



MULTIMEDIA RESEARCH

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Summative Evaluation of
PlanetMania Mobile App in Maryland Science
Center's *Life Beyond Earth* Exhibit



Report for
Maryland Science Center
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INTRODUCTION

Supported by the National Science Foundation, *PlanetMania* is a new mobile app produced by Maryland Science Center (MSC) and Eduweb to accompany the center's latest permanent exhibit, entitled *Life Beyond Earth*. Multimedia Research carried out a summative evaluation of the *PlanetMania* app as it was used in the exhibit by 9-11 year olds. The evaluation reported here focuses on the app's usage in the exhibit, appeal, value and learning outcomes.

***Life Beyond Earth* Exhibit**

In MSC's exhibit *Life Beyond Earth*, "visitors are introduced to our planet's extreme environments that support life and can explore tiny models of microbes, considered to be Earth's first living things. They will learn about our planet's relationship to the Solar System and our place in the Milky Way, and begin to compare these conditions to other worlds, including detecting planets outside our Solar System. Among the exhibition highlights are tactile models of bacteria, the Milky Way, and the terrains of worlds in our Solar System; a gallery with views of our Solar System; meteorites on loan from the Smithsonian Institution; and a touch-table with interactive activities exploring methods of detecting planets in distant solar systems."¹



¹ <http://s.tt/1tqvO>. National Aeronautics and Space Administration (NASA) supported production of the *Life Beyond Earth* exhibit.

PlanetMania Mobile App

Released with the exhibit opening on November 2, 2012, *PlanetMania* presents an interactive quiz and card game designed to be used in the exhibit area. The app is available for download from app store sites for Apple and Android mobile devices, described as follows:²

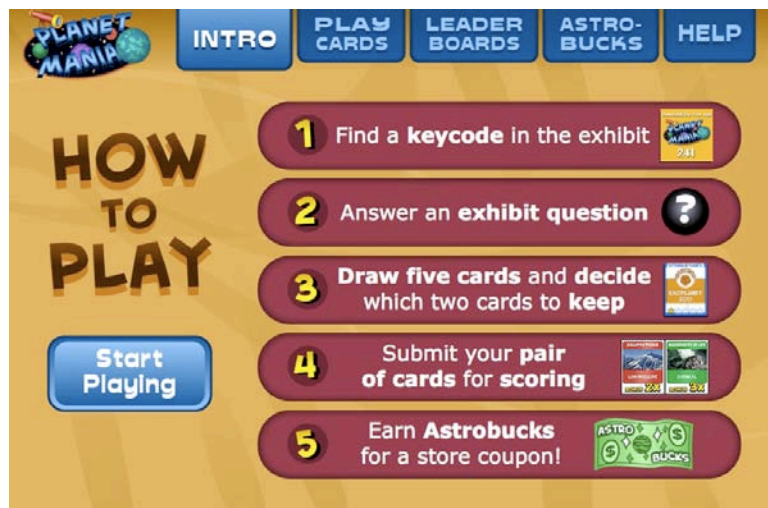
“Play this game at the “Life Beyond Earth” exhibit at the Maryland Science Center, in Baltimore’s Inner Harbor. As you explore the exhibit, draw cards about planets orbiting other stars, the ingredients of life, and the ways that life adapts to extreme environments. Choose carefully to make your best pair of cards, then submit your hand to earn Astrobucks -- and a coupon at the museum shop!”

Intro. An introductory screen (at top right) presents three statements that summarize the app’s main messages. <Start Playing> brings up a How to Play screen (bottom right).

Keycodes. Posted at strategic spots around the exhibit are 15 keycode labels (#275 appears below).

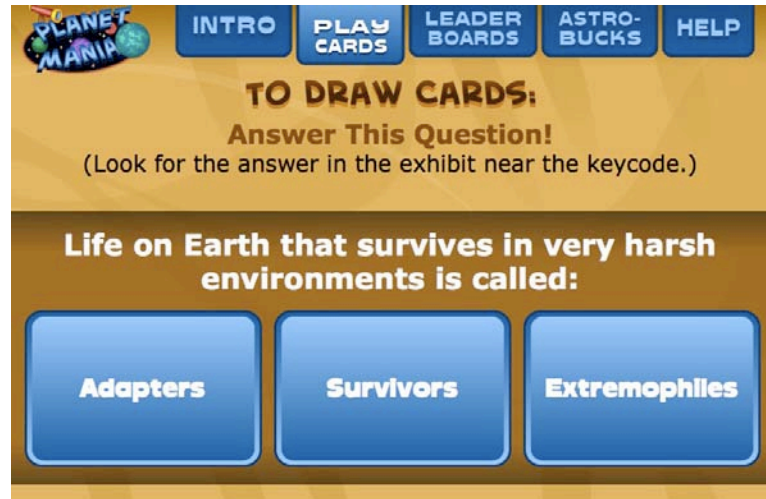


Each round of play involves one keycode and its exhibit related multiple-choice question. With 15 keycodes distributed about the exhibit area, the app on an individual device can access up to 15 questions, one per each of 15 rounds of the *PlanetMania* card game. Keycodes may not be entered twice.



² <https://itunes.apple.com/us/app/planetmania/id573955953?mt=8>
https://play.google.com/store/apps/details?id=com.eduweb.planetmaniab1&hl=en_GB

Exhibit-related questions. With each keycode entered into the app via a dedicated number keyboard, a player receives a multiple-choice question and is encouraged to discover the answer nearby in the exhibit (see top screen image). If an incorrect answer is touched, players are encouraged again to look in the exhibit near the keycode.

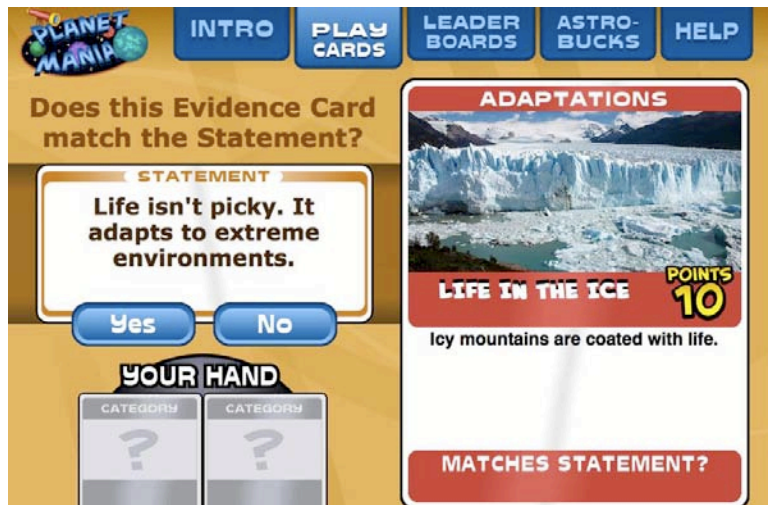


Message Statements. The middle screen shows answer feedback for a correct answer (“That’s correct”) and a related transition clause (e.g., “Extremophiles can be found all around the world because”), which leads into one of the three message statements (in this case “Life isn’t picky. It adapts to extreme environments.”).



Evidence Cards. Touching <Now Draw a Card> in the middle screen presents a randomly drawn evidence card, as shown in the bottom screen. The app draws on three types of evidence cards:

- Adaptations cards illustrate how life on Earth adapts to extreme environments and match the statement of “Life isn’t picky. It adapts to extreme environments.”
- Ingredients of Life cards exemplify what life needs to survive and match the statement of “Life as we know it needs certain things to survive.”
- Exoplanets cards show ways that planets outside our solar system are found and match the statement of “Astronomers can detect planets around stars other than our sun.”

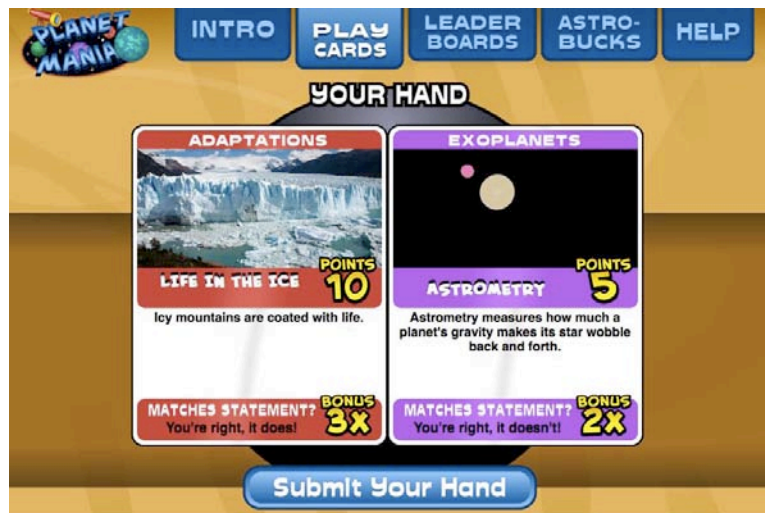


Matching Activity. With consecutive draws of each of five cards, the player decides whether or not an evidence card matches the statement presented (see previous screen). The statement remains the same for each of the five cards. Upon touching <yes> or <no>, the player receives feedback and scoring points related to their correct or incorrect match choice for the card.

Keep or Drop Card Activity. After the matching choice, the player must decide to keep or drop each card. The screen image at top right shows that this player kept the Adaptations card; drew a second random card (Ingredients of Life); decided whether or not the card matched the “Life isn’t picky” statement; and now in this screen must decide to keep or drop the Ingredients of Life card.



Thus, for each of five randomly drawn evidence cards, the player first makes a choice of matching to the statement and then a choice to keep or drop the card. When two cards have been kept in the hand, the player can drop new cards or replace a kept card, so that the hand has only two cards at one time.



Scoring. After choices have been made for five cards, the player submits the hand for scoring (bottom screen). In this screen, the Adaptations card of 10 points times the 3x bonus is worth 30 points; the 3x bonus is given because the player was correct that the card matches the statement. The Exoplanets card of 5 points times the 2x bonus is worth 10 points; the 2x bonus is given because the player was correct that the card does not match the statement. No bonus is given if the player is incorrect in their statement-match answer. If two cards in a hand are of the same category (e.g., both Adaptations), additional points would be received.

Store Coupon Incentive. With this round, the player earned 40 points or 40 astrobucks for an incentivizing museum store coupon of 5%. During the evaluation period, the astrobucks exchange rate was 5% discount for a score of 25-49 points, 10% for 50-99 points, 15% for 100-199 points, and 20% above 200 points.

METHOD

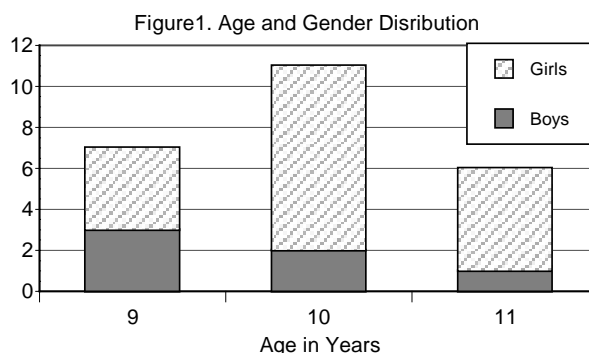
Study Design

The *PlanetMania* app is intended to engage youngsters with exhibit content, add value to the exhibit, and increase knowledge about the content of the exhibit and app. Since budget limitations prevented the inclusion of a control group, the summative evaluation is a pre-post quasi-experimental study in which a sample of 24 9-11 year olds were interviewed prior to and after experiencing the app and exhibit as well as observed during their exposure to the app and exhibit. The evaluation focuses on app usage, appeal, value and learning.

Sample

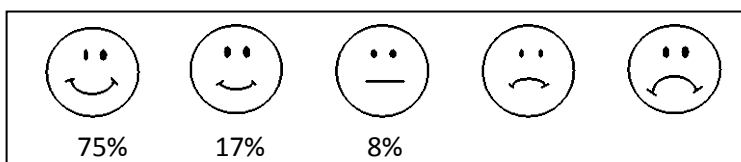
Invitations to participate in an individual one-hour session to review the exhibit and app were emailed to MSC's homeschool list and posted on MSC's Facebook page. Participants were offered free museum admission for their family and four IMAX tickets upon session completion.

With written parental and child consent, researchers completed evaluation sessions with 24 9-11 year old children over a Friday-Sunday period, one week after the exhibit opened. Participants had not viewed the exhibit or a related Planetarium show prior to their session. Figure 1 summarizes the sample's demographics. Three-quarters of the 9-11 year old sample were girls. African- and Asian-American minorities comprised 29% of participants. All children were familiar with the interface of the iPodTouch device provided during the session and had played app games on similar devices.



In the pre-interview, participants rated their interest in exploring the idea of life beyond earth on other planets (see Figure 2). Three-quarters (75%) were 'very interested.' Note that because these children volunteered for the evaluation, they may not represent the full visiting audience in terms of previewing interest, but they do represent those of this age group with a positive interest in the exhibit content.

Figure 2. Interest in Exploring the Idea of Life Beyond Earth on Other Planets

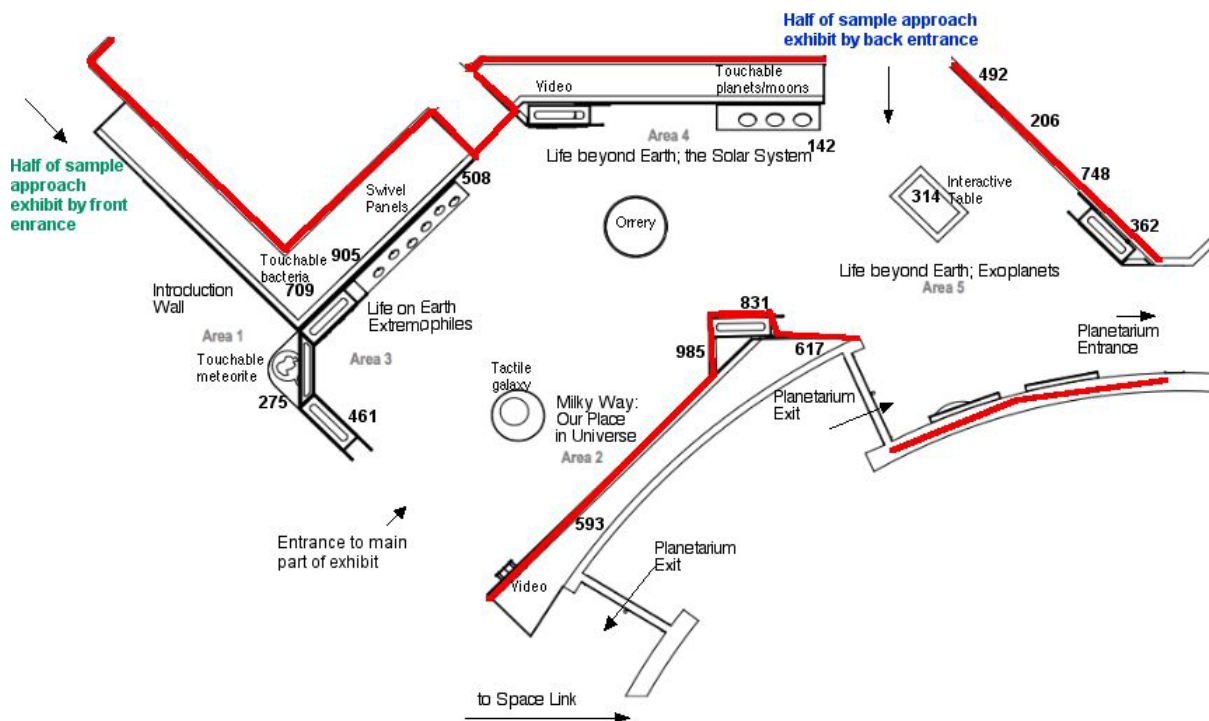


Procedure

Participants met individually with Dr. Flagg or Dr. Holland for one 45-60 minute session using a structured interview protocol. Each session began away from the exhibit with background questions followed by open-ended knowledge questions related to exhibit and app content.

Players were provided with an iPodTouch device with the *PlanetMania* app and given a general instruction of “you can explore the exhibit as much as you want and use the app as much as you want and when you are done, we’ll talk about your experience.” If players had not voluntarily quit the app and exhibit by 20 minutes, they were stopped in order to maintain the one-hour session limit. To ensure that the evaluation process covered the full experience of the app and exhibit, half of the sample were led to approach the exhibit at the front main entrance and half were led to approach the exhibit at a back entrance. Gender was equally distributed across the two entrances. Figure 3 presents the exhibit floor plan with the entrances marked by arrows. The red color outlines the active exhibit area. Text summarizes the general content of the exhibit and indicates hands-on touchable components in Areas 1 through 5. Three-digit numbers indicate the approximate positions of 15 *PlanetMania* keycode labels mounted on the exhibit.

Figure 3. *Life Beyond Earth* Exhibit Floor Plan with Content Descriptions & App Keycodes



To gather data on app usage, the app database recorded keycodes and scores for each round, and researchers observed players in the exhibit, noting paths through the exhibit and start and end times in the area. Timing for individual components was not recorded. If players requested help from researchers, they were prompted to read the screen on which they paused. An occasional frozen screen required researcher intervention to restart the app.s

Players were debriefed away from the exhibit area through a series of structured interview questions focused on game play, appeal, value of the app, and learning outcomes. Bugs and programming issues revealed during the evaluation were conveyed separately from this report.

Data Analysis

Qualitative data generated from the structured interviews were analyzed deductively drawing on content and main messages of the app and exhibit and inductively by looking at the responses themselves for themes, keywords and key phrases. Illustrative quotes from participants are presented in italics verbatim with the elimination of “like” and “ums.”

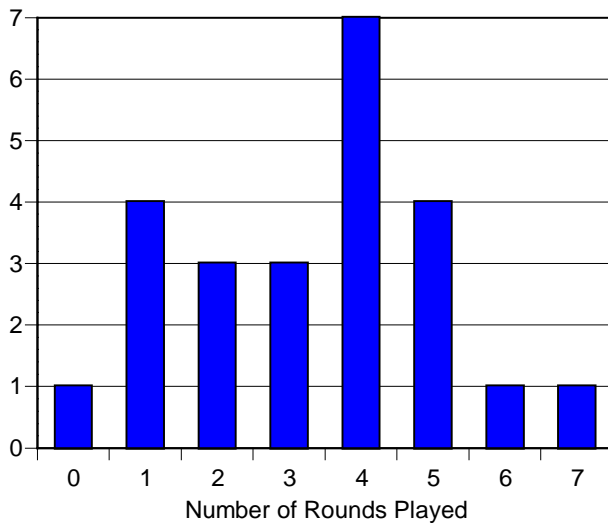
Quantitative data are presented as frequency and percentage distributions with descriptive statistics. Additional statistical analyses were conducted to explore relationships of quantitative data with demographic variables (age, gender, minority status), background variables (pre-viewing interest), procedural variables (exhibit entrance), app usage (e.g., number of rounds, scores, pattern of use in exhibit, difficulty playing, etc) and post-use appeal rating. Statistically significant results are reported in the text when p values are less than .05. If results are not reported, then comparisons were not statistically significant.

RESULTS: USAGE

This section first presents descriptive statistics of app usage, then paths of app usage within the exhibit area, and finally user evaluations of app play.

➤ Players most often completed four rounds of the game while in the exhibit

Figure 4. Rounds Played with *PlanetMania App*



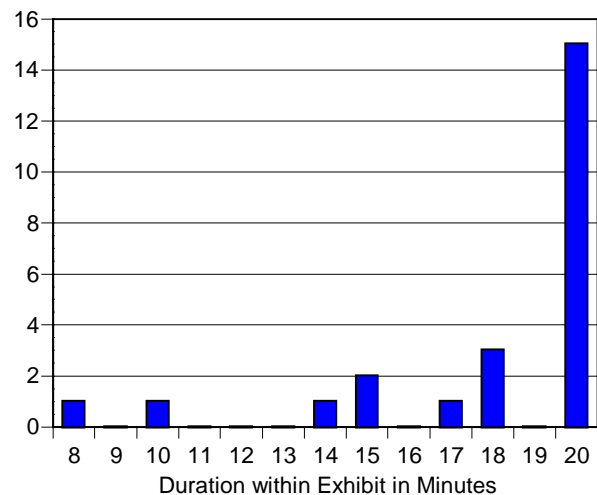
Number of rounds played gives us an estimate of the engagement of players with the game. Of a possible 15 rounds, participants played zero to seven rounds, with most children playing four rounds, as indicated in Figure 4.

➤ A majority of children stayed in the exhibit for the 20 minutes permitted

Prior to entering the exhibit area, instructions to participants were intentionally non-directive: *you can explore the exhibit as much as you want and use the app as much as you want*; however, researchers terminated visits at 20 minutes in order to maintain the promised one-hour session limit.

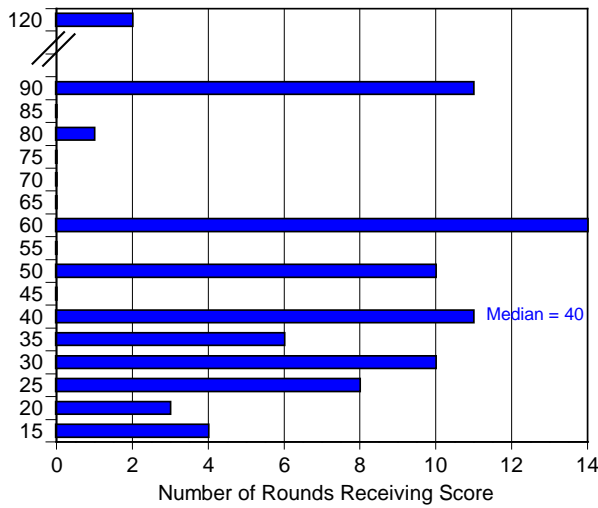
Duration in the exhibit ranged from 8 to 20 minutes as shown in Figure 5. Two-thirds (63%, $n = 15$) of participants chose to remain in the exhibit area for the full 20 minutes permitted to them. It should be noted that invited visitors, as our children were, are likely to spend more time in an exhibit than an average visitor.

Figure 5. Duration in Exhibit with *PlanetMania App*



➤ **Single round scores did not improve with playing experience**

Figure 6. Frequency of Single Round Scores



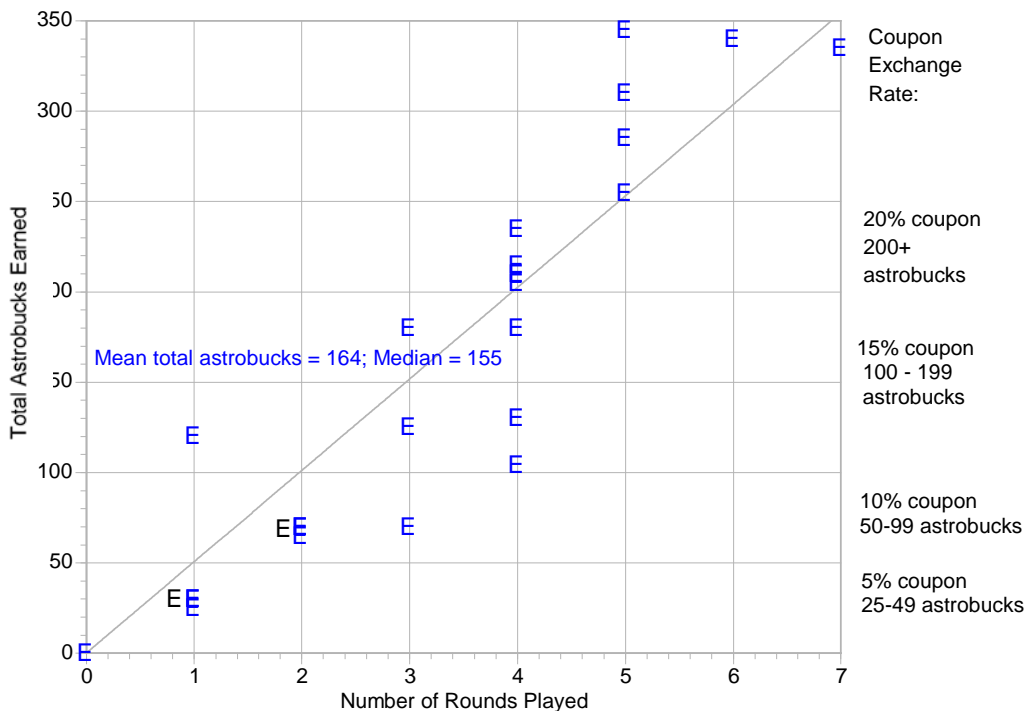
For a round of play, the minimum available score is 10 and the maximum score is 120. For our players, single round scores ranged from 15 to 120 points, with the most frequent score being 60 points, as shown in Figure 6. Half of the single round scores were above the median of 40 and half below 40.

Of the 19 players who proceeded to play a second round, 47% scored higher, 42% scored lower, and 11% scored the same as their first round. Scores were equally likely to decrease in a subsequent round as increase.

➤ **Total astrobucks increases linearly with number of rounds of play**

Across all rounds of app play in the exhibit, total astrobucks ranged from 0 to 345, as shown in the scatterplot of Figure 7. The average astrobucks total was 164, with half of the children scoring above 155 (median) and half scoring below 155. As would be expected, more astrobucks were earned with more rounds of play, as indicated by the light gray regression line in Figure 7.

Figure 7. Number of Rounds of Play versus Total Astrobucks Earned

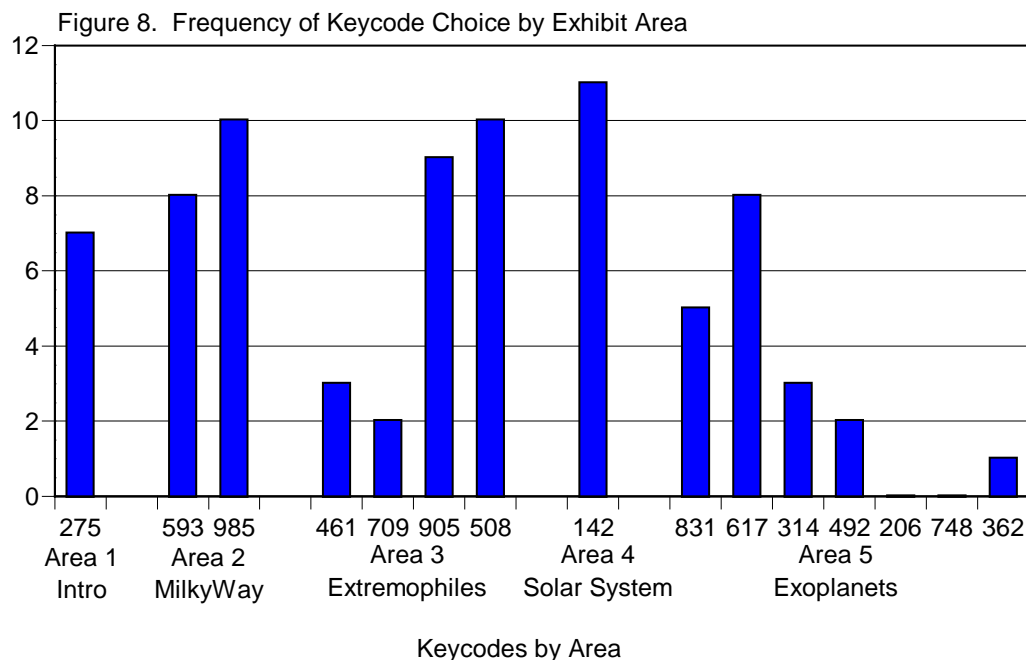


Astroback totals were highly correlated with rounds of play³ and duration in the exhibit.⁴ With their astroback totals, ten participants earned a 20% discount coupon; six earned a 15% discount; four, a 10% discount, and three, a 5% discount. The participant who did not complete her first round was also provided with a 5% discount at the end of her session.

- **Players entered 3 keycodes on average during their exhibit visit.**
Of 15 keycodes, 13 were used by the 24 players.

Players used 1 to 7 keycodes, with a fairly normal distribution about a median of 3.5 and mean of 3.2 keycodes. PlanetMania’s 15 keycodes were distributed physically across the full exhibit in each of the five main content areas. Figure 8 presents the frequency of keycode choice by exhibit area.

Area 1 (keycode 275) received attention from 29% of players, all of whom approached the exhibit by the front entrance (see Fig. 9 on the next page). Interactive components attracted our players: 58% used Area 3 numbers near interactive lenticular images (461), touchable bacteria (709) and swivel panels (905, 508); and 46% used Area 4’s number (142) near a set of three touchable planet/moon surfaces. However, interactives were not necessary to attracting our children to *PlanetMania* numbers. The numbers on the text/picture wall panels of Area 2 (593, 985) were chosen for the game by more than half (58%) of players. Numbers on text/picture wall panels of Area 5 (831, 617, 492, 362) were used by 54% of players, although numbers on the exoplanet back wall panels were least frequently used (492, 206, 748, 362). Also the interactive touch table number (314) was infrequently entered as a keycode.



³ $r_s(22) = .93, p = <.000001.$

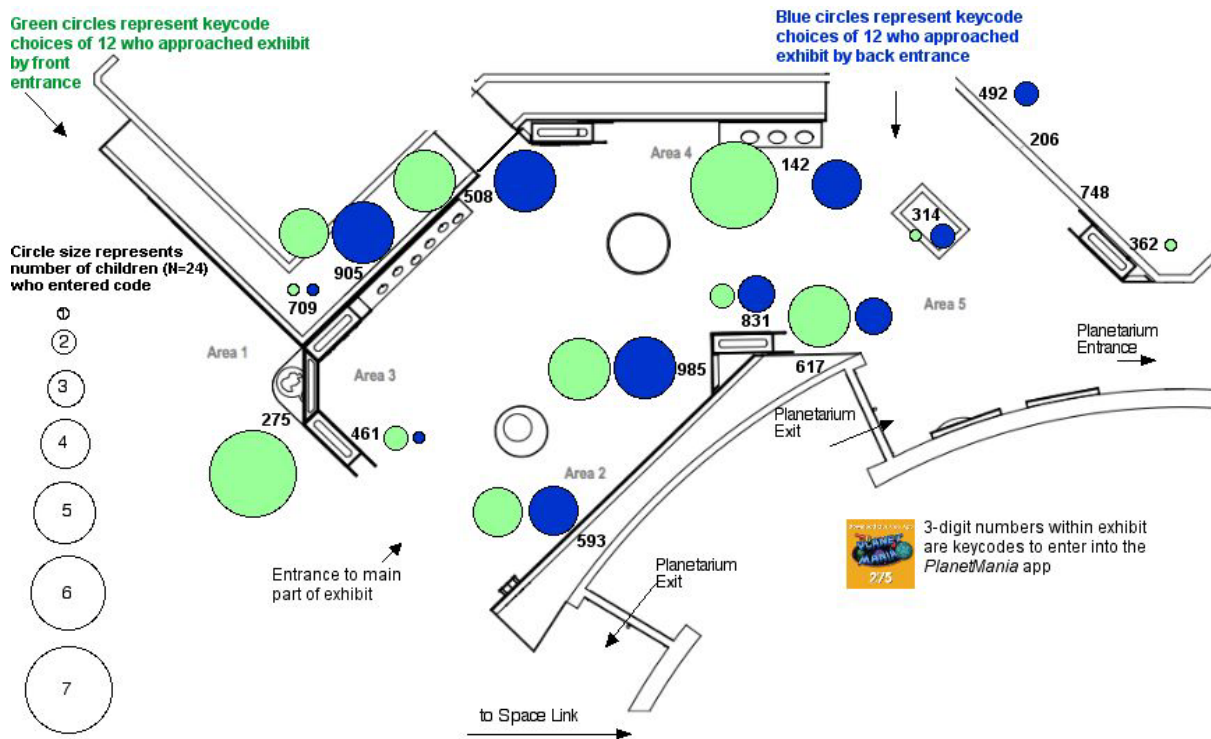
⁴ $r_s(22) = .46, p = .011.$

Figure 9 presents the frequency of keycode choices, represented by circle size, of those who entered by the front entrance (n = 12) and those who entered by the back entrance (n = 12).

#275 in Area 1 was the only keycode for which usage was significantly influenced by which entrance players used to move into the exhibit.⁵ Seven of the 12 front entrance players used #275. None of the back entrance players moved around to view the introduction wall of Area 1.

Very low frequencies of both groups entered numbers from Area 5's back wall of panels presenting exoplanet text and images (492, 206, 748, 362) and from the exoplanet touch table (314).

Figure 9. Frequency Distribution of Keycode Choices for App Play within the Exhibit

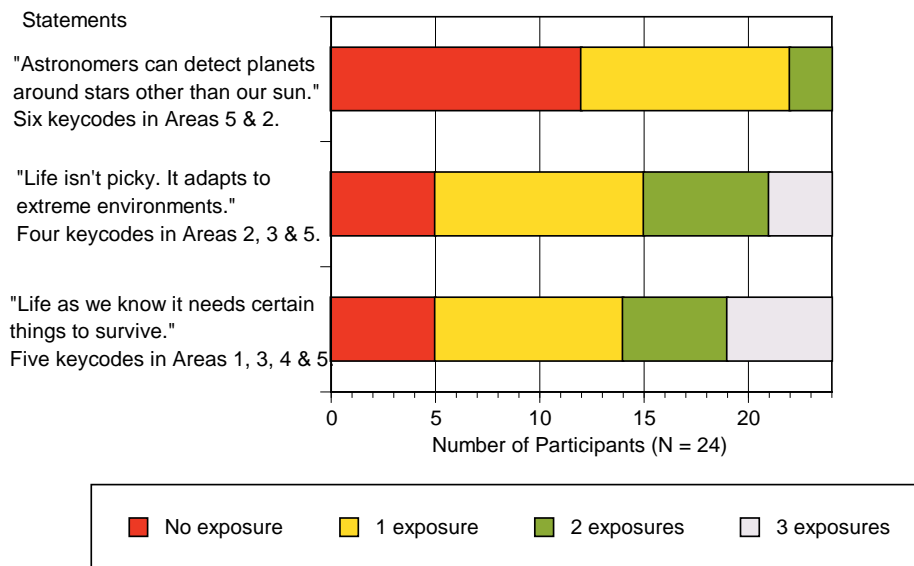


⁵ Fisher Exact test = 0.0046

➤ **Players were significantly less likely to see the game’s Astronomy message statement as compared to the two Life statements**

After answering the app game’s multiple-choice question, one of three message statements was introduced to the players. Figure 10 shows the number of players who were exposed to each statement and their frequency of exposure. The majority of players (n = 19, 79%) saw the two Life statements, which were tied to areas most frequently visited by the children. Half of the players (n = 12, 50%) saw the Astronomy statement. Although the most keycodes (6) were tied to the Astronomy statement, players spent minimal to no time in the exoplanet section where most codes associated with the Astronomy statement were displayed.

Figure 10. Frequency of Exposure to Statements in App Play



➤ **App usage in the exhibit area ranged from playing only the app and ignoring the exhibit to exploring only the exhibit and ignoring the app**

Observations of participants’ game play while in the exhibit revealed a wide range of behaviors that fell into five patterns:

1. 17%, ignored the exhibit, focusing only on the app
2. 17% skimmed the exhibit with some app/exhibit interaction
3. 38% used the exhibit to play the app and also explored the exhibit
4. 13% focused only on the exhibit, ignoring the app
5. 13% did not engage with either the exhibit or the app

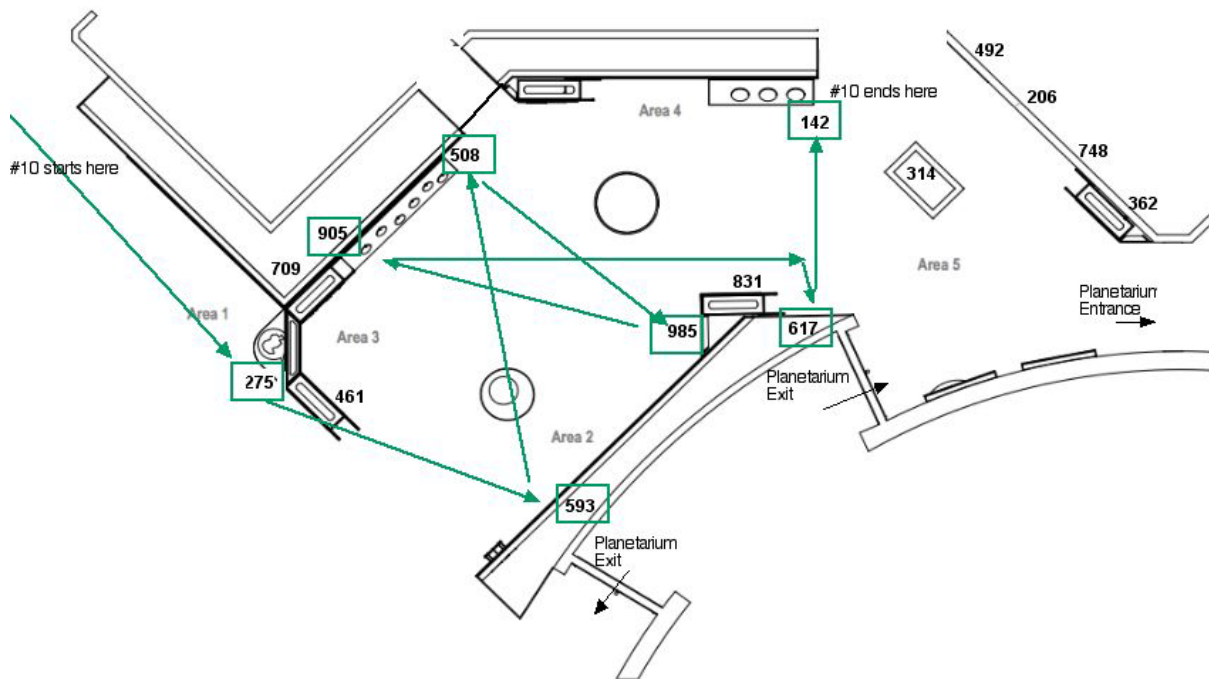
These categories are differentiated by number of app rounds played, total astrobucks scores, and reading and physically interacting with the exhibit. Presented in the following pages are path charts and observation descriptions for one representative child for each of the above five patterns. Those who entered by the front entrance (represented by green lines) were distributed across all five categories as were those who entered by the back entrance (represented by blue lines).

1. Focused only on app

Four (17%) children mostly ignored the exhibit and focused only on the app. Three of the four children with this pattern were boys. This group did not read much, if any, of the exhibit to answer the app questions and did not interact with the exhibit by touching touchables or watching videos. This group played more rounds and had higher total astrobucks scores than other participants, and three of the four stayed the full 20 minutes. Participant #10 is an example of the category, as described and illustrated in Figure 11 below:

Figure 11. Path and Observation of Child who Ignored Exhibit and Played App

Child #10 entered keycodes [shown in boxes] and answered app questions without looking at or reading the exhibit information. She moved confidently from one keycode to another, standing still while reading the app cards, completing each round before moving directly to another number to play another round. Child #10 did not touch or interact with exhibits or view videos in her 20-minute period. She played 7 app rounds and earned 335 astrobucks.

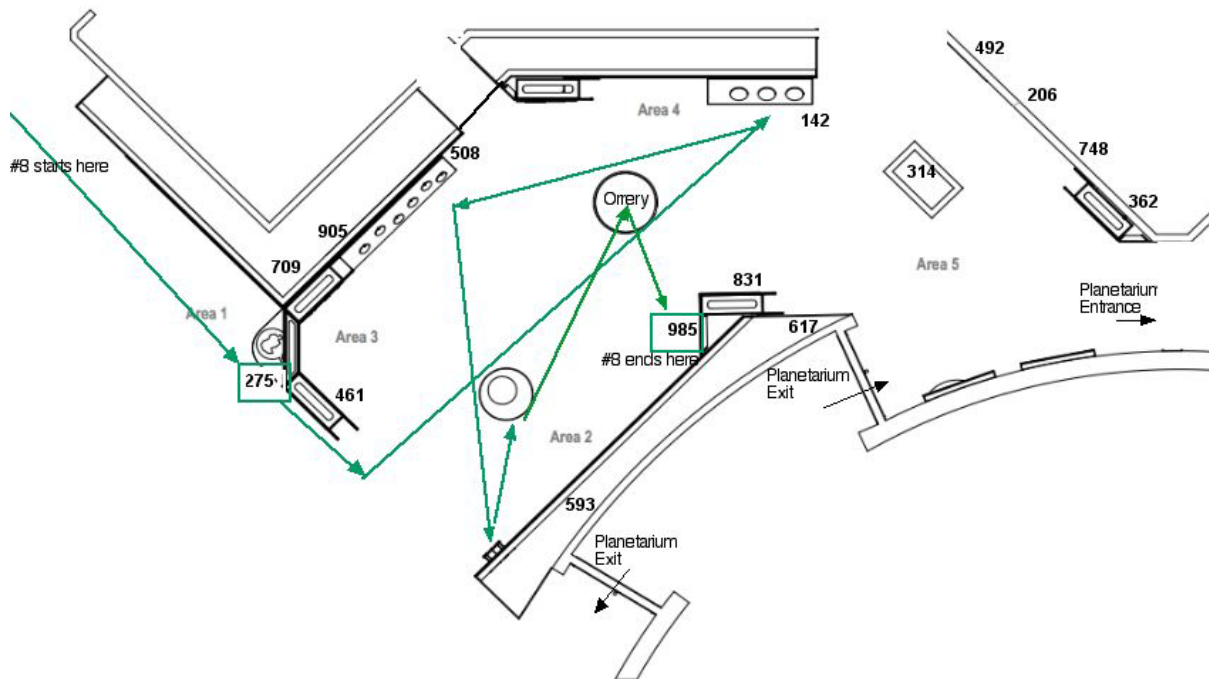


2. Skimmed exhibit with some app/exhibit interaction

This group of four children (17%) tended to skim the exhibit with some app/exhibit interaction. These children used the exhibit to locate answers to the app questions but did not interact much physically with the exhibit. Three of the four stayed the full 20 minutes and produced astrobucks scores in the middle of the distribution of scores. Participant #8 is an example of the pattern, as shown and described in Figure 12 below:

Figure 12. Path and Observation of Child who Skimmed Exhibit but Used Exhibit to Play App

Child #8 immediately entered keycode #275, read the exhibit for the app answer and continued playing in place. He then roamed across the exhibit floor to examine briefly the planets near #142, then skimmed passed Area 3 to look briefly in the Milky Way video porthole. He touched the Milky Way sculpture, then walked around and read the Orrery, moving on to enter #985, reading the panel for the answer. While playing this last round, he roamed the room without interacting with the exhibit. Child #8 played 2 app rounds and earned 65 astrobucks.

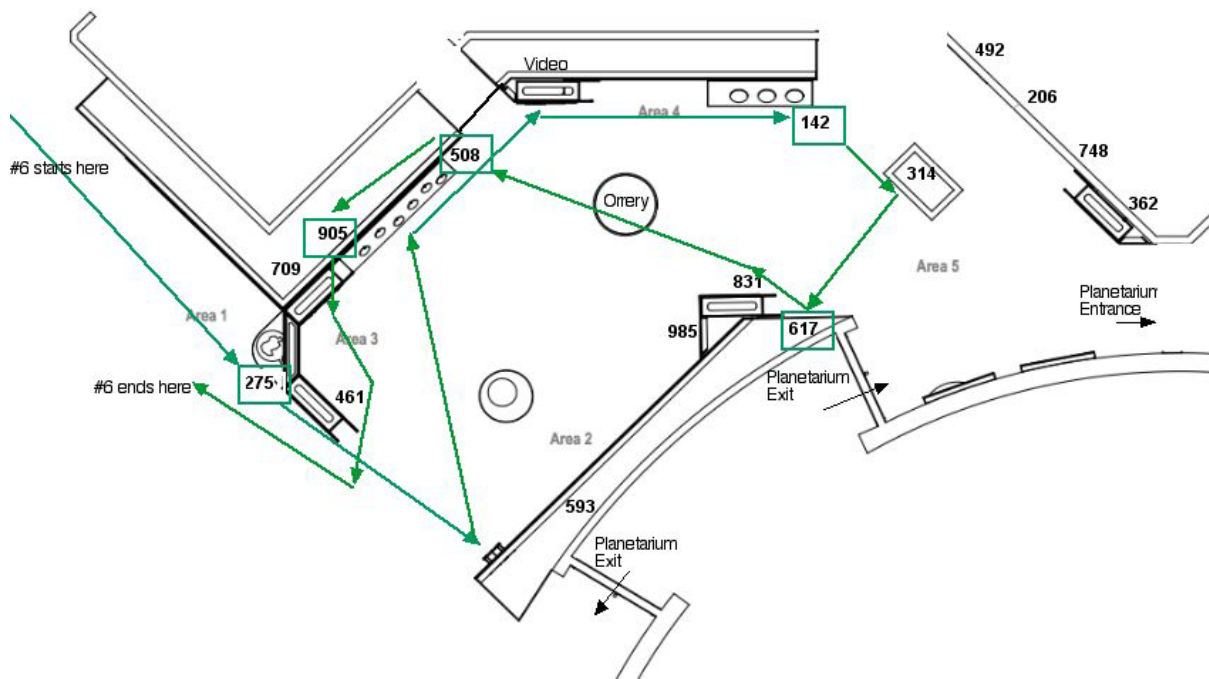


3. Used exhibit to play game and also explored exhibit

The pattern of involvement shown by most children (n = 9; 38%) was to draw on the exhibit to play the app but also explore the touchables and videos beyond what the app required. All players in this category stayed 18-20 minutes, played a high number of rounds with high total astrobucks scores. Participant #6 is an example of the category, as shown and described in Figure 13 below:

Figure 13. Path and Observation of Child who Played App and Interacted with Exhibit

Child #6 started app play with #275, read the exhibit for the app answer and continued playing in place. She looked briefly at the Milky Way porthole and crossed the floor to read the outside of each extremophile swivel panel in Area 3. Child #6 then viewed part of a video in Area 4, entered #142 into the app, feeling the nearby planet/moon touchables. While completing her round, she sat by the exoplanet detection touch table but did not interact with the table. She then entered #617 and read the panels for #617 and #831. She crossed the floor to play #508 and #905, felt the bacteria touchables by #709, and ended her 20 minutes by going out to feel the meteorite by #275. Child #6 played 5 app rounds and earned 255 astrobucks.

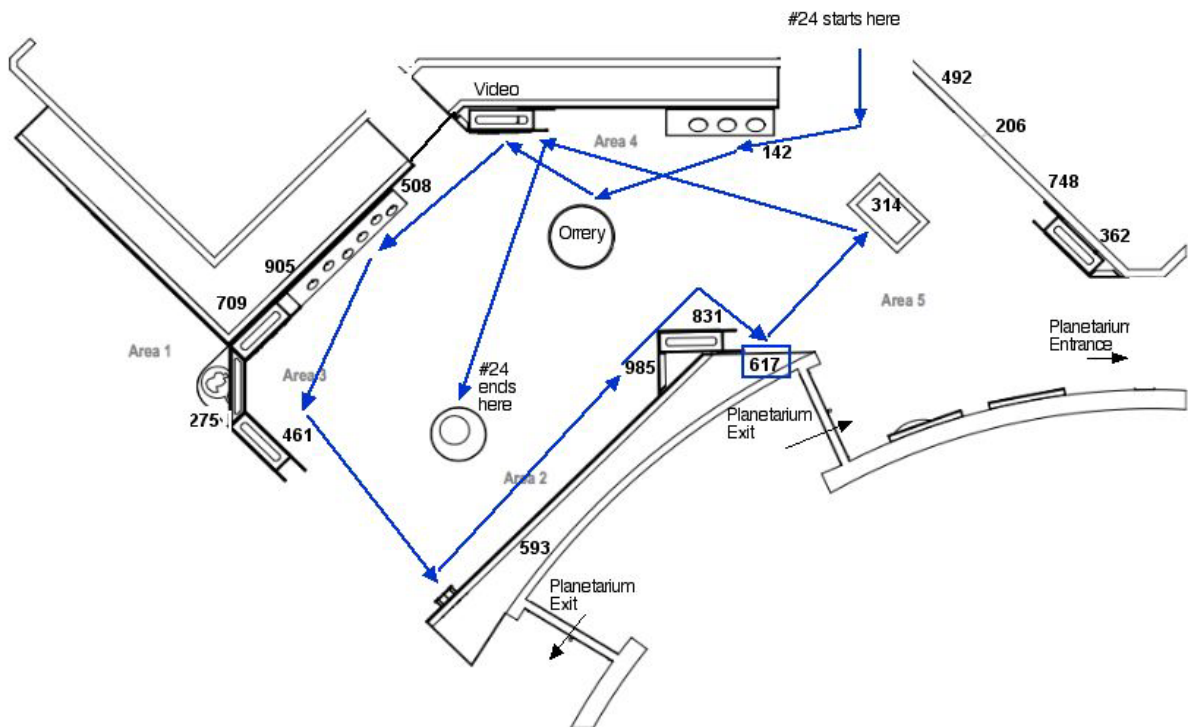


4. Focused only on exhibit

Three (13%) children focused only on the exhibit and mostly ignored the app. This group played only one or two rounds, earning low levels of astrobucks, but focused instead on reading and interacting physically with the exhibit. Participant #24 is an example of the category, as shown and described in Figure 14 below:

Figure 14. Path and Observation of Child who Interacted with Exhibit and ignored App

Child #24 entered and moved through Area 4, feeling all the planet/moon touchables. She read the Orrery briefly and watched a Mars video. She then moved through Area 3, examining inside the swivel panels and moving her body left and right in front of lenticular planet images near #461. She peered into the Milky Way porthole, read some of Area 2's wall panels and eventually entered #617 to start a round of the app. She read the panel for the question answer, then sat at the exoplanet touch table to continue playing. After round completion, she proceeded systematically through four detection methods at the touch table, leaving only when another visitor sat down. After viewing a second video, child #24 crossed to the Milky Way sculpture. After 20 minutes exploring the exhibit, she completed one round for 25 astrobucks.

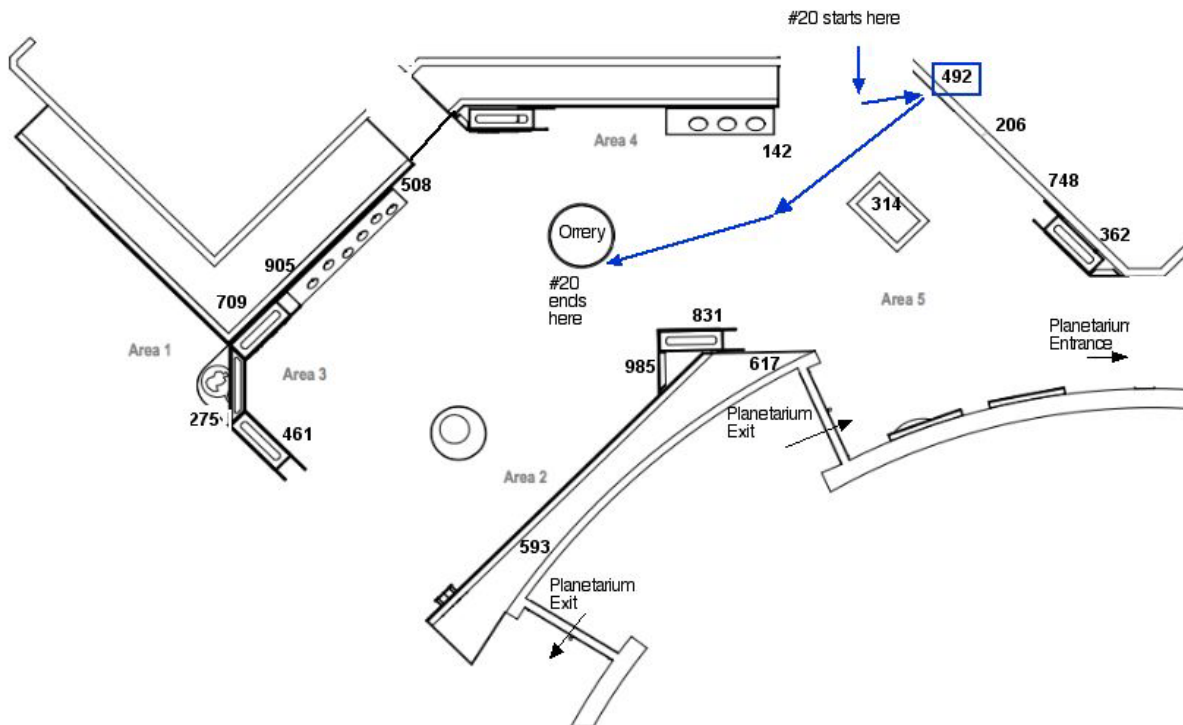


5. Not engaged with either exhibit or app

Finally, four (13%) children were not engaged with either the exhibit or the app activity. This group played one or no rounds of the app, earning very low levels of astrobucks. Although they spent 8-18 minutes in the exhibit, they interacted minimally with the exhibit. Participant #20 is an example of the category, as shown and described in Figure 15 below:

Figure 15. Path and Observation of Child who Interacted Little with Exhibit or App

Child #20 entered and read the app intro, then looked around for keycodes. After entering keycode #492, he moved to an open space and continued to play through the round, often distracted by sounds and people. After 12 minutes, he observed: “Seems like the only thing it has is cards. I’m going to look around.” He moved to the Orrery but watched the Science on a Sphere story that was visible outside the exhibit. After 18 minutes within the exhibit, engaged by neither the app nor the exhibit, #20 ended his visit.



➤ **Two-thirds of players noted difficulty at some point in playing the game**

Two-thirds of the children described some confusion with various activities of the game.

Finding codes: One-fifth (21%) of players did not know what to look for when directed by the app screen (to the right) to “look for the PlanetMania logo,” although they were observed scanning the exhibit walls; for example:

It was confusing because I couldn't find a PlanetMania sign. [player roamed for 8 minutes before asking the researcher] I didn't see the code at first, so I wasn't sure what it was. I was kind of confused what the code was. There's a little sticker on the board and numbers on it.

Finding the numbers - but then I realized 'oh, there's squares everywhere with numbers on them'.

At first I thought it was the 2 and the 1 [referring to Braille numbers on exhibits].



Finding question answers: Four (17%) players were not aware of the screen suggestion (to the right) of looking for an answer “near the keycode.” They roamed all over the exhibit or guessed answers; e.g.:

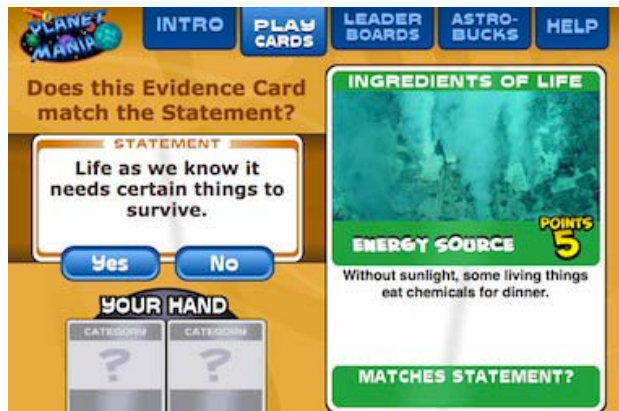
The questions were a little hard. I was reading the question and thinking about the answer. I didn't see that [suggestion to look in exhibit].

I didn't see the sentence saying look around the exhibit to find the answer to the question.

It's a little confusing cuz you have to look all over the exhibit for an answer, otherwise, you have to guess. That's what I had to do.



Making a match: In response to the right-hand screen, four (17%) players did not understand that they were to decide whether or not the evidence card matched the statement. Instead, a few interpreted this screen as asking for a decision on the truth of the statement (i.e., is the statement true or false, yes or no) or asking for a decision on the truth of the card information.



Those players described above as not understanding the matching screen were among those who reported that matching cards to statements was ‘hard.’ The majority of players (58%) felt the activity of matching cards to the statement was ‘just right’ in terms of difficulty (see Figure 16).

In their interview responses, a good number of players were not able to describe coherently their own matching process, but those who could reflect on their thinking revealed that the task is appropriate for this age group; for example:

[easy] *One example says that “living things*

need different things to survive.” I used what I learned and what I knew already that water would be one of them. It was easy, because for the life [statement], I know that it [a match] wouldn’t be some kind of telescope, it would be water or food.

[just right] *Quite a few times it popped up – “living things need certain things to survive”. A certain living thing uses whatever to produce energy or to produce food – that [card] matched it. A card said something like astronomers use satellites to locate planets, and that’s not saying that the satellite needs something to survive so that didn’t match [the statement].*

[just right] *When it [statement] said something about a planet and there was a life card – we need water to survive – that didn’t have anything to do with planets, so I pressed no. If it was too easy, I wouldn’t learn anything. I got a couple wrong.*

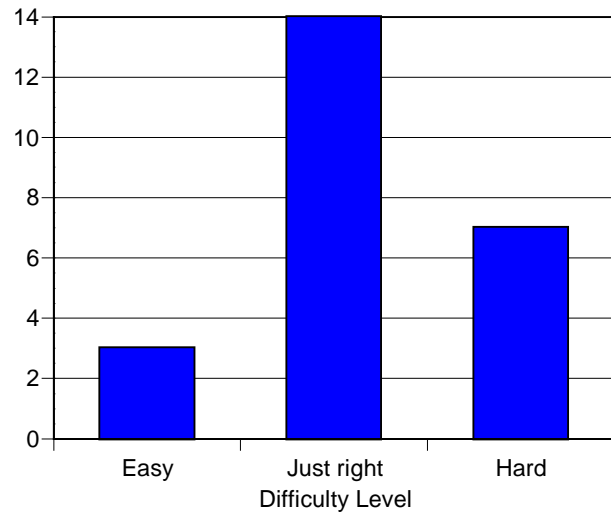
[just right] *I’d be looking at the picture and reading the statements and seeing if they are both alike and similar in a way. I was looking for key words in there and see if they match up.*

[just right] *Sometimes I could tell by the background on the picture, color of the cards and by reading the cards.*

[hard] *Some of the cards had nothing to do with the statement, or if it did I couldn’t match it. That’s why I was trying to drop the cards cuz they wouldn’t help me.*

[hard] *“Life as we know it” had a caterpillar picture and animals need the right kind of food, and that matched with the statement. It’s a challenge but you can’t learn unless you advance. Hard but a good challenge.*

Figure 16. Difficulty of Matching Cards & Statements



Keeping or Dropping Cards:

Four players (17%) approached researchers in the exhibit when faced with the initial keep/drop screen at the top right. They were confused as to the goal of game; for example,

I didn't know that you could keep the card, and I didn't know that you could get points. I dropped all the cards. It picked the cards for me. I didn't get it.

One-quarter (25%) of the players became confused when the game, at bottom right, showed two cards in the hand and a third one at the side. There was a feeling that with two cards in their hand that they had completed the game. Players were not aware there are five cards to decide about. For example, one player approached the researcher in the exhibit and asked: *What happens after I get my cards?* Alternatively, there was a lack of understanding that

players could exchange cards in their hand with new ones; for example:

I wasn't really sure what I was supposed to do. I was confused what to do with the two cards.

But then I understood and I started matching up the cards, giving proper answers and thinking about it.

I just found it a little confusing because you could only have two cards to submit.

A few players approached the researcher in the exhibit showing these screens; others tried to touch <intro> or to restart the game, and one chose <help>.

Players described several strategies for keeping or dropping cards:

- 46% kept cards that showed the most points; e.g., *I looked at the points and the bonus and saw how many points it would give you. 5 points, I would have dropped, but 10 points, I would have kept it.*
- 29% kept cards that they had correctly matched to the statement; e.g., *If I got them right, then I put them in my hand.*
- 25% kept cards that matched in category; e.g., *I didn't get it until the third round that you wanted to get two cards that were the same category.*
- 21% described strategies that yielded low total astrobucks scores for them. These players also reported confusion at many stages of the game:
I just dropped cards if I had two already.
I sort of dropped all the cards.



I never did drop a card. I took the first two and replaced cards because I'm thinking I needed a new card.
I decided on which cards would be helpful and which cards wouldn't be so helpful.
I kept the cards that had pretty interesting information and dropped cards that weren't very interesting.

Only four (17%) players agreed that they changed how they played the game as they played more rounds; however, their scoring trends did not differ from other players:

I think I paid more attention to what the statement was and relating it to what the card was. I was thinking about it a little more.

I looked more carefully at the statement and the card because at first I was confused, but I looked more carefully later.

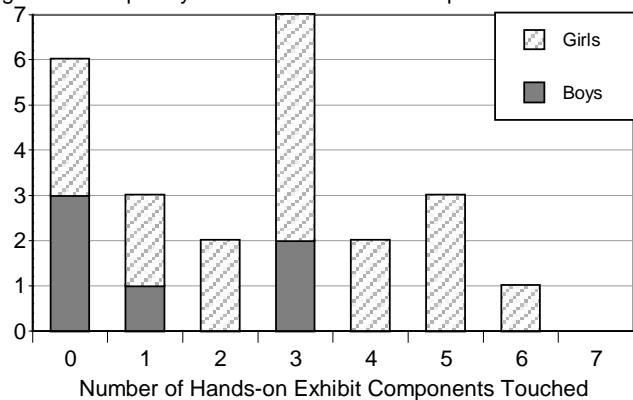
I started matching the cards to get more points.

At first I was trying to get all the hints [from the exhibit for the questions] that I could get, but toward the end, I started using my real life experience to help me.

➤ **Using PlanetMania did not prevent users from interacting physically with exhibit components**

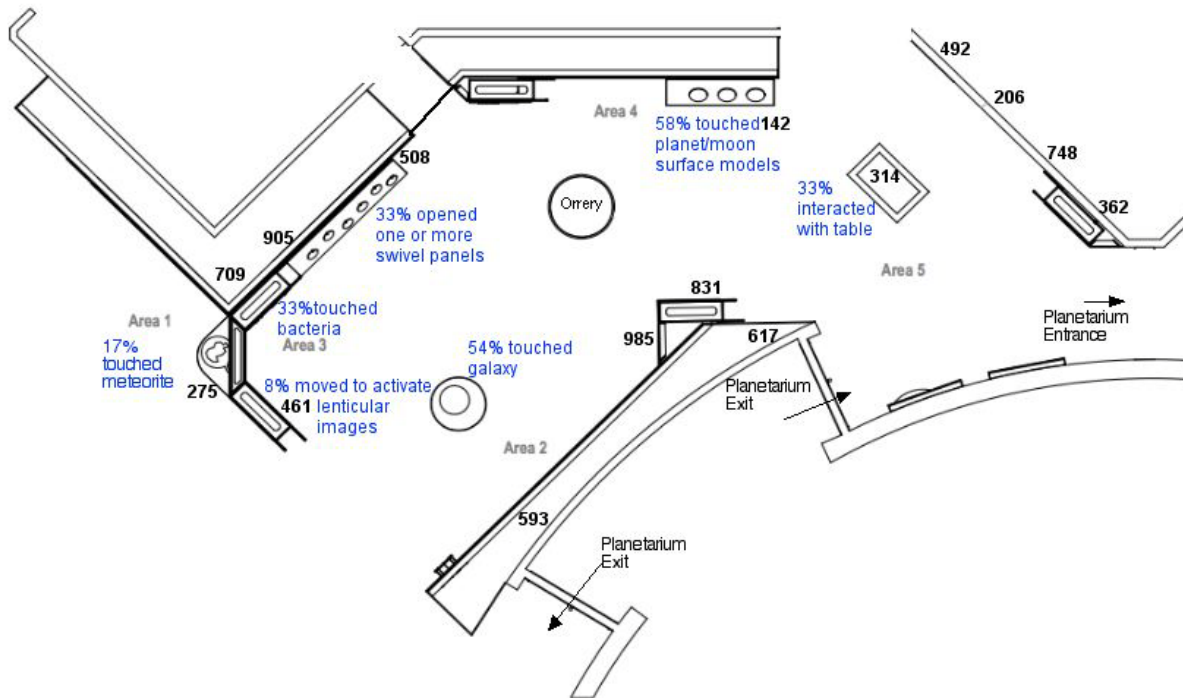
In addition to reading text and viewing images in the *Life Beyond Earth* exhibit, visitors could touch or interact with seven exhibit components. Three-quarters (n = 18, 75%) of our app users interacted physically with one to six of the seven components, as indicated in Figure 16. Girls tended to interact physically with the more hands-on components than boys, although our male sample is very small.

Figure16. Frequency of Hands-on Exhibit Components Touched



Frequency of interaction with individual components is shown in Figure 17. The galaxy sculpture in Area 2 and the planet/moon surface models in Area 4 attracted the hands of more than half of our users. In addition to the 33% who interacted with the exoplanet touch table, another 8% sat at the table to play the app game but did not interact with the table activity.

Figure 17. Percent of App Users Interacting with Exhibit Components



Those who spent time at the exoplanet touch table were asked to describe their experience. Half of those who used the table appeared to understand the activity and content:

I liked that. It was about the stars and the scientists looking at the stars and how planets affected it and stuff. It's this transmitting thing so when the planet passes the star, it dims.

It was pretty interesting. There 's some things that you got to try out. You got to find an exoplanet and there's stars that the exoplanets orbited.

I liked how they had the giant iPad-like thing. You could know how to find different radio waves or find a planet. It was about how to find exoplanets. How they found different kinds of exoplanets. There was one where you got to block out the sun, and it would show a planet moving around it if there was a planet. And then there was like heat, there was angle to another sun, and I forget what else. I did all of them. It was really fun.

The other half who used the table misinterpreted the goal as locating stars/suns, not planets:
I think most people would like it. It's a hands-on activity. Most exhibits have a no touching rule. Kids want to touch everything. I learned how some scientists locate stars by the droop.

I thought it was really cool that you had many different suns so you could figure out what kind of suns they were, I believe, how hot they were?

That was pretty cool. It was a TV that you were able to touch, like a gigantic iPad. It was something about methods about searching for the sun I think?

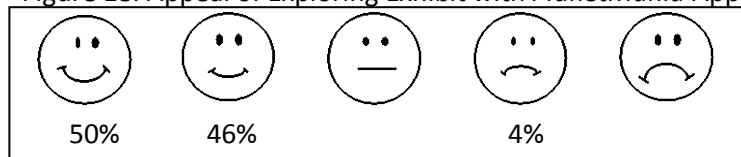
RESULTS: APPEAL

This section describes what was appealing or not about the *PlanetMania* app.

➤ All but one participant liked exploring the exhibit with the app

When asked to rate how much they liked or did not like exploring the exhibit with the *PlanetMania* app, half of the participants liked it “a lot” and about half liked it “somewhat,” as shown in Figure 18.

Figure 18. Appeal of Exploring Exhibit with *PlanetMania* App



➤ The app's most appealing features are the card game activity and answering questions

Participants enjoyed many aspects of the *PlanetMania* app:

- 38% liked the cards and the card game activity; for example:
I liked how there was different cards. It was like a real game instead of all scientific facts to make it boring.
I liked the pictures that went with the cards.
It was confusing at first, but I went to help and it helped me. I liked the yes/no questions. I liked the pictures that went with the yes/no questions.
I liked where you find to see if it matches and if it's yes or no.

You got to choose which cards you wanted to keep and try to get two cards from the same category.

- 29% enjoyed the multiple-choice questions; for example:
*The part where you got to guess the question.
The questions were really good to ask.
I got to explore and find things and answer the questions. They're pretty tricky but I got most of them right.
Even if it was annoying, it was kind of fun trying to figure out what the questions were.*
- 29% felt they had fun learning; for example:
*I liked that I'm playing and having fun and also learning.
Mostly I liked that it was teaching me more stuff than any other app would. It was fun.
It turned into a fun card game. You could have fun learning things at the same time.
How it would quiz you hard and make you think hard and learn more things. It was interesting and fun.*
- 21% liked the concept of astrobucks for a store coupon; for example:
*I liked the idea of astrobucks, kind of funny.
The thought of the astrobucks was kind of interesting.
I liked how you could get the astrobucks. I didn't know if you could buy stuff with them.
I liked that I could get a coupon to the science center.*
- 17% appreciated the app's connection to the exhibit; for example:
*It's interacting with the actual museum.
I liked how it was when you type the number in, it would know what exhibit you were at. I liked that you could play a game in the museum.
It was a fun way to interact with the exhibit.
It connects to the exhibit. You could look at the exhibit and look at the game and answer some questions.*
- 17% enjoyed using codes; for example:
*I like that you had to type in a special code that was next to the information to make sure that you could find the information.
I liked in the beginning that you have to find stuff with the bar codes.
I liked the searching part where we had to go searching for keycodes, like hide and seek.
The keycodes are hiding.*
- 8% liked the variety; for example:
*It was creative. There was different stuff you could do. At first, it was a little confusing but as you did it a little more, it got more interesting.
It was cool how you could choose what you could do. It gave you big varieties of stuff you could choose.*

➤ **The majority of players liked looking in the exhibit for answers to the questions**

Players were asked specifically what they thought about having to look in the exhibit for answers to questions:

- 66% thought looking in the exhibit for answers was a good idea and fun; for example:
I loved that idea. I think it's cool to interact with the exhibit instead of just interacting with the iPhone and just paying attention to the iPhone - you could be in the dinosaur exhibit and just do that.
I like that it's not just that you have to use common sense to answer, you can learn it. There were some answers that I didn't know but I found answers when I looked around the exhibit.
I liked it because it kind of guides you through the game and gave you some of the answers.
Really cool. Not hard to find the answers to the questions.
I knew some of it and I used the exhibit. It helps you to remember what you're seeing.
Pretty fun, more of exploring.
I like it. It was cool because you could look around the exhibit a lot. It was a little hunt.
I think it was cool because if you don't know an answer you could look around.
On a scale of 1 to 10, it was an 8.
- 17% reported that they knew the answers without using the exhibit; for example:
I didn't have to look in the exhibit.
I tried what made sense. I didn't really look at the exhibit.
I kind of knew them. I got most of them right. I liked the questions.
- 8% found the app confusing for this activity; for example:
It's a little confusing cuz you have to look all over the exhibit for an answer, otherwise, you have to guess. That's what I had to do.
I think it would be good if there was a help guide of pointing you in the right direction, a humanoid guide that points you in the right direction.

➤ **One-fifth of players felt the card game was repetitious**

When asked what they did not like about the *PlanetMania* app, 42% could not think of anything that they did not like. Others noted specific confusions that have been discussed in the Usage section of this report (pgs. 18-21). One-fifth of players (21%) focused on what they perceived as the repetitious quality of the card game:

It would keep giving me cards. I just got a little tired with it. If you're not completely into card games, it got a little annoying when it was just cards. Even if it was annoying, it was kind of fun. Trying to figure out what the questions were and the thought of the astrobucks was kind of interesting. [played one round]

I didn't like that it kept on showing me different cards, until a little while after it did something else. It should be a shorter time for cards. It was boring just sitting there doing different cards like that. [played one round]

It just wasn't very interesting, entertaining, it doesn't do anything. Not very interesting cuz not entertaining as a game or second screen education. When you play the game, you'll be 'what the heck is this?' After a while you get the hang of it, and after about three times, you start to get bored. [played four rounds]

It took long to get through all five cards, you couldn't do everything. [played 5 rounds]

I always saw the same two statements - the life isn't picky, it can adapt- and then - life as we know it needs certain things to survive. There should be a bigger variety of statements. [played 7 rounds]

RESULTS: VALUE

This section addresses how the *PlanetMania* app may add value to the *Life Beyond Earth* exhibit. To assess value, without a control group that experiences only the exhibit, we asked the children to think about how they have visited other exhibits in the science center and to describe how their experience in the *Life Beyond Earth* exhibit was more or less enjoyable using the app and how use of the app affected their learning.

➤ **Two-thirds of players felt using the app helped them enjoy the exhibit more**

Two-thirds (66%) of our children thought that their experience in the exhibit was more enjoyable with the *PlanetMania* app. This group focused on the question-answering feature of the app and liked that the app helped them interact with the exhibit and understand the exhibit content better; for example:

You could do something a little more fun using the exhibit instead of just walking around reading and feeling. And you could learn and memorize the stuff you learned.

It helps you understand more instead of just reading what all the stuff said, you interact with it.

I could kind of enjoy it [the exhibit] and relate to it in a sort of way in the game. It has sort of the answers and when you look at the answers, you can also know.

Kind of like a treasure hunt looking for the codes and then it helped me look more at the exhibit to find the answers.

When it said to find those codes, I went around and looked for them. It gave me all sorts of questions that made me think and that's what made it exciting.

Four (17%) app users chose the middle road between more and less. They felt that the app contributed some to their enjoyment of the exhibit but also detracted from or did not add to their experience; for example:

It was kind of like in the middle [between more or less]. I like using the app but I think it takes a long time to get through all that.

It helped a little bit. It taught you what kind of things you need and things that related to each other kind of. You spend most of your time answering questions on the app. You don't really get to see more of the exhibit.

After I learned how to play, I enjoyed the app, but without it, I still would have been fine too.

Four (17%) children, including three boys, felt that using the app did not contribute to their enjoyment of the exhibit. This group did not particularly like the card game aspect of the app; for example:

It kept on showing cards and it wouldn't go on until I dropped the cards a second time. I wish after one or two cards, it would let me do something else.

If you're not completely into card games, it got a little annoying when it was just cards.

The app wasn't very fun to me.

I wasn't really doing the exhibit much. I was just looking for key codes. I think it might distract people from the actual exhibit.

➤ **Almost all players felt using the app helped them learn more from the exhibit**

Almost all (88%) of our children thought that using the *PlanetMania* app helped them learn more from the exhibit than without the app. This group focused on the question-answering activity and matching activity as supportive of their learning; for example:

I know I learned a lot. I think the app kind of helped me go straight to questions so I would remember it. I tend to learn more when I'm asked questions.

More, in an entertaining way, because it asked you questions about the exhibit so it caused you to read more instead of just looking at the pictures and not really getting it.

When it asks you questions, if you are paying attention to the exhibit and thinking about it, you can learn stuff.

It's almost like a quiz kind of.

There were yes or no questions. A lot I got wrong. The ones that I got right are now facts that I know.

The app kind of gave you as you were answering questions with the different cards, it gave you information. It helped you learn stuff on the way through picking the right card and the wrong card.

Cuz you can learn, oh, this is what we need to live – and relating that to what planets have to offer basically.

It gave me more information on the numbers that I picked than what it actually said up there [in the exhibit].

Two (8%) children who played only one round each did not feel that the app made a difference to their learning one way or another. And one boy (4%) felt he learned less because *It's pretty much not very educational, more of a game.*

➤ **Three-quarters of families made an astrobucks purchase at the museum store**

One additional measure to assess the value added by the app to both participants and the science center itself is the percentage of participants who turned their astrobucks coupons into the science center store. Three-quarters of the participating families made store purchases using their coupons, averaging about \$19 per family. One parent later exclaimed to a researcher that her son purchased a microscope because he had learned that scientists focus their search on microscopic life (his first multiple-choice question).

RESULTS: LEARNING

➤ **About half of the participants spontaneously recalled information from their app experience and about half from the exhibit touchables.**

When asked to recall something that they learned from their “experience with the exhibit and app,” almost all (88%) could recall something specific. Participants responded with information drawn from app-related content and from the exhibit touchables.

One-third (33%) of respondents recalled that “life isn’t picky” or gave information related to the app questions for this statement. These children played four or more rounds of the game. For example:

I was surprised when it said that life isn't picky, it adapts. Animals can adapt to habitats if they have all the basic needs and they can find them okay.

It helped me learn about adaptations that some animals have.

That life on earth can go through extreme measures – some animals could live on chemicals – they could adapt to that because that was the closest thing to water.

How they started to look for life on Earth, not on other planets.

About adapters [‘adapters’ was a distraction answer in an app question]

A few (17%) respondents noted learning from the other two app statements and exhibit questions related to the statements:

That lifeforms need water.

They taught me about things that life on earth needs to survive.

That it is very hard to detect other planets orbiting around stars.

Information from the planet/moon surface models in Area 4 was particularly memorable for 29% of participants; for example:

It showed you where Mars had water on it in the exhibit, instead of just telling you, and you could feel it.

I learned that the planet Titan has pools of – I don't remember the metal – it has a liquid on it. Mars used to have water, and it used to be called a blue planet.

The exhibit showed how water changed the different surfaces of the planets. I liked feeling the examples of the surfaces of the planets. Mars is dry, and underneath the ice of Europa, there's like an ocean below.

The textures of the Milky Way galaxy sculpture were recalled by 13%; for example:

I'd never seen a 3D of the Milky Way. Interesting that some of the stars were far apart, and some were really close together and small.

- **One-third of participants acquired new knowledge about what scientists look for when searching for extraterrestrial life, what kind of extraterrestrial life scientists might find, what extreme places on earth support life and ways astronomers detect exoplanets.**

Before and after their exposure to the exhibit and game, participants were asked six open-ended questions related to the main messages and content. Table 1 below gives the percentage of participants who provided relevant responses to the six questions before seeing the exhibit and game and the percentage who acquired knowledge from their experience to reply appropriately after their exhibit visit and game playing. Almost all (96%) participants acquired knowledge related to at least one interview question, 46% to two questions, and 13% of the participants demonstrated new knowledge for three of the six questions.

Table 1. Percent of Participants with Knowledge Prior to App/Exhibit Exposure and Knowledge Acquired from App/Exhibit Exposure

Open-ended questions before and after exposure to app and exhibit	% with prior knowledge	% who acquired knowledge
Why do scientists think there might be life beyond earth?	38%	17%
Describe some ways that astronomers can detect planets around stars other than our sun.	42%	33%
What do scientists look for when searching for life on other planets?	58%	38%
What kind of life do scientists think we might find on another planet?	13%	33%
What things do you think life needs to survive on other planets?	100%	0%
What are some extreme or strange places or environments on earth where you think life can be found?	54%	38%

In answer to the question of “why scientists think there might be life beyond earth?” prior to seeing the exhibit and app, 38% noted that water and/or ice had been found or was thought to have been on Mars at one time. After the exhibit and app experience, an additional 17% suggested that finding signs of liquid, ice or water might indicate the possibility of life beyond earth; for example:

Pre: *They've sent probes up to different planets to scan around them, and they've actually found life.* Post: *From past things, they have seen water. They said they had seen water more than the Mississippi River, so there must be life. In order for things to survive they need water.*

Pre: I don't know. Post: *Because they found liquid on planets.*

Pre: *UFO sightings and alien abductions, scientists are trying to figure out if that's real or not. I think its real.* Post: *Io is made of ice and Europa is mostly ice.*

Not mentioned by participants were other exhibit/app-based possibilities of why scientists think there might be life beyond earth such as the existence of billions of planets or discoveries of extremophiles on earth.

When asked to “describe some ways that astronomers can detect planets around stars other than our sun,” most (42%) suggested “telescopes” prior to visiting the exhibit. An additional 25% mentioned “telescopes” after their exhibit/app exposure; for example, *I saw they use the Hubble telescope, a really giant telescope.* Another three participants (13%) tried to describe a method based on their touch table experience:

I guess they can just look for planets without the sun's light.

They can look at the droop of the sunlight.

They find the planets orbiting some sort of star and they figure out what type of planet it is.

They showed the picture of the exoplanet orbiting the star.

Prior to entering the exhibit area, participants (54%) said that water is what “scientists look for when searching for life on other planets.” After the exhibit and game, 8% more suggested water and 8% suggested more specifically that scientists look for “liquid,” which is a term presented in both the exhibit and the game. Air or atmosphere was suggested by 21% before the exhibit and game and an additional 8% after. A third category of food was suggested by 13% before their experience; and after, 13% reported more specifically a “food source.” “Energy source” is a title phrase for some of *PlanetMania's* cards. Prior to the experience, one (4%) child put forward that scientists look for microorganisms, and two more (8%) suggested “microscopic life” after their experience. Some example pre and post responses follow:

Pre: *Aliens. Atoms.* Post: *Liquid. Types of food sources that they might have.*

Pre: *Aliens. Buildings.* Post: *Microscopic life.*

Pre: *Heat monitors to look for signs of life. Possible air that's breathable.* Post: *Liquid. That's mainly what I absorbed from one of the questions.*

Participants were asked “what kind of life do scientists think we might find on another planet.” Bacteria or microorganisms were noted by 13% before the exhibit and game and by an additional 25% after. Four (17%) children recalled some sort of extremophile after their experience; for example:

Pre: *I don't know.* Post: *Some animals that can live in extreme temperatures. Underwater sea dwellers in the dark.*

Pre: *Type of plant or animal or insect species.* Post: *A vampire squid – it lives under water. They might find bacteria. They were showing different bacteria that they have found on other planets.*

When asked “what things life needs to survive on other planets,” virtually everyone provided pre and post answers of what they had learned in school about things that humans need to survive, focusing on water, food, air/oxygen, sunlight and shelter. A few (17%) post-answers reflected exposure to the exhibit/game by changing terminology from “water” to “liquid” or from “food” to “something to eat” or “food source.” Reporting on more specific exhibit/game information did not occur; for example, no one mentioned the possibility of sulfur, even though 38% of participants were exposed to the game question content (keycodes #905, #709) that life needs sulfur.

Prior to seeing the exhibit and game, over half (54%) of the participants could list one or more extreme or strange places or environments on earth where life could be found, including deserts (42%), deep sea (21%), frozen or icy cold places (13%), and caves (8%). After experiencing the game and exhibit, 38% added to their pre-responses, reporting on deserts (8%), deep sea (21%), frozen or icy cold places (13%), caves (4%), and a new category of geysers or very hot places (13%). Some children were quite specific about their new knowledge; for example:

Pre: *Underwater, caves, Antarctica.* Post: *Dark caves, north pole, deep underwater with creepy fish, bacteria about geysers cuz they like the warmth. I read the card.*

Pre: *Desert where there's no oasis. It doesn't ever rain.* Post: *Places that are really hot or really cold, really deep in the ocean and the pressure is high. I didn't know that they could live in pressures that would crush us.*

Pre: *Grand Canyon.* Post: *Oceans, deserts – got that from the [lenticular images]. There's a lot of weird stuff in deserts. Gulf of Mexico where they found that hairy crab, and inside the cave was that thing that ate poison.*

The knowledge acquisition results were not significantly related to any of the measured variables.

DISCUSSION

Mobile phones are pervasive in everyday life. As of September, 2012, 45% of American adults owned a smartphone.⁶ Apps are downloaded by 43% of smartphone owners,⁷ and 40% of app usage time is spent playing games.⁸ Moreover, access to app-enabled devices like the iPod Touch ranges from 8% to 28% for 9 to 11 year olds,⁹ which is the target audience for *PlanetMania*; and indeed, some of our evaluation participants reported owning an iPodTouch.

Reflecting the increased ownership statistics, smartphone apps are becoming more common in museums of all types. The website *museums2go.com* lists 203 museum apps, but game formats are very few, and even scarcer are games like Maryland Science Center's *PlanetMania*, which is played on site encouraging interaction with a permanent exhibit. Other apps meeting these criteria include *Tate Trumps*, a digital card game to score and compare art on display,¹⁰ and *WildSpy*, an I Spy game to spot species and answer questions within a nature preserve.¹¹

One barrier to developing a game app for a museum setting is the fear that young visitors will become immersed in the game and miss the museum exhibits themselves. Of our participants, only 17% ignored the exhibit and focused only on the app, and three-quarters of the app users interacted physically with hands-on exhibit components that were not directly related to game play. *PlanetMania*'s design encouraged interaction with the *Life Beyond Earth* exhibit via its quiz format. The distribution of keycodes and game questions across the exhibit's physical space exposed users to most of the exhibit content, although our visitors spent little time in the exoplanet area for reasons more likely related to the exhibit design than to the game design, since one-third of the game keycodes are posted in the exoplanet area.

PlanetMania is for the most part a user-friendly game. Although two-thirds of players noted difficulty at some point in the playing the game, relatively minor screen design revisions can address usability issues of locating keycodes and finding answers to game questions. Games have rules, and in some cases, the rules of playing *PlanetMania* were not sufficiently transparent to users; for example, some players were confused about the matching activity and why to keep or drop cards. *PlanetMania* meets a gaming criteria of giving higher values to some actions than to others, but one-fifth of players, confused by game rules, described strategies for keeping or dropping cards that yielded low total astrobucks scores. Revisions to clarify game rules at key points will improve playability and player effort.

⁶ <http://pewinternet.org/Commentary/2012/February/Pew-Internet-Mobile.aspx>

⁷ <http://pewinternet.org/Commentary/2012/February/Pew-Internet-Mobile.aspx>

⁸ <http://blog.flurry.com/bid/92377/The-Gamification-of-Mobile-Games>

⁹ Chicago Museum of Science and Industry (2011). *Digital Media in Everyday Life*, p. 7.

¹⁰ <http://www.tate.org.uk/context-comment/apps/tate-trumps>

¹¹ <http://www.wildlifetrusts.org/news/2011/06/20/new-technology-wildlife-lovers-will-'app'-reciate>

PlanetMania is an engaging game: most children played four rounds of the game. They liked exploring the exhibit with the app, looking for answers to the multiple-choice content questions and playing the subsequent card game in each round. Two-thirds of users thought that using the app made their experience in the exhibit more enjoyable. Successful games provide different possible outcomes. In *PlanetMania*, the 15 quiz questions, three different message statements and a large variety of randomly presented content cards supported the replayability of the game, encouraging visitors to explore the exhibit area; however, the repetitious nature of the five-card game decreased appeal for one-fifth of our participants.

PlanetMania is an educational game. Almost all players felt that using the app helped them learn more from the exhibit than they would without the app, pointing to the quiz and activity of matching cards to message statements. Without a study that includes an exhibit-only control group, we cannot conclude that the app experience makes a significant difference in visitors' learning outcomes, but our interviews before and after exposure to the combination of the app and exhibit reveal that almost all of the participants acquired some new or more sophisticated understanding about astrobiology. Moreover, children frequently specified the game as the source of their new knowledge. Different portions of our sample described new knowledge in each of the following areas: what scientists look for when searching for extraterrestrial life; what kind of life scientists might find on other planets; ways astronomers detect exoplanets; and what extreme places on earth support life. The game statement of "life as we know it needs certain things to survive" and game cards associated with this statement presented information that our age group was already familiar with prior to exhibit and game exposure.

Finally, *PlanetMania* adds value to the museum in that three-quarters of families involved in the evaluation used astrobucks earned through app play to make a purchase at the science center store, averaging about \$19 per family after applying the coupon discount. To put this amount somewhat in perspective, consider that free entertainment games that "monetize" their game by including real as well as virtual purchases earn revenue from in-app purchases in the range of \$9.99 to \$19.99,¹² so the museum store's gain from the *PlanetMania* coupon incentive appears competitive with the world of commercial games.

The interactive quiz and card game format of *PlanetMania* successfully met its goal to make the *Life Beyond Earth* exhibit more accessible, engaging and understandable for upper elementary school visitors. The design of *PlanetMania* is such that the game can be applied to an entirely different exhibit by populating the game with different card content and questions. In this way, *PlanetMania* creates a new opportunity for youth to engage with a variety of museum exhibits, adding value both in terms of deepening exhibit engagement and increasing knowledge. However, these outcomes will only occur if the app is actually downloaded and played by visitors; thus, the next challenge for Maryland Science Center is how to increase awareness and usage of *PlanetMania*.

¹² <http://blog.w3i.com/2013/01/10/the-best-way-to-monetize-your-freemium-game-is/>