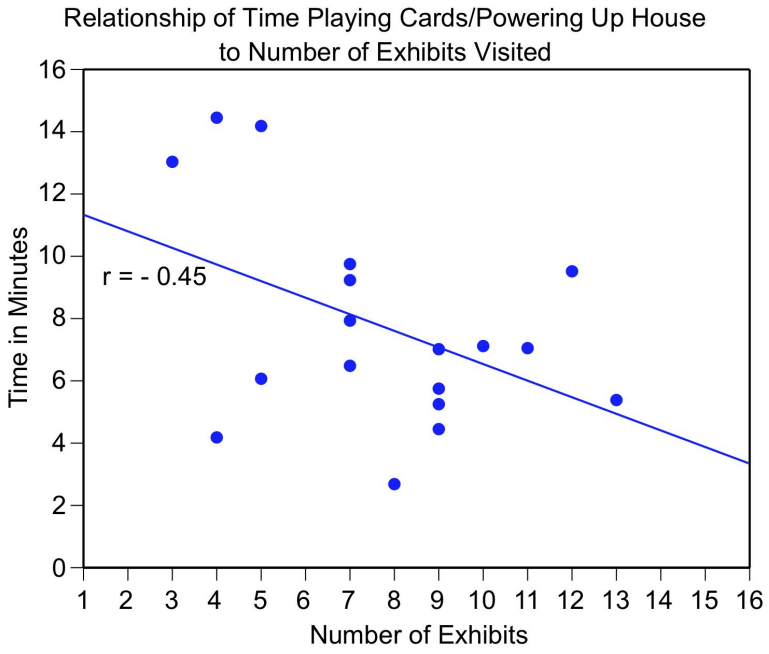
Children who entered at the front of the exhibition area visited significantly more exhibits on average (9.3, n = 18) than those who entered from the back (7.4, n = 16)[7]. The front area presents eight exhibits (six interactive, 2 graphic/text). The back area presents seven interactive exhibits. In between the two areas is a hallway graphic/text exhibit.

[7] $t(31) = 2.10$, $p = 0.04$.

The top chart shows that game players varied more in number of exhibits visited compared to the Exhibit Only participants. This variation is due to differences in how long individual game players took to complete a game round between exhibits. Average duration of card matching and house play per keycode for the Exhibit+Game group was 1.4 minutes, ranging from a high of 4.4 minutes for the player who visited 3 exhibits to a low of 0.5 minutes for the player who visited 13 exhibits.



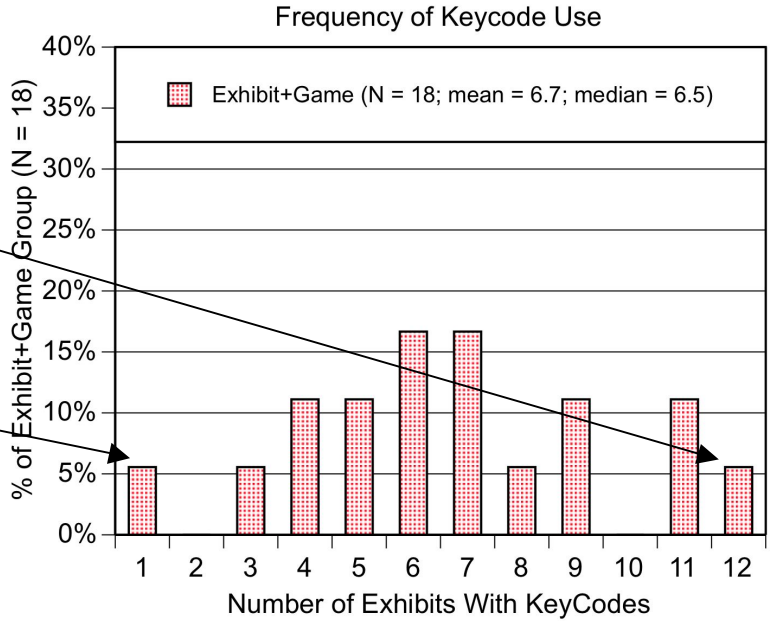
For the Exhibit+Game group, the scatter plot to the right presents the individual <u>total</u> times playing cards and powering up the house plotted against the total number of exhibits visited. As game players increased in time spent playing cards and powering up their house with the "mobile" exhibit, the number of "permanent" exhibits visited decreased, as evidenced by a significantly strong negative correlation (r = - 0.45).[8]



8 r (16) = - .45, *p* = 0.03. The Pearson product-moment correlation coefficient, r , assesses the strength of association between two continuous variables, in this case, time in game play vs. number of exhibits. A perfect negative correlation is - 1.0. The figure displays the regression line for the data. The square of the correlation, r^2 = .20, indicates that 20% of the variability in time in game play is tied to variability in number of exhibits visited.

The game players used an average of 6.7 keycodes of the 12 available. A majority of players (61%) answered keycode questions for every exhibit they visited; however, game players also indicated interest beyond the parameters of the game, as 28% visited one or more exhibits without entering the relevant game keycode and 39% visited one or more of the four exhibits that do not present a game keycode.

As the chart illustrates, game players showed a relatively flat normal frequency distribution of keycode use. Keycode use ranged between a child who interacted little with the exhibits and mostly played the game by entering all 12 keycodes to a child who focused mainly on exhibits and used only one keycode.

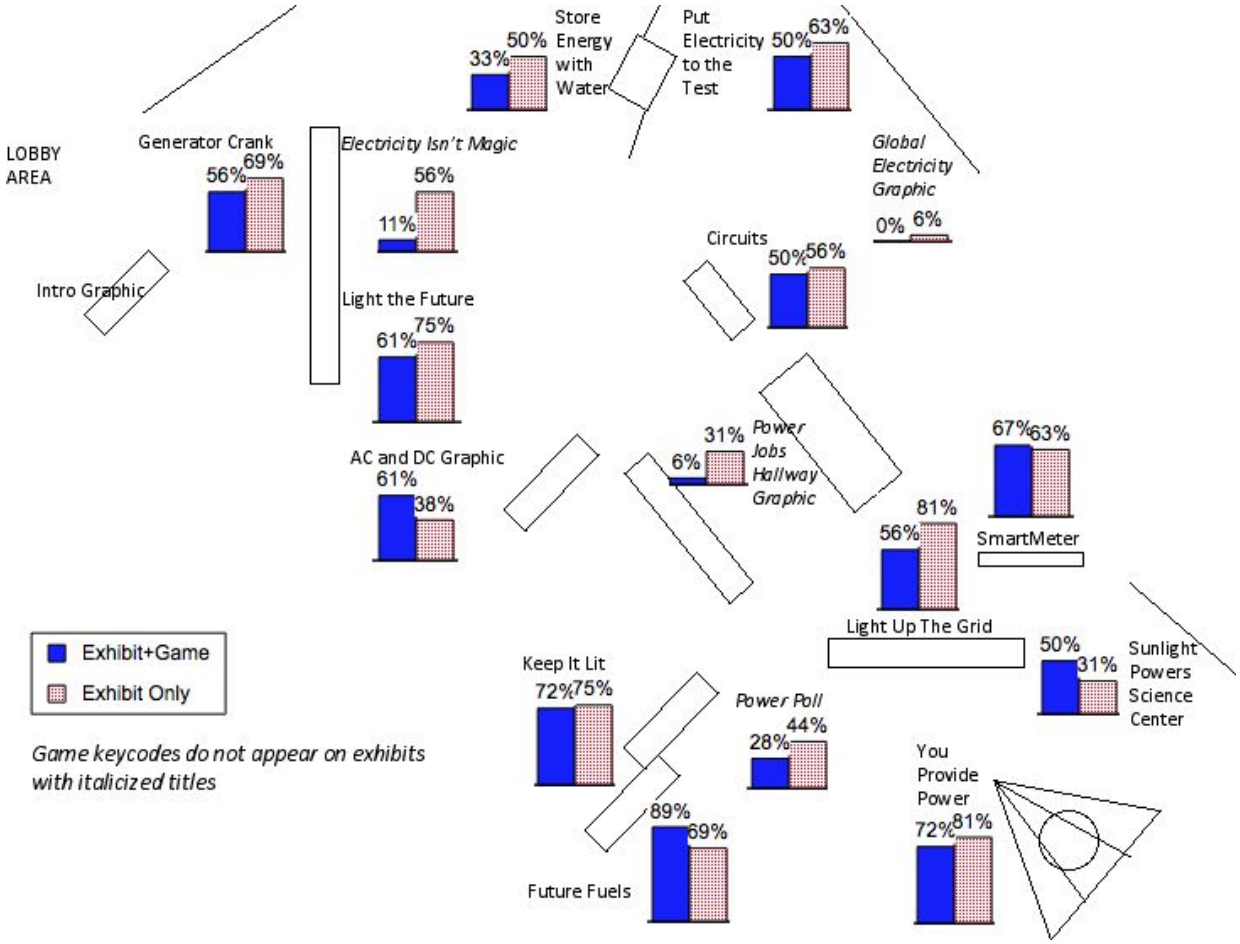


The child who completed 12 keycodes focused his appeal response on learning: *I learned a lot. You learn even more than just with the exhibit. It was kind of hard to guess which card was the right one. It was fun powering up the house. You could pick out of all the possible things and then customize the house.* In contrast, the child who ignored the game declared more interest in the exhibits: *I wanted to look at some other exhibits. I wanted to spread my time out doing different things. I wanted to do the exhibits.*

- **Playing the game increased the likelihood that children would visit non-interactive exhibits that presented game keycodes and also skip exhibits without keycodes.**

Superimposed on the exhibition floor map sketched below are bar graphs of the percentages of the two groups who visited individual exhibits. The Exhibit+Game group was more likely than the Exhibit Only group to visit two non-interactive exhibits, probably because they presented game keycodes: *AC and DC Graphic* (61% vs. 38%) and *Sunlight Powers Science Center* (50% vs. 31%), although these group differences did not reach statistical significance. Game players were less likely than Exhibit Only children to visit the four exhibits that did not present game keycodes, marked on the map with *Italicized* titles: *Global Electricity Graphic* (0% vs. 6%), *Power Jobs Graphic* (6% vs. 31%), *Power Poll* (28% vs. 44%), and *Electricity isn't Magic*, which reached a statistically significant difference (11% vs. 56%).[9] The latter is the only exhibit of the 16 that attracted significantly different percentages of visitors from the two groups.

Percent of Groups Who Visited Individual Exhibits



[9] Fisher Exact Test is used with small samples to test whether two groups (Exhibit Only and Exhibit+Game) differ significantly in the proportion with which they fall into two classifications (visited exhibit, did not visit exhibit), $p = 0.009$ for *Electricity Isn't Magic.*

The most frequently visited exhibits for the Exhibit Only group were *You Provide Power* and *Light Up the Grid* and for the Exhibit+Game group were *You Provide Power, Future Fuels* and *Keep It Lit.* The children liked *You Provide Power* because of the physical interaction and the clarity of message; for example:

Exhibit Only group:

I like how you could turn that little wheel and there is a sign that says 'How does it work?'

When I tried spinning that big thing, that was a fun activity, but when I read it, I understood how it worked, not just 'oh, I'm doing this,' but I understood.

Exhibit + Game group:

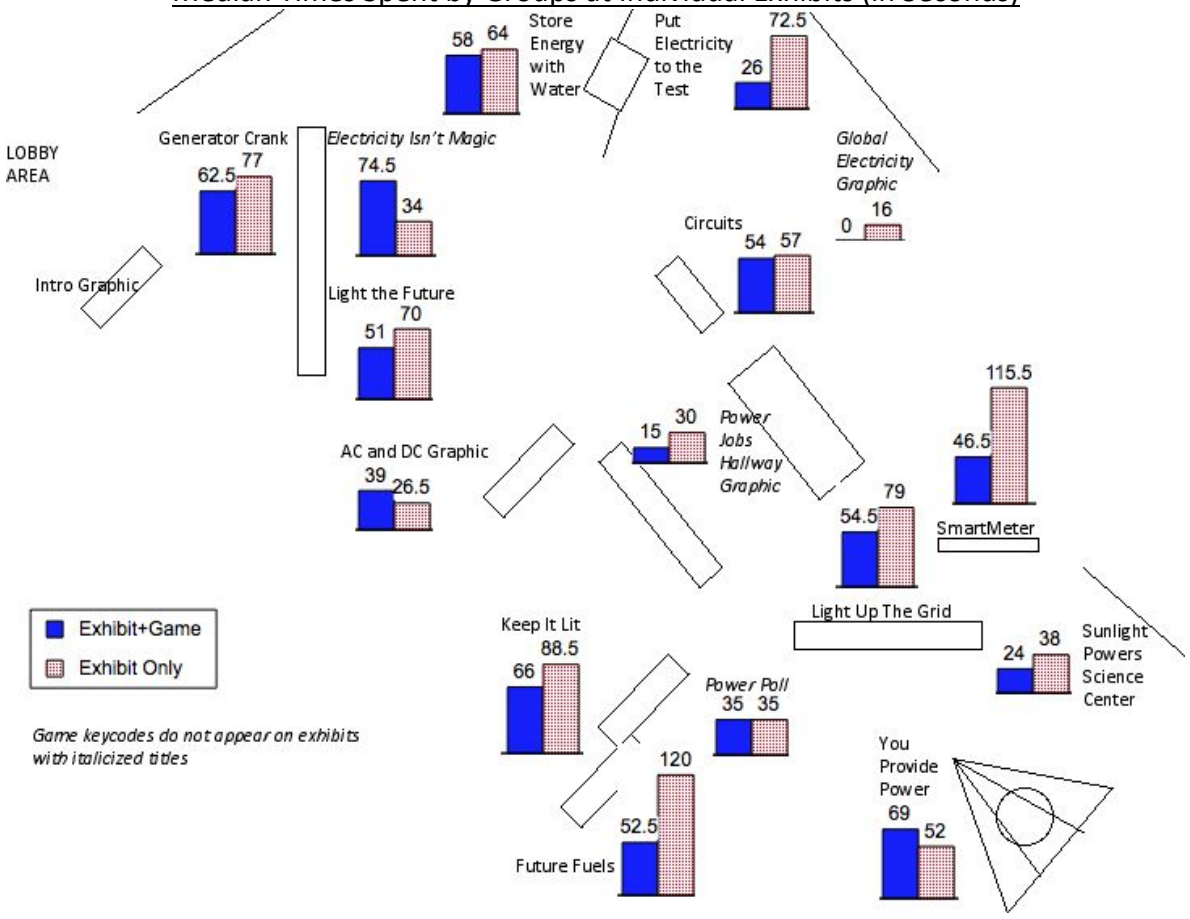
I liked the thing that you turned. It generated electricity and the light bulb turned on and the blender.

You could interact with the things that powered electricity, like with the light, blender, fan and leaf blower. You could spin it to see how it powered the electricity.

- **The median individual exhibit visitation times of the Exhibit Only children were significantly higher compared with Exhibit+Game children for all exhibits combined and for the two individual exhibits of *Future Fuels* and *Smart Meter*.**

Superimposed on the exhibition floor map below are bar graphs of the median times in seconds that the two groups spent at individual exhibits.[10] The distributions of median times for <u>all</u> exhibits visited differed significantly for the two groups: the median individual exhibit holding time for the Exhibit Only group at 89.2 seconds was significantly longer than the 59.7 seconds for the Exhibit+Game group.[11] Two individual exhibits showed statistically significant differences between group medians: *Future Fuels* and *Smart Meter*[12].

<u>Median Times Spent by Groups at Individual Exhibits (in Seconds)</u>



[10] Medians are reported because the time distributions are not normally distributed. Some children stayed very short times (e.g., 5 secs on *Power Poll*) and some stayed very long times (e.g., 698 secs on *Keep It Lit*). Half of participants stayed shorter than median times and half stayed longer. During the evaluation period, turning the crank at *Store Energy with Water* was exceptionally difficult perhaps suppressing times at this exhibit.

[11] Mann-Whitney U = 77, p = .02. Mann-Whitney U tests whether one group's distribution (of times) tends to have values higher than the other, when distributions are not normal.

[12] *Future Fuels*: Mann-Whitney U = 26, p = .006. *Smart Meter*: Mann-Whitney U = 17, p = .04. Note that other bar graph comparisons in the floor map on this page may look different visually but the group distributions are not different statistically.

For the Exhibit+Game group, time at exhibits tended to be limited by the game design as most players answered the exhibit/game Q&A and then focused on the remainder of the game activity rather than extending their interaction time with the exhibit.

For the Exhibit Only group, exhibits with the highest holding power in terms of median times were *Future Fuels* with multiple stories and *Smart Meter* with a two-minute audio presentation. In describing the appeal of these exhibits, children focused on their content; for example:
Future Fuels:

> *I liked how you could tap on the screen, and it would show you these different ways you could produce energy which never would be thought of at first.*

Smart Meter:

> *I liked the talking meters. I liked how you made them actually talk…. the female was a smart meter and calculated how much electricity we use in an hour and the male one calculated how much electricity we use in a month.*

Exhibits with the highest holding power for the Exhibit+Game group were *Electricity Isn't Magic* with multiple stories and the interactive exhibit *You Provide Power.* Like the Exhibit+Only group, in describing appeal of these exhibits, children focused on their content; for example:
Electricity Isn't Magic:

> *I like the one that was showing me different, like what is electricity, what it traveled through. I did like that cuz it was teaching you what electricity is, this is how lights come on, this is what it travels through.*

You Provide Power:

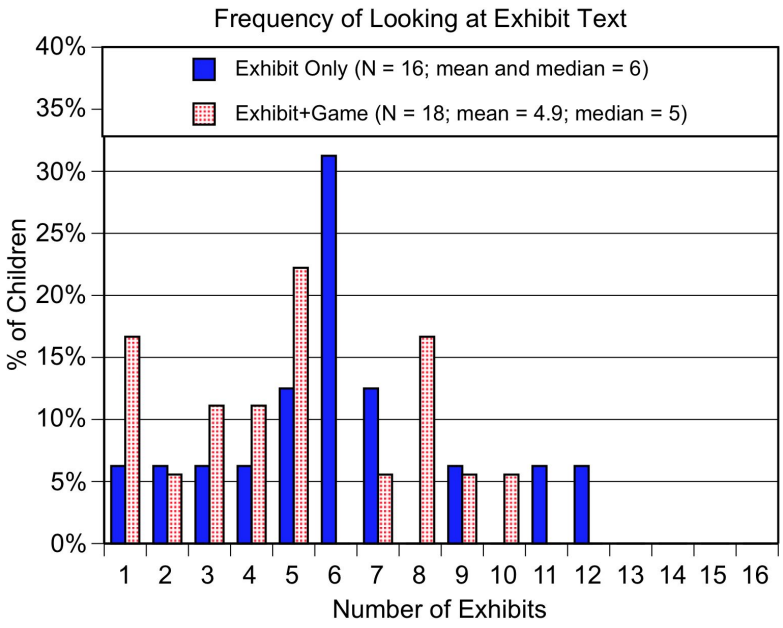
> *I liked how it didn't just tell you about it, it let you experience it yourself, like it let you turn the wheel that lit up the candle and fan. I liked the fact that it went along with the game.*

- **Significantly more Exhibit Only children returned to exhibits than game players.**

Significantly more Exhibit Only children (75%) compared with Exhibit+Game children (17%) returned to at least one exhibit that they had visited earlier in the session.[13] Exhibit Only children returned to exhibits one to five times compared with a maximum one return visit for game players. Game players were motivated to acquire more keycodes at exhibits that they had not visited. The exhibit returned to most frequently was *Light Up the Grid.* An Exhibit Only child commented: *I liked that one where it started out at the power plant and you could connect all the wires. That one was fun because if one* [wire] *is knocked out, all of it shuts off.*

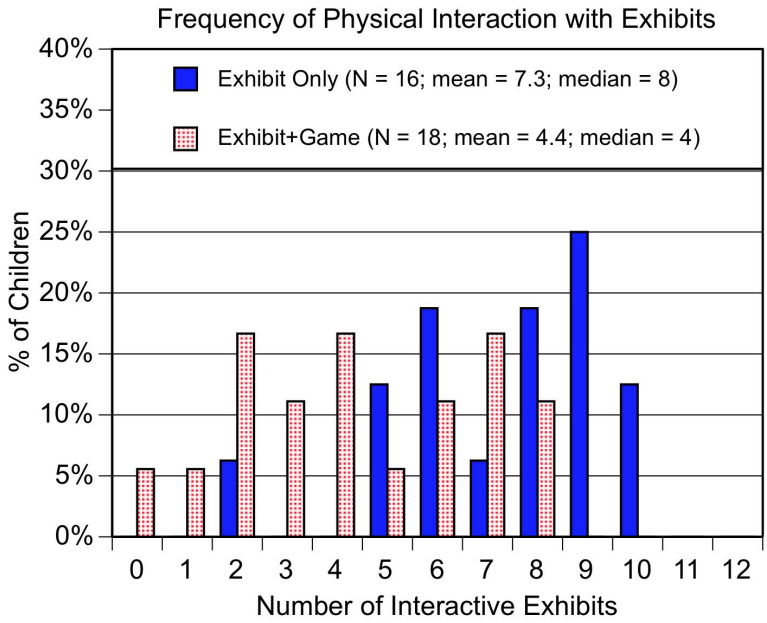
[13] Fisher Exact Test, $p = 0.001$

➢ **Every child looked at text on one or more exhibits. On average, both groups looked at text on a similar number of exhibits.**



Actual reading of text cannot be observed reliably so we recorded "looking at text" when the children were close enough to read exhibit text and appeared to be directing their visual attention toward text. The chart shows the frequency distributions of each group for their behavior of looking at exhibit text. Every child looked at text of at least one of the exhibits that they visited. The Exhibit Only group looked at text of 77% of the exhibits visited compared with 75% for the Exhibit+Game group. There were no significant differences in means or medians between groups for exhibits read.

➢ **Exhibit Only children interacted physically with significantly more exhibits than Exhibit+Game children.**



Physical interaction with the *Power Up!* exhibits takes many forms including cranking handles, flipping switches, pushing buttons, connecting components and simply listening to audio. Of the 16 exhibits, 12 were classified as interactive by this definition. During their visits, the Exhibit Only children interacted physically with 2 to 10 exhibits, with a median of 8 exhibits (see chart). The Exhibit+Game children interacted with 0 to 8 exhibits, with a median of 4 exhibits. The groups differed significantly in their distributions[14] for physical interaction with exhibits, with the Exhibit Only group interacting physically more frequently than the game players.

[14] Mann-Whitney U = 0, p = 0.002

When asked what they liked about their experience, both groups most frequently mentioned physical interaction with the exhibits; for example: *I liked the cranking, turning, turning on things, the thing with the buttons I liked best*.

The lower physical interaction by the Exhibit+Game group could be related to the difficulty of handling the iPod touch and interacting with an exhibit simultaneously. The children put their mobile devices in pockets, on the floor and on the exhibits themselves in order to free their hands for physical interaction with an exhibit. For example:

Evaluator: *What did you not like about your experience with the exhibit and the game?*
Player: *When I tried to turn the handle on the crank* [in *Store Energy with Water*] *and I had my iPod in one hand, I had to somehow turn it, which it was a tough wheel to turn, so maybe a ledge would be nice to put the iPod down.*

The game Q&A was designed to encourage exhibit interaction, and some players noted that connection in what they liked about their experience. One player who interacted physically with 6 of the 11 keycode exhibits she visited commented about the appeal of her experience with the exhibit and game: *I liked it a lot because you had to interact with some things to figure them out, as soon as I figured out towards the end that you had to interact with some things or else the app wouldn't work. You had to interact with things in order to know the answer to the game.*

On the other hand, some game players answered some keycode questions without physically interacting with the relevant exhibit; instead they read the text panels, observed others interact, knew the answer already or guessed. A post-interview conversation with the player who completed all 12 Q&As but only interacted physically with two exhibits illustrates the extreme of this behavior:

Evaluator: *I noticed that you answered the game questions really fast. Did you use the exhibits for the answers?*
Player: *I used the exhibits sometimes. Other times I knew the answer.*
Evaluator: *For example, the exhibit on the lightbulbs where it asked which lightbulb uses the least electricity?*
Player: *I knew that right away.*
Evaluator: *How about the storing water, the water ones?*
Player: *I was just reading the description.*
Evaluator: *And when you got back to the big wheel and the game asks you which item powers up first, how did you figure that one out?*
Player: *I just thought that because it* [candle] *was on the bottom it would light up first.*

- **A significantly larger proportion of Exhibit Only children repeated a round at an interactive exhibit than children using the game.**

Of the 12 available interactive exhibits, 11 were defined as having discrete rounds of experience that could be observed reliably. For example, in the exhibit *Light up the Grid,* a first round involves connecting the electromagnetic circuit to light up the end houses, and a repeat round would be recorded if a child broke the circuit and started connecting chains again. Significantly more Exhibit Only children (88%) compared with Exhibit+Game children (22%) started a repeat round of activity at one or more exhibits.[15]

Three exhibits accounted for most of the repeat rounds: Of those who visited *Future Fuels,* 30% looked at more than one story. Of those who cranked the wheel and flipped switches on *Generator Crank*, 24% started cranking again; and of those who lit all three light bulbs in *Light the Future, 23%* started cranking for another round.

Independent of group, the crowd level in the exhibition area significantly influenced round repetition. Those in more crowded conditions were more likely to repeat a round of an exhibit: 83% of high crowd participants repeated a round on an exhibit compared with 64% in medium crowd conditions and 29% in low crowd conditions.[16]

- **A significantly higher proportion of Exhibit Only children than game players observed other visitors' actions with the exhibits, but the groups did not differ in how frequently they interacted with other visitors.**

Almost all Exhibit Only children (94%) observed other visitors talking about and/or playing with exhibits during their session; whereas significantly fewer game players (39%) watched others' activities with the exhibits.[17] Those in more crowded conditions were significantly more likely to observe others: 100% of high crowd participants observed other visitors at an exhibit compared with 79% in medium crowd conditions and 36% in low crowd conditions.[18] An Exhibit+Game child who played in a high crowd period and observed visitors more frequently than other participants commented that the only thing he did not like about his experience was that *there was a lot of people there and I couldn't do some of the exhibits*.

The frequency with which children in each group interacted verbally or physically with other visitors did not differ significantly and did not occur frequently. The participants were singletons and maintained their distance from other visitors.

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[15] Fisher Exact Test, $p = 0.0002$

[16] With categorical data, Chi-Square tests whether there is a relationship among proportional distributions of the two variables, in this case: crowd level and round repetition. χ^2 (2, N = 34) = 6.29, p = 0.04.

[17] Fisher Exact Test, $p = 0.001$

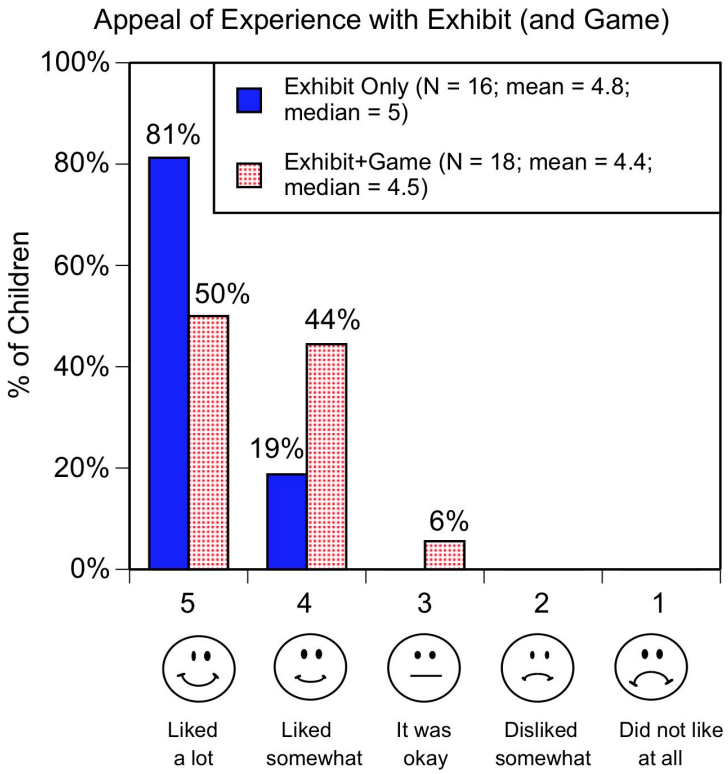
[18] χ^2 (2, N = 34) = 9.60, p = 0.008

RESULTS: APPEAL

Both the Exhibit Only and the Exhibit+Game groups gave their experience in the exhibition area a high mean appeal rating. Both groups liked most the interactivity of their experience, and one-third of the children noted the appeal of learning from their experience. A majority of game players liked the Q&A feature and powering up their house, and one-third liked playing cards. Relatively few children described something they did not like about their experience.

- **The Exhibit Only group and the Exhibit+Game group gave their experience high mean appeal ratings.**

After their respective experiences in the exhibition area, participants chose a face from a face scale that told how much they liked or did not like their experience. Evaluators read the face descriptors (see chart under faces) in opposite order for half of each group. All but one child liked their experience "a lot" or "somewhat." Although rating distributions did not differ statistically between the Exhibit Only and the Exhibit+Game groups, 81% of the Exhibit Only liked their experience "a lot" compared with 50% of the Exhibit+Game group.



- **Participants liked most the interactivity of their experience and about one-third liked learning from their experience. Group category did not make a significant impact on these two categories of what was liked.**

When asked what they liked about their experience with the exhibit [and game], the majority of both groups noted the interactivity, being able to touch and do things, often giving examples:

Exhibit Only group (94% mentioned liking interactivity):

They had many things I could do to see how it works like the generator up at the front that you could crank [Generator Crank] *and connecting all the circuits* [Light up the Grid].

[I liked] *touching things. The power line thing that you connect and the three houses light up* [Light up the Grid] *and the thing that you turned and the water filled and you drained it* [Put Electricity to the Test].

I liked that there was a lot of things that you as a person could do and test out. That was a big smiley for me.

It was fun because I like to do things so I liked to interact with the different exhibits.

Exhibit+Game group (78% mentioned liking interactivity):

I really liked doing the hands on things, like when I was doing the water [Store Energy with Water], *I liked turning the crank. And then it took a lot of effort to do a lot of things. Then when I did the green one* [Put Electricity to the Test], *I noticed it would only do 40 cents, so I noticed that it was really hard. And also I did the lights* [Light up the Future], *and I had to turn the crank, and I found that it was really easy to turn the crank for the LED, and it was really hard for the other ones.*

I liked how I had to connect the wires to bring electricity to the homes [Light up the Grid] *and how I had to turn something in circles to give some stuff electricity* [You Provide the Power]. *I liked giving electricity to Baltimore* [Keep It Lit].

I liked that there's a lot of things that you can interact with.

That it was interactive and that you could create energy yourself.

About one-third of the two groups spontaneously noted that they liked learning from their experience; for example:

Exhibit Only group (31% noted learning in what they liked):

I liked the different fun ways they taught kids how to learn about electricity. It was really interesting.

I liked it because I learned new things from the exhibit.

It was fun and you could learn information about how to use less energy but you still had fun while you were learning.

Exhibit+Game group (33% noted learning in what they liked):

I liked that it taught me about different ways that we control the flow of electricity and different supplies of electricity, different ways to generate electricity. [In Put Electricity to the Test], *I hit the electricity button, and it* [the water] *went up faster because electricity works faster than a human being does.*

It taught you a bunch of stuff about how to use electricity and save electricity and stuff.

I learned a lot.

- **The few participants who could describe something that they did not like about their experience focused on confusing exhibit interactivity or content.**

Confusing interactivity:

For the electronic ones for touch screen [Keep it Lit], *putting more instructions and directions about how to use it. You don't know what you are doing. I thought it was about keeping it so there's no blackouts.*

Some of it could get kind of confusing. There was one where you had to have a pump to create water and press a button to turn the light on but it wasn't really working that well [Store Energy with Water[19]].

Some of it was hard to turn. Too hard for a child. Some stuff was too hard to push. Little kids would not be strong enough to do it - the one where you flush and you need the air to turn it [Store Energy with Water].

Confusing content:

Didn't really like the computer ones. The one that showed different sources of electricity [Future Fuels] *and the one like Electricity Isn't Magic. I really didn't know what it said.*

I really didn't get the one with the water all that much [Put Electricity to the Test]. *It was hard for me to understand*.

Some of the things in the wheel [Generator Crank], *you have to get it going and then walk over to see it. You might want to make some things a little more visible so you can see the robot moving. It's a little bit out of sight. On the spinning thing* [You Provide Power], *you might want to put a sign up saying how did it show that, showing the reason why the electricity is getting power when you are spinning it.*

One mobile game user did not like her experience with the exhibit and game because *reading is boring*. She was observed to have difficulty reading.

- **In describing the appeal of the mobile game, 72% of the players noted the Q&A feature, 50% mentioned powering up their house, and 33% liked playing cards.**

When the Exhibit+Game group was asked what they liked about the game, most spontaneously responded that they liked the Q&A (72%) interaction with the exhibits. Players also desribed the appeal of powering up their house (50%) and matching cards to statements (33%). For example:

How it made science into a fun way for kids, and you can make your house with what you learned and what you should do. You get points with getting a question right. You have to study and do well. I liked the cards cuz if you don't get the answer correct, it tells you the correct answers.

It was fun. [I liked] *that after you were done you could use the points you got to have your own house and get things that used energy and put them around your house.* [I liked]

[19] Developers were aware that the crank was extremely hard to turn and adjusted after the evaluation.

that you would have to actually go around and find the icons with the numbers to answer questions.

I liked how it had different steps and it would let you read the thing and answer the questions on there so it went together [Evaluator: The exhibit and game went together?] *Yeah. I liked the questions because you could learn about the exhibit, that was the main thing, and then you used that information to answer the other things.*

I liked that a lot. Trying to generate the house, getting points. I used the exhibit to find the answers. I read the paragraph and when they gave me the question, I found the answer and got a 20 point bonus when I got it right. It was a good experience, something new to try.

That it taught you how to create a house that used electricity on it. Like my house had LED lights, and it had, I believe, smart generators for keeping track of electricity. It had you win points instead of just giving you answers.

I liked that you could actually interact with your iPod, and you could play a game…I liked that on the game you could build a house and use different appliances that you learned about into your home and then you could use that knowledge in real life.

I liked how you had to look at the exhibit to do it and how you need to think hard. The game had the questions and the exhibit had the answers.

It was fun powering up the house. You could pick out of all the possible things and then customize the house.

It shows you how you can save electricity. It teaches you while also being a game. I liked the cards best.

- **The few players who described something that they did not like about the game raised issues about the interactivity of matching the cards and powering up the house.[20]**

It was kind of hard to guess which card was the right one.

It showed you different cards and it would be the same cards every single time. I would think that you would have different cards. …Sometimes they asked the same questions and I think you should put different questions so it was harder. [Evaluator: Are you talking about the matching? To decide if the card was the same as that particular statement- is that what you are talking about?] *Yeah.*

I didn't understand what the house meant. So I think what you had to do was that you got points and you got something for the house…I looked at it and tried to figure it out. So I went to electricity, I think, and I got something - I don't remember what it was. It came up with these like blue things. [Evaluator: Then what did you do?] *I didn't. That's when I got stuck.*

It's hard sometimes: power up the house. I didn't get to finish it.

Well for the house thing there wasn't really a purpose for it. It didn't really do anything.

Some of the words, I didn't know what they meant.

I didn't exactly get how the points worked.

It's boring.

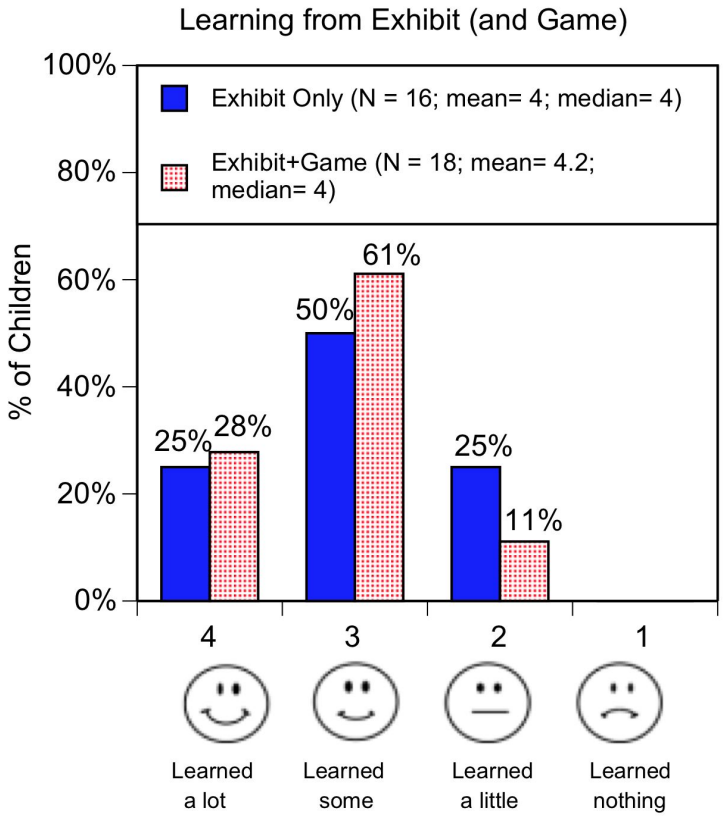
[20] After data collection, changes were made in the powering up the house feature to clarify what to do.

RESULTS: LEARNING

All children gained new knowledge from their experience in the exhibition area. The majority of both the Exhibit Only and Exhibit+Game groups felt they learned "some" from their experience. The Exhibit+Game group acquired significantly more knowledge about ways to use less electricity compared with the Exhibit Only group. However, the two groups did not differ statistically in their overall knowledge gain nor in their recall of the specific content areas of energy sources that generate the electricity we use and methods that move, control or change electricity as it comes to our homes.

- **The groups did not differ in how much they felt they learned from their experience. The majority of participants reported that they learned "some."**

After their respective experiences in the exhibition area, participants chose a face from a scale that told us how much they learned from their experience. The face descriptors (see chart below faces) were read in opposite order for half of each group. The majority of children felt they learned "some" from their experience, and the groups did not differ in their learning ratings. Learning ratings were not correlated with appeal ratings.



- **All participants could describe something about electricity that they learned from their experience, focusing most frequently on energy sources that generate electricity.**

When the children were asked what they learned about electricity, spontaneous recall responses reflected the distribution of messages in the exhibition area. There were no differences between the groups in spontaneous recall of the three electricity content areas, thus the data are reported for the sample as a whole. Five interactives dealt with different energy sources for generating electricity: three-quarters (74%) of the children remembered content from these exhibits. Four exhibits addressed distributing and controlling the flow of electricity: half (47%) of the participants spoke of this content. Three exhibits focused on energy efficiency, and 38% of the children recalled content from these exhibits.

- 74% described energy sources that create electricity; for example:

[Generator Crank] *How a generator works, it has to spin and that makes these magnets push electrons and that makes electricity.*

[Store Energy with Water] *I thought it was very interesting like the water pump thing and how you can just use like hand cranks to pump water to get electricity out of it…. I learned that electricity doesn't just have to come through wind, humans can make their own electricity - you can set up cranks and you can crank to make electricity.*

[You Provide Power] [I learned] *that it could require strength to power electricity.*

[Future Fuels] *We can use cows, which give methane, and our garbage, which releases methane, to create electricity by boiling it down and just creating energy.*

[Sunlight Powers Science Center] *The science center is powered by solar power.*

- 47% recalled how electricity is distributed and controlled; for example:

[Circuits] *I learned about switches and resistors and those things and what they do. The switch controls how much the current is flowing. The resistor can block it.*

[AC and DC graphic] *I learned that alternating current powers a longer distance than direct current.*

[Light up the Grid] *I learned that all lamps have to be connected from the power plant to the next building to all the circuits and finally to all the homes.*

[Keep It Lit] *That if you use it a lot, the lights can dim. I learned that it's a brownout, not a blackout.*

- 38% described energy efficiency in what they learned about electricity; for example:

[Light the Future] *I learned that LED light bulbs are the most efficient light bulb.*

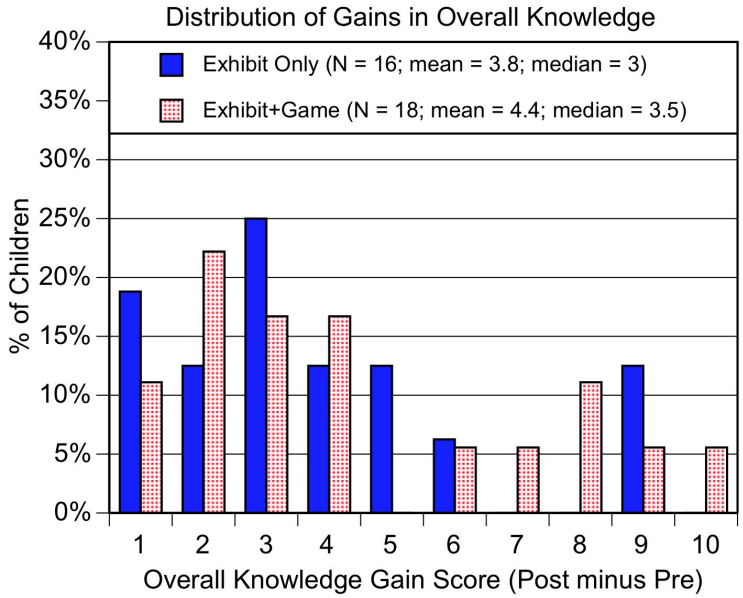
[Put Electricity to the Test] *I learned that having electrical things is a lot more efficient than by doing it by hand. It really was. There was a thing you had to turn, and it was a lot easier with the electrical one.*

[SmartMeters] *SmartMeters help people in electrical ways. They help people not use as much energy because I think they show you how much electricity you used and how much the bill will cost.*

- **Each of the two groups, Exhibit Only and Exhibit+Game, gained significant new knowledge from their experience, but the groups did not differ statistically in their overall knowledge gains.**

Before and after their respective experiences, the Exhibit Only and Exhibit+Game participants were asked about three content areas: (1) energy sources that create or generate the electricity we use; (2) methods that move, control or change electricity as it comes to our homes; and (3) ways to use less electricity in our homes. Participants received numerical scores based on the number of correct sources, methods and ways that they suggested before and after their experience. Because we are interested in gain in knowledge, if a child named a source, method or way in the pre-interview, they were given credit for that knowledge in the post-interview score even if they did not repeat the response. Gain scores were calculated by subtracting pre scores from post scores.

All children gained new knowledge from their experience. The chart below shows the distributions of overall gains for the two groups as well as the means and medians. Individually each group gained significant new knowledge from their experience in the exhibit,[21] but the pre to post gains were not significantly different between groups.



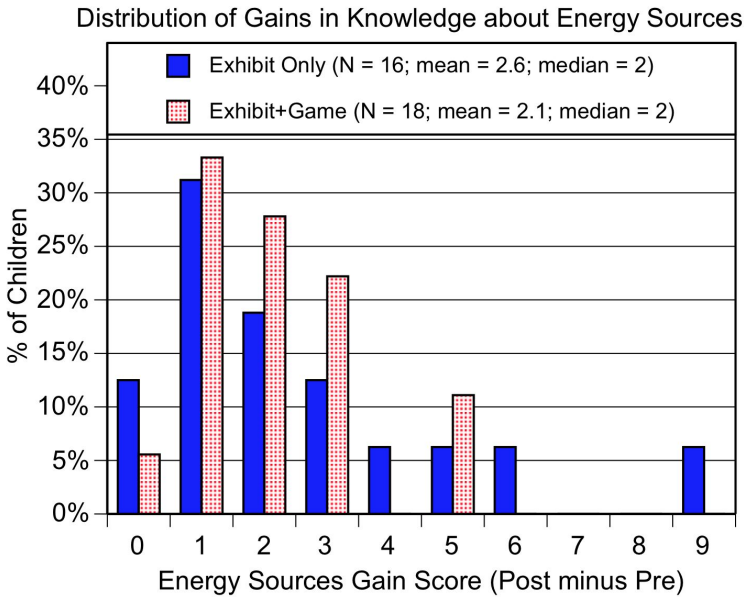
The following pages present the gains for each of the three content areas that make up the overall knowledge gain scores presented above.

[21] The paired *t*-test assesses the likelihood that the difference between the means of two matched groups (pre, post) could have been caused by chance. Paired $t(33) = 8.95$, $p \leq .0001$.

- **The Exhibit Only and Exhibit+Game groups did not differ from each other in how much knowledge they aquired about energy sources that generate the electricity we use; however, each group separately gained significant knowledge about energy sources.**

Before and after their experiences, the Exhibit Only and Exhibit+Game participants were asked what energy sources create or generate the electricity we use. The exhibits present information about 13 different energy sources to generate electricity and the game covers 14 energy sources. The exhibits and game overlap for 10 sources.

The chart below presents the distributions of gains in knowledge about energy sources as well as means and medians. The post-interviews showed that each group individually gained significantly in their knowledge about energy sources over what they knew in the pre-interviews.[22] Upon comparison, the two groups did not differ in their overall gain scores related to energy sources.



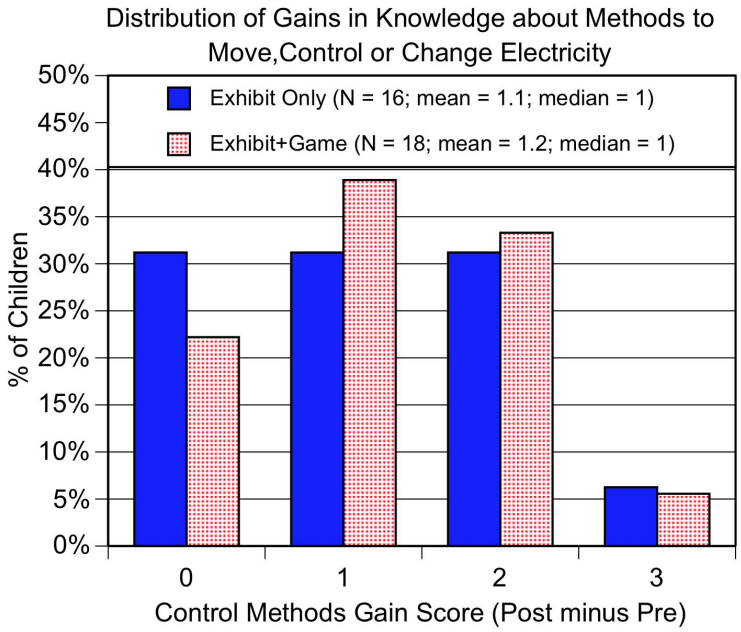
Solar and water power were the most commonly mentioned energy sources by all the children in both the pre- and post-interviews. Most frequently added energy sources in the post-interview by both groups were cow poop and human power.

[22] Exhibit+Game: Paired $t(17) = 6.551$, $p \leq .0001$. Exhibit Only: Paired $t(15) = 4.23$, $p = .0004$.

- **The Exhibit Only group did not differ significantly from the Exhibit+Game group in knowledge gain about methods or technologies that move, control or change the electricity we use. Individually, each group gained signficantly in their post-interview knowledge about controlling electricity.**

Participants were asked before and after their experience what methods or technologies they know of [or remember] that move, control, or change the electricity we use. The exhibits present information about 13 methods, the game covers 10, and the exhibits and game overlap for 9 of the methods.

As shown in the gain distribution chart below, each group separately demonstrated significant overall gains in learning about methods that control electricity,[23] but the gains for the two groups are not significantly different.



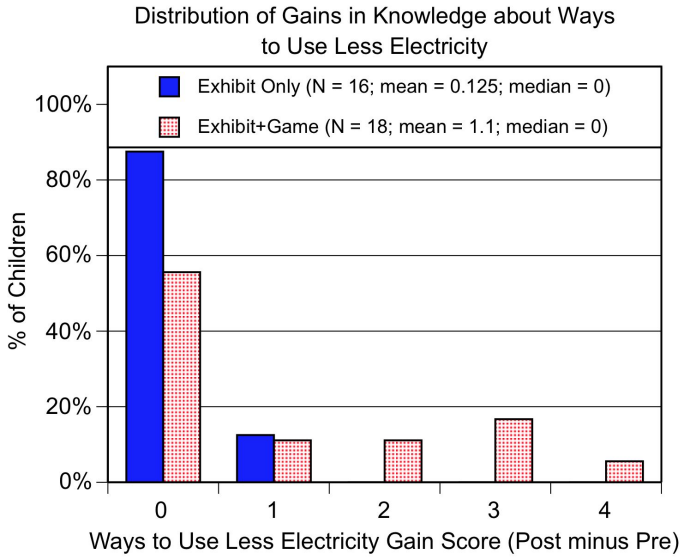
In both the pre- and post-interviews, the most commonly mentioned methods by all the children for moving, controlling or changing electricity were power lines or wires and switches. These methods were also the ones added most frequently in the post-interview by those who had not suggested them in the pre-interview.

[23] Exhibit+Game: Paired $t(17) = 5.91$, $p \leq .0001$. Exhibit Only: Paired $t(15) = 4.70$, $p \leq .0001$.

- **From their experience, the Exhibit+Game group gained significantly more knowledge than the Exhibit Only group about ways to use less electricity. Individually, the Exhibit+Game group gained signficantly in their knowledge about saving electricity but the Exhibit Only group did not.**

Before and after their experience, the Exhibit Only and Exhibit+Game participants were asked what people can do to use less electricity. The exhibits suggest 2 ways to use less electricity, the game presents 8 ways, and the exhibits and game overlap for 2 ways.

The game cards provided more opportunities to learn within this content area and that influenced the gain results such that the Exhibit+Game group learned significantly more new ways to save electricity compared with the Exhibit Only group, as shown in the chart below.[24] The Exhibit+Game group demonstrated a significant overall gain in knowledge about new ways to save energy,[25] whereas the Exhibit Only group did not show a statistically significant gain over their pre-experience score.



In the pre interview, all the children mentioned that to save electricity people can turn off lights, appliances and devices. Neither the exhibit nor the game actually proposes this method. Most commonly learned methods for saving electricity were using LED bulbs and SmartMeters, neither of which was mentioned in the pre-interviews by any child. The majority of the post-interview gain for the Exhibit+Game group was due to recall of LEDs: significantly more gamers (39%) recalled LEDs as energy-saving bulbs compared with non-gamers (6%),[26] even though fewer gamers visited the comparative light bulb exhibit (61% vs. 75%, see *Light the Future* in chart on p. 17).

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[24] The two-sample *t*-test assesses the likelihood that the difference between the means of two independent groups (with and without game) could have been caused by chance. $t(19) = 2.745$, $p = .01$, two-tailed.

[25] Exhibit+Game: Paired $t(17) = 3.22$, $p = .003$.

[26] Fisher Exact Test, $p = 0.04$

RESULTS: PERCEIVED VALUE OF THE GAME

The Exhibit+Game group felt that the *Power Up!* game helped them learn more about electricity and increased their attention to the exhibits and their activity in the exhibition area.

- **Game players felt that using the game helped them learn more, attend more closely to the exhibits and increase their activity in the exhibition area.**

Exhibit+Game participants were asked how using the game affected their experience with the exhibits. The main impacts noted were learning more (38%), attending more closely to the exhibits (22%), and increasing activity in the exhibition area (22%).

- 39% of game players felt they learned more by using the game in the exhibit:
  I guess you learn even more than just with the exhibit.
  The game and the exhibit together helped you learn new stuff.
  It made a difference because I learned more from the exhibit when I was using the app.
  It teaches you a little bit more about the exhibit by telling you like when you get the cards, it shows you how to save electricity, you can pick two cards that show that choice and if you were wrong, they correct you.
  It tested your knowledge of what you knew from the exhibit. If you didn't have the game, it would be basically you just remembering things instead of taking things and putting them into a device that would have the information in it. So it would help students to realize that they need to remember all of it.
  I think it was pretty cool how you could learn something and use electronics at the same time. You tested what you learned on it and you got to get points for what you learned about it and you could get the house. It was really fun. You learned a lot of stuff.
  It was kinda like the meter thing [SmartMeter exhibit]*, instead of telling you, it was asking you questions to see if you knew it.*

- 22% suggested that the game helped them attend more closely to exhibit information:
  Usually I would just like go through and look at it, but like this I was looking for something specific and I was reading everything more closely. It was fun because I was looking for code and I was reading more information than what's already put on the game.
  You had to look closely at what it said. [Evaluator: Is that a good or bad thing] *Good thing.*
  I was looking for the answers to the questions, so I read a lot more of it than I probably normally would.
  I think it made me think a little more about it. It was asking me questions about the exhibits so I could understand what it told me.

- 22% noted that the game increased their activity in the exhibition area:
  It made me be more interactive with all the exhibits.
  [The game made] *a lot of difference because they actually gave you something to do in the exhibit.*
  How it made it better because it gave you a game that kids might want to do, and they can answer questions.
  I think I liked it more than if I didn't have the game. I wouldn't have liked it as much as I did. I liked it more because you could actually have something to do.

- 11% simply felt the game was a fun addition to their experience:
  It was still really fun, but the game made it really interesting.
  It was fun cuz you got points and you get to decide.

- 6% did not feel that the game affected their experience with the exhibit:
  It didn't make a difference.

➢ **All game players felt that using the game increased their learning about electricity.**

When asked how the game affected their learning about electricity, all players suggested that the game increased their learning, and many pointed to specific game components as influencing their understanding.

- 33% of game players focused on the game Q&A as affecting their learning:
  The game helped me learn. It asked you questions and you had to read the exhibit to answer the questions.
  You have to read the things on the side to be able to answer the questions.
  Because it would make you answer a question about the exhibit so you would have to read the whole exhibit to find out. It made me kind of get more into the learning part.
  People actually read and learn what it says in the exhibit rather than just walk past it.
  Because I looked everywhere for the codes so I didn't miss any of it, so I learned more from it all in 20 minutes.
  A good way because it taught me things, it gave me more motivation when I got it right.

- 23% of game players noted the game cards as affecting their learning:
  It [the game] *gives more information and it helps me understand the things more because of matching the cards, so then I would match the cards and I would understand what it means more.*
  There were the cards and they explained that there is different types of electricity. It [the game] *explained what you just learned about.*
  Probably learned from the cards.
  I know more about electricity and how it is used and where it comes from and how it changes. It taught me more about capacitors and I learned that they change the flow of a current of electricity flowing through it. I didn't know that before.

- 11% of game players suggested that powering up their house affected their learning about electricity:
  The end when it said powering your house, it would help you know what a balance of what you could use.
  It showed me, on the house, how to set up different places for a house, like the transformer to a smart generator. So it helps me realize that this connects to this, connects to this, and connects to the house.

DISCUSSION

Using the *Power Up!* game within the Maryland Science Center's *Power Up!* exhibition is intended to engage youth with individual exhibits and increase their knowledge about electricity. To assess if and how the game influences the exhibit experience, the authors observed and interviewed 18 ten-year-olds who used the game within the exhibition area and 16 ten-year-olds who did not use the game, collecting data about four variables: holding power, appeal, learning, and perceived value of the game. **The main conclusion of the study is that game players experienced the exhibition area differently but enjoyed their experience as much and learned as much, and more, about electricity as their non-gaming counterparts.**

Holding Power

The question and answer section of the *Power Up!* game is tied to individual floor exhibits whereas the card playing and powering up sections act as a "mobile exhibit" that can be experienced anywhere in the exhibition area. This two-part design influenced the attraction and holding power of the exhibits for those who played the game versus those who did not.

Compared with non-gamers, game players remained in the exhibition area significantly longer on average, but gamers visited exhibits for significantly shorter times on average; interacted physically with significantly fewer exhibits; and were observed significantly less often repeating activity rounds at exhibits, returning to exhibits, and observing others' actions with exhibits. Although holding the game device made physical interaction with exhibits awkward, game players were more motivated to acquire key codes at exhibits that they had not yet visited and less motivated to return to or explore in more depth the exhibits they had already encountered. Gamers frequently searched strategically for answers to questions posed in the game and then turned away from the physical exhibits to complete the subsequent card game and power up their house; thus, engagement with exhibits tended to be more superficial but directed than was the case for those exploring without the game. The median individual exhibit holding time for the Exhibit+Game group was significantly shorter than for the Exhibit Only group.

On the other hand, game players were more likely than non-gamers to visit non-interactive exhibits that presented key codes and more likely to skip exhibits that did not have key codes. Key codes and the Q&A feature in the *Power Up!* game serve the purpose of directing and controlling visitors' attention in an exhibition area.[27]

On average, game players spent about the same amount of time matching cards to the three message statements and powering up their house as they did visiting the floor exhibits and answering questions related to the exhibits. Thus, the "mobile exhibit" of the game acted as an additional meaningful exhibit and was competitive with the "permanent exhibits" in holding gamers' attention and interest. Given our arbitrary time limit for visitors' sessions, more time spent on the "mobile exhibit" resulted in decreased time spent with the "permanent exhibits." All but one (94%) of the game players remained in the exhibition area for at least 18 minutes compared with slightly more than half (56%) of the non-gamers doing the same. It is possible that more learning differences would have been obtained between groups had there been no arbitrary cut off time allowing gamers to continue their experience.

Appeal

In the open-ended post-interviews, a majority of both groups identified that they especially liked the interactivity of the exhibits, being able to touch and do things. One-third of both groups liked learning from their experience.

On average, game players rated the appeal of their experience with the exhibit and game as high as the Exhibit Only group. However, appeal was more intense for non-gamers: more non-gamers liked their experience "a lot" as compared with the gamers (81% vs. 50%).[28] In describing what they liked about the game, three-quarters of the Exhibit+Game group noted the Q&A feature, half mentioned powering up their house, and one-third liked playing cards.[29]

Learning

Using pre and post interviews to assess learning, both groups of participants demonstrated statistically equivalent gains in their recall of new information overall and their recall of two of the three specific content areas: energy sources that generate the electricity we use and what methods move, control or change electricity as it comes to our homes. In these two areas, the exhibits and game overlap appreciably in their content. In the third content area of ways to use

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[27] Keycodes and the Q&A feature served the same guidance function in a similarly featured *PlanetMania* game used in Maryland Science Center's Life Beyond Earth exhibit. There was no Exhibit Only comparison group in the *PlanetMania* study. See footnote #3 for study reference.

[28] In the *PlanetMania* game evaluation, 50% of gamers also liked the game "a lot."

[29] In the *PlanetMania* game evaluation, 29% enjoyed the Q&A feature, 21% mentioned the astrobucks for a store coupon (the reward equivalent of powering up the house), and 38% liked playing cards. In this text-based exhibition, the game Q&A required reading more than hands-on interactivity, perhaps explaining the lower appeal of this feature compared with *Power Up!.*

less electricity, the game presented more content than the exhibits and the gamers outperformed the non-gamers in knowledge acquisition. Thus, where the exhibits and game overlap in content, the different patterns of use of the exhibits (and game) yielded similar learning outcomes, but when the game presented more content in an area, the gamers learned more than the non-gamers.

The difference between groups with respect to learning new ways to save electricity is due mainly to the recall that LED light bulbs use less electricity. This is an important finding because it speaks to the potential power of the game design. The *Light the Future* exhibit was very popular. Children were constantly turning the wheel to see which of the bulbs would light and how much energy they expended to light them. Even though fewer gamers visited this exhibit for a shorter median time, the point that LED lights could save electricity was recalled significantly more often by gamers (39%) than non-gamers (6%). A design analysis of the game presentation yields some basis for why the gamers had the advantage in this case:

- The *Light the Future* exhibit text emphasized powering the incandescent bulb in particular (*Which bulb requires more work to power?*), whereas the game Q&A encouraged participants to interact with the exhibit and look for the bulb requiring the least work to power (*Which bulb needs the smallest amount of energy?)*.
- An LED game card presents this bulb in a slightly different context, with both text explanation of energy-efficiency and an image that echoes the visual in the exhibit.
- In powering up the house at the end of the game, LED lights are an option for reducing electricity usage. Including the LEDs in the culminating activity directly reinforces the concept in a new context.

This three-pronged approach to learning (direct instruction, repetition in varied contexts and reinforcement) with the addition of a memorable interactive experience with the exhibit itself may have contributed to the gamers' more successful recall that LED lights use less energy.

Perceived Value of the Game

The game players felt that the *Power Up!* game helped them learn more about electricity, particularly through the Q&A feature; increased their attention to the exhibits and increased their activity in the exhibition area.

Conclusion

Although the sample sizes in this study were small, the results indicate that the *Power Up!* game adds value to the visitors' experience in the exhibition area in terms of engagement and knowledge acquisition. Game players distributed their time and effort differently from the Exhibit Only group, necessarily dividing their time between the physical exhibits and the game components. Gamers particularly liked the Q&A feature and felt that using the game helped them attend more closely to exhibits and learn more. The use of keycodes encouraged a wide exploration of the museum floor and attracted game players to exhibits that others overlooked. The game was particularly valuable for those exhibits that were not interactive, effectively directing visitor attention and

traffic to them.[30] Although interaction with the hands-on exhibits was physically more challenging for our lone gamers, children in groups will likely pass their device to another group member thus potentially increasing their interactivity time beyond what was measured in this study. Moreover, because the features of card play and powering up the house promote learning beyond the floor exhibits, the *Power Up!* "mobile exhibit" may also be of greater value when the area is crowded and visitors have difficulty getting their hands on the many interactive exhibits.

Most importantly, those who used the game demonstrated statistically significant gains in learning of all three content areas evaluated. In addition, when the design tenets of direct instruction, repetition in new contexts, and reinforcement were present, the game plus exhibit experience outperformed experiencing only the exhibit in promoting learning of specific content. Overall, using the *Power Up!* game within the exhibition has a clear value in promoting appealing engagement and learning. The next challenge will be how to encourage visitors to download and use an interactive mobile game within an already strongly interactive exhibition.

[30] The similarly formatted *PlanetMania* game was particularly effective this way in an exhibit that is mostly text-based.