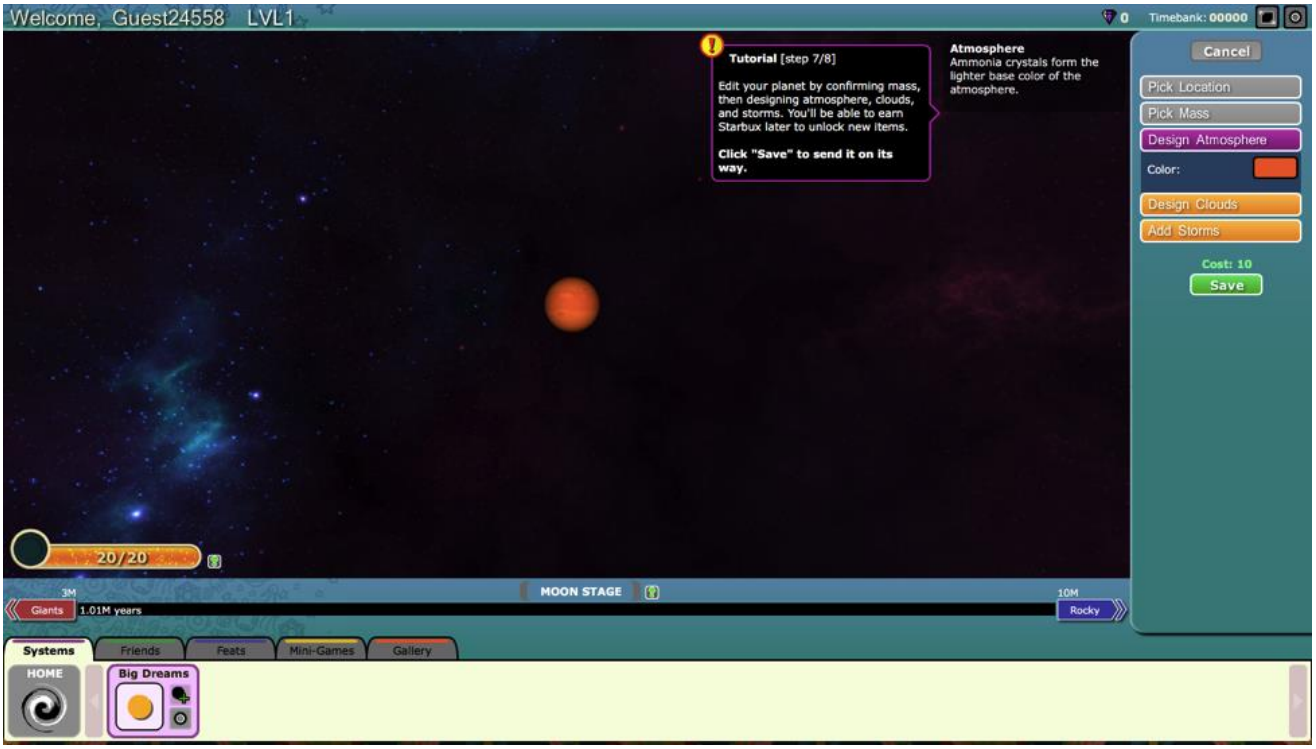

NATIONAL CENTER FOR INTERACTIVE LEARNING

AT THE SPACE SCIENCE INSTITUTE

Expanding the frontiers of knowledge and understanding

Starchitect

NSF- 1010624

Summative Evaluation for Space Science Institute

By

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Executive Summary

The Starchitect project was an exploratory project, designed to better understand the potential of casual sporadic games, both in terms of audience and in terms of learning. Funded by both the National Science Foundation and National Aeronautics and Space Administration in 2010, the Space Science Institute, led by Project Director Dr. James Harold, designed an origins space science game called Starchitect. Unlike most informal science education projects, Starchitect is positioned to connect the general public with space science by going where the public goes -- in this case to Facebook and Google -- rather than holding events, programs, and exhibits where generally only those who are already science-interested will attend.

Starchitect is fairly unique within the science education sphere, despite the fact that there are many other online science games. While there is significant research on gaming and learning, there is relatively little academic or publicly available research on Facebook games, especially sporadic games. (Richards, Stebbins, & Moellering, 2013) Starchitect was one of the first "educational" games within this platform, spurred by the release of the Facebook Developer Platform in May 2007.

The Space Science Institute, and their external evaluator Audience Viewpoints Consulting, studied Starchitect both through game-based data on each and every individual player, and through a much smaller controlled pre-post study designed to measure change in knowledge and interest and gather qualitative data on game play.

In both the larger pool of game-based data and within the controlled study, Starchitect players were more likely to have a high interest in astronomy. Nearly 90% were interested in learning more about space science. Over 90% enjoy learning about new scientific discoveries or inventions. Over 50% said other individuals would describe them as a "science person". Starchitect players were more likely than average Americans to understand basic concepts of origins Space Science prior to playing the game. Still, despite this population being relatively knowledgeable, their knowledge increased during the game, and more than half felt they were learning from the game.

The game not only taught individuals concepts about Space Science, but those that stuck with the game continued to play for extensive periods of time. Of the players who start the game, including those who do not complete the tutorial, over 800 individuals (6%) went on to play for more than five separate days, interacting with more and deeper content. It was this sort of repeated play Starchitect was designed to foster.

Introduction and Project Background

Starchitect is a casual sporadic game centered on origins space science. The game was funded in 2010 by NSF and NASA as part of the Making Space Social grant. Dr. James Harold of Space Science Institute in Boulder Colorado directs the Starchitect project.

Starchitect is fairly unique within the science education sphere, despite the fact that there are many other online science games, and a significant amount of research on gaming and learning. Such research is often presented at the Games, Learning and Society, Games for Change, and Serious Games conferences. Nonetheless, academic or readily accessible research on educational Facebook games, especially sporadic games, is scarce. Starchitect was one of the first "educational" games within this platform, spurred by the release of the Facebook Developer Platform in May 2007.

Unlike most informal science education projects, Starchitect is positioned to connect the general public with space science by going where the public goes (Facebook) rather than holding events, programs, and exhibits where generally only those who are already science-interested will attend. Facebook is an excellent platform for those wishing to reach life-long learners. Studies have shown women over 40 play most often and spend more hours per week playing web-based games than other individuals, including both teenagers and adult males (Heller 2014, Pearce 2008).

Informal science institutions struggle to attract this audience of adults in the mid-to-late age categories; those adults are the main consumers of Facebook games. Older adult gamers tend to be attracted to problem solving, exploration, and communication (even with single-player games) (Pearce, 2008). These populations (online casual gamers) may not see themselves as gamers (Perrin, 2015) though they play with a frequency and at amount of hours that might appear to be more than "casual". (Kuittinen et al, 2007) Perhaps partially due their lack of self-perception as gamers, these populations have also been largely ignored by both the gaming industry and the academic study of gaming. (Takeuchi& Vaala, 2014).

For Starchitect the Space Science Institute contracted with Kate Haley Goldman, recently of Audience Viewpoints Consulting, to complete the evaluation. Ms. Haley Goldman has deep experience in informal science games, and has been with Starchitect since the initial grant proposal.

The Starchitect team developed the following key evaluation questions:

> Does the population who plays *Starchitect* significantly differ from the main Facebook game players? In what ways?

Does *Starchitect* attract individuals who are already interested and engaged in science and science activities?

Within this project and this report, we are using several terms to place Starchitect within the context of gaming. Definitions of what a "real" game is and who is a gamer are currently hotly debated topics (Heller 2014), we will offer the following definitions for the purposes of this report. Following the Mason (2014) writing for Mobile Developer , we will define casual games within the context of Hard-Core and Mid-Core games:

"(1) Hardcore arranges their schedules around their gaming.
(2) Mid-core arranges their gaming around their daily schedule.
(3) Casual entertains self with games when time presents itself."

Perhaps even more central to the nature of Starchitect is the sporadic nature of game play. Starchitect is modeled on other sporadic play Facebook games, where the player initiates an action within the game, and then a certain amount of time must pass before the player can take the next action. In some Facebook games this means planting virtual "crops" and waiting a set period so that you can virtually harvest those crops and earn currency or points. In Starchitect, this means initiating events in the development of a solar system, and then waiting until enough time had passed in order to initiate another event. The benefit of this type of game is that the repeated play interaction over a period of time dovetails well with what we know about successful learning—that multiple interactions with the content over a sustained period of time are more likely to foster learning.

…

Starchitect Game Context

Entry-point

The initial starting point was that Facebook would be the primary point of access for Starchitect. As the project evolved, a component was added for schoolchildren to play Starchitect. This necessitated adding an alternate sign-in mechanism, as only individuals who are 13 years old or older can use Facebook, eliminating some of the target school audience. Currently the game's homepage at starchitect.net offers three play options: signing in through the game's own login system; signing in through Facebook, or playing as a "guest". In this last case the player's ID is stored locally. Extended play is still possible, but only on a single computer.

How individuals hear about the game

Once the Starchitect game was launched, individuals might hear about the game in a variety of ways. Based on email correspondence and spikes in game-playing behavior, some individuals are clearly hearing about the game from their teachers or professors, and are playing as part of an assignment. Unless the teacher contacted the Starchitect team directly, there were no specific way to know they were playing as a class, other than patterns in play and in server traffic. The bulk of individuals were individual learners, with a smaller proportion from schools.

Methodology and Sample

For the purposes of this evaluation, we worked with two primary samples. First, we have population data on everyone who has played during the analysis period. The analysis period was from October 1st, 2014 through midnight September 30th, 2015. Any new users, sessions, feats, or quiz questions answered were not included in the analysis after that period of time. Players that began earlier than October 2014 were eliminated, as individuals who signed up earlier tended to have errors in how their sessions were counted. These "errors" in counting are partially due to the ever-evolving state of the game. This is typical challenge of measuring this sort of game where the game individuals are playing today is not entirely the same game as was being playing last year.

The main data set consists of population data on everyone who began play during the analysis period, and includes only actions taken by those players during that period. If a player began prior to the analysis period, they were not included. If they began during the analysis period but continued on after analysis ended, the full scope of their game play was not included. For some of those individuals, there are gender or age demographics, if they were publicly available through Facebook. If individuals joined in some other sign-in, such as through Google, gender, age, and other demographic data is not available.

The second data set is a study population. In order to measure the impact of the game on the players over time, we recruited individuals to play Starchitect through Facebook and Google ads. These prospective players were then asked to fill out a consent form for participating in the study, asked to complete a pre-survey, and asked to play Starchitect for approximately two months. No particular amount of time or level was specified, simply that players play as they might any other game. At the end of two months, players were asked to complete a web-based post-play survey. If they completed the survey, they received a $40 Amazon gift card. We also attempted to interview all the players who completed both the pre and post surveys.

Game-wide Sample

Where individuals initiated their game play had an enormous impact on how much information we have about them. Just over half of the players used Facebook as an entry-point for Starchitect. The other players came through Google or through a direct link.

Table 1: Where Players Found Out about Starchitect

	Percent	n
Facebook	53.0%	7,193
Google	41.4%	5,623
Other	5.5%	751

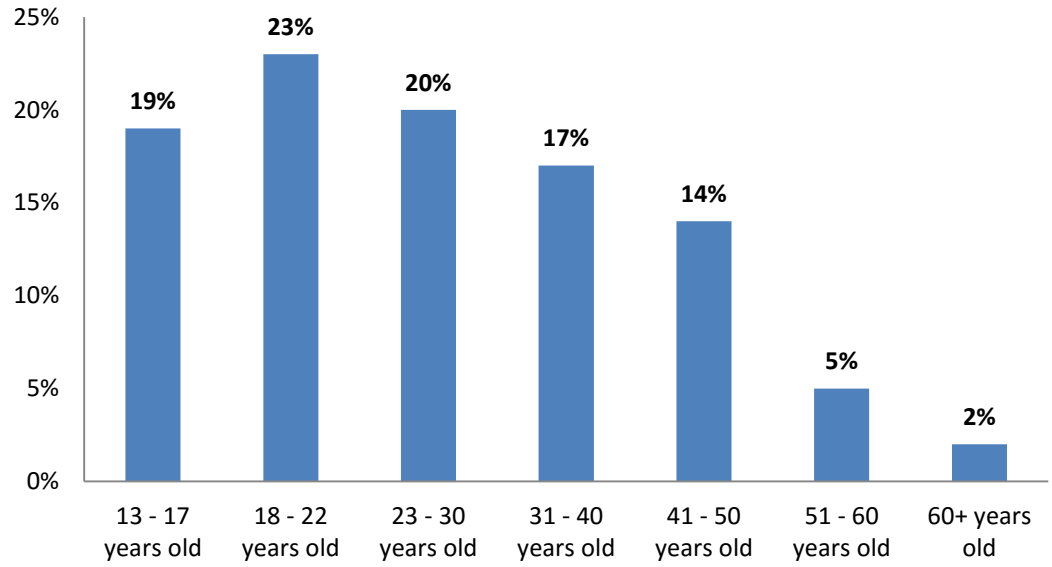
If individuals joined for game play outside of Facebook, such as through Google, we do not have any demographic data. In addition, some individuals choose not to provide their age-related data through Facebook. Or, they could be choosing to lie about their age, for example in the case of children who wish to join Facebook before they are old enough (13 years old) to legally be allowed to join. In total, age data (however accurate it is) is available for just under 20% of the players.

Table 2: Age Provided Game-Wide

	Percent	n
Age provided	19.7%	2,678
No age provided	80.3%	10,889

Looking at only the 20% of game players that provided age-related information within their Facebook profile, just under one-fifth (18.6%) were under 18 years old. (See) Another 23% were young adults aged 18 to 22 years old. All in all, 62% of all game players who provided data were age 30 or under. While this suggests the game was mainly played by younger individuals, in practice it is difficult to determine. It is possible that individuals who don't give age-based data on Facebook, or who play games through Google, are disproportionally likely to be older than those that do give age-related information.

Figure 1: Age Game-Wide



As a point of comparison, in the United States 67% of individuals aged 18 to 29 play video games, 58% of adults aged 30-49, 40% of individuals aged 50-64. One quarter of those individuals aged 65 or older play video games. See Figure 2 below.

Figure 2: Demographics of Americans who Play Video Games
Source: Pew Internet and the American Life

Demographics of those who play video games

% of all adults who play video games on a computer, TV, game console, or portable device like a cellphone

	Play video games
Total	*49%*
Men	50
Women	48
White, non-Hispanic	48
Black, non-Hispanic	53
Hispanic	51
18-29	67
30-49	58
50-64	40
65+	25
Less than high school	40
High school graduate	48
Some college	55
College+	47
<$30,000/year	46
$30,000-$49,999	54
$50,000-$74,999	53
$75,000+	52
Urban	52
Suburban	48
Rural	45

Source: Survey conducted June 10 – July 12, 2015.

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Table 3: Gender provided Game-wide

	Percent	n
Gender provided	45.7%	6,198
No gender provided	54.3%	7,369

Game players tended to be male in both the controlled study and in the larger game population, 50% of all men play video games, and 48% of all women. As over 50% of the individuals did not elect to provide gender in their Facebook profile, there is no certainty of the gender proportions of players. There is some research that indicates females may be more likely to hide their gender, at least in gaming environments. (Luu 2015 and Yee 2008).

Of the gender data available, nearly 30% of the game players were female.

Table 4: Gender Game-wide

	Percent	n
Male	70.8%	4,392
Female	29.1%	1,806

Differences between those that played the game and the American Public

In order to gauge the level of scientific understanding of the players, we asked a number of questions, as players began to play. One set of those questions wasS drawn from General Social Survey conducted by the National Opinion Research Center. These questions were designed by the National Center for Science and Engineering Statistics to study public understanding of science, specifically within the physical and biological sciences. These nine questions were mostly true-false. In each case, the Starchitect players had substantially more correct answers than the general public, even before they began to play.

Table 5: Starchitect Players are More Knowledgeable about Science than the General Public

	Starchitect Players Before Playing	General public*
The continents on which we live have been moving their locations for millions of years and will continue to move in the future [True]	97%	83%
Does the Earth go around the Sun, or does the Sun go around the Earth? [Earth around Sun]	97%	74%
All radioactivity is man-made [False]	89%	72%
It is the father's gene that decides whether the baby is a boy or a girl. [True]	67%	63%

Electrons are smaller than atoms [True]	83%	53%
Antibiotics kill viruses as well as bacteria [False]	60%	51%
Human beings, as we know them today, developed from earlier species of animals [True]	85%	48%
Lasers work by focusing sound waves [False]	79%	47%
The universe began with a huge explosion [True]	92%	39%

*Source: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Public Attitudes Toward and Understanding of Science and Technology, Appendix Table 7-9, 2014

A second set of questions focused specifically on astronomy misconceptions. We drew a series of these misconceptions from a study by LoPresro and Murrell, focusing on questions that were addressed within the game. Within this knowledge sub-domain, people who choose to play Starchitect were still more knowledgeable than the average college student, though multiple questions had less than one-third of the players responding correctly.

Table 6: Astronomy Misconceptions

	Starchitect Players Before Playing	**College Students Before Astronomy Class**
Which is a possible color for a star? a. red b. white c. blue d. yellow e. [more than one of the above] CORRECT	68%	68%
Astrology is: a. basically the same as astronomy b. a science related to astronomy c. not the same as astronomy CORRECT	60%	45%
Which statement is true: a. The Sun is a star that is close up. b. The stars are suns that are far away. c. [actually both are true] CORRECT d. [both a and b above are NOT true]	47%	43%
Astronauts in orbit are: a. apparently weightless because they are in free fall CORRECT b. apparently weightless because they are in a vacuum c. truly weightless because they are in a vacuum d. truly weightless because there is no gravity in space e. [both c and d above]	33%	15%
What causes the phases of the Moon? a. the Moon's shadow on Earth b. Earth's shadow on the Moon c. the Sun and Earth's shadows on the Moon d. [none of the above—no shadows are involved	31%	12%

CORRECT		
On Earth, what causes summer to be hotter than winter? a. the Earth is closer to the Sun in summer b. the daylight period is longer in summer c. the Sun gets higher in the sky in summer d. [both b and c above] CORRECT e. [all of the above]	29%	18%

Source: LoPresto and Murrell (2011) An Astronomical Misconceptions Survey, Journal of College Science Teaching, Vol 40, Number 5, pgs 14-22.

As a project team, we were curious what portion of our player population would be knowledgeable about current science news and pop science. We created a short survey designed to cover a range of science topics that might be found in the news including questions on astronomy, but also human evolution, biology, mathematics, computer science, biology, and biochemistry. A few questions were more about pop culture than science, but indicated an interest in science fiction and science fan culture. Starchitect players showed a range in their knowledge, with a lower number of questions correct in this category of current science, than in the more official test NSF test of knowledge.

Table 7: Current Science in the News/Pop Culture

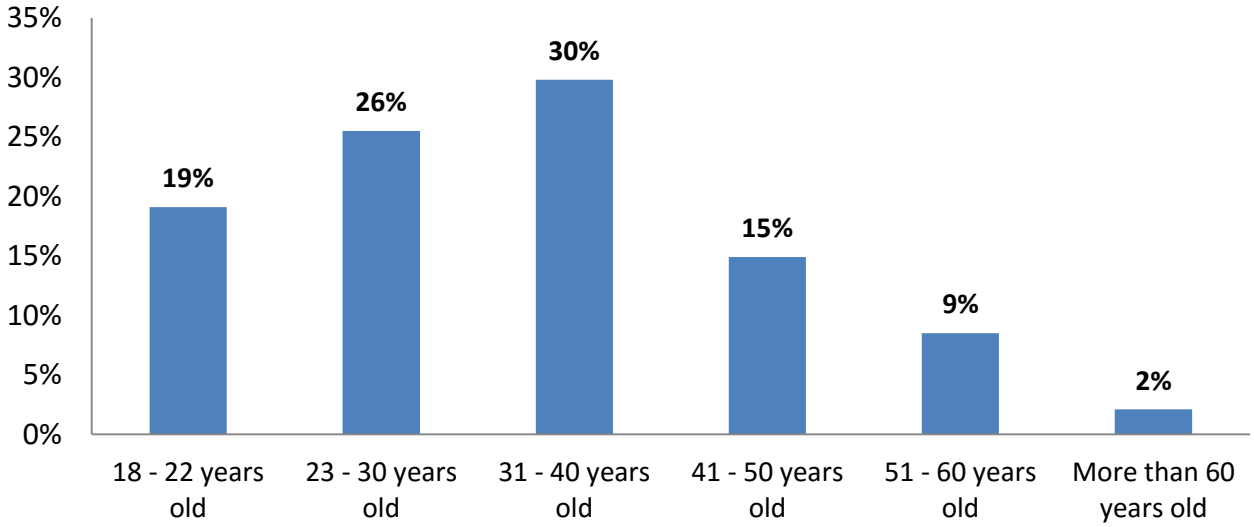
	Starchitect Players Percent Correct
Lucy was the name of what type of skeleton?	81%
SETI refers to:	74%
What is "GMO"?	70%
Which of these is a Mars rover?	67%
When is Pi day?	62%
Where can you find sulfur-based lifeforms?	60%
What does the "Turing Test" refer to?	51%
What is known as the "God Particle"?	51%
Who shot first?	44%
The Rosetta spacecraft recently visited:	44%
What did Rachel Carson get outlawed?	37%
What does "Arduino" refer to?	34%
HeLa cells are named after:	16%

Answers: a human ancestor, an ancient early human; The Search for Extraterrestrial Intelligence Project; Genetically Modified Organism, Curosity, March 14th; deep sea hydrothermal vents or hot springs; artificial intelligence test; Higgs Boson; Han Solo; a comet (Comet 67P); DDT; Microcontroller; Henrietta Lacks.

Sample: Controlled Study

Within the smaller controlled study on the impact of Starchitect, there was direct contact with the individuals playing, so full age and gender data is available. In order to facilitate consent issues associated with human subjects review, the controlled study was limited to adults, so the age categories are slightly different than within the larger gaming population. Just under half of the individuals within the controlled study were age 30 and under. Over a quarter of individuals in the controlled study were over age 40. (See **Figure 3**)

Figure 3: Age Controlled Study



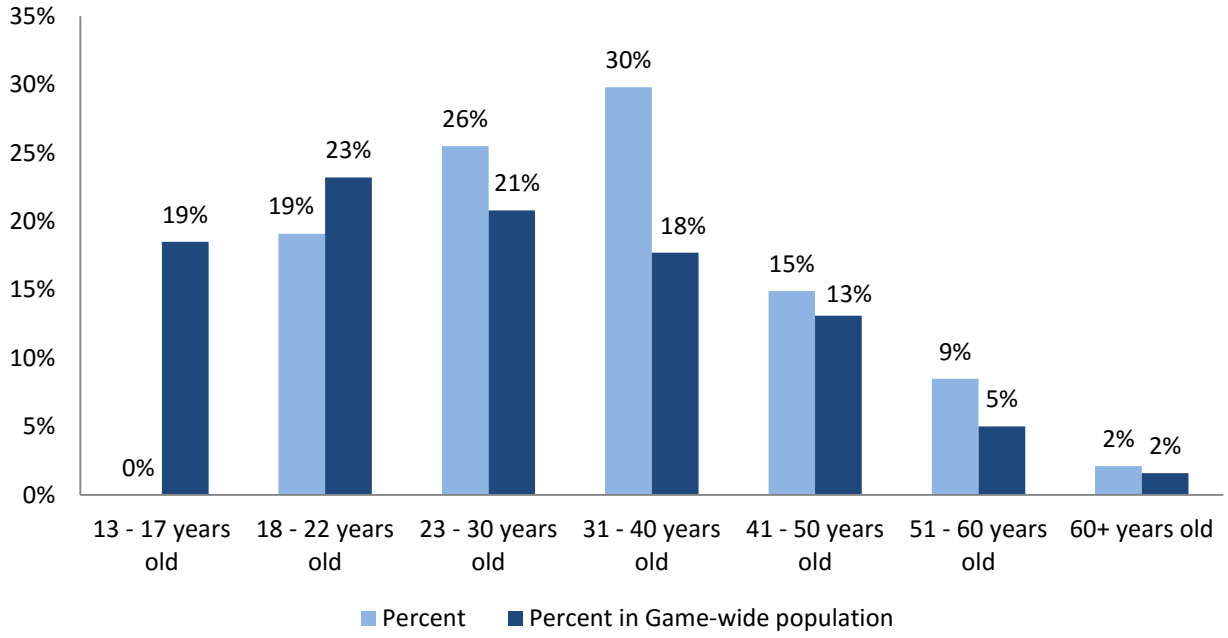
Partially due to the fact that only adults were allowed within the controlled study, the age of players varied considerably between the game-wide population and within the controlled study (**Table 8**).

Table 8: Controlled Study had Older Players

	Percent in Controlled Study	Percent in Game-Wide population
13 - 17 years old	0%	18.5%
18 - 22 years old	19.1%	23.2%
23 - 30 years old	25.5%	20.8%
31 - 40 years old	29.8%	17.7%
41 - 50 years old	14.9%	13.1%
51 - 60 years old	8.5%	5.0%
60+ years old	2.1%	1.6%

Note: Age data is only available on 20% of the game-wide population

Figure 4: Age Comparison



The controlled study population tended to skew older than the larger game-wide population (**Figure 5**).

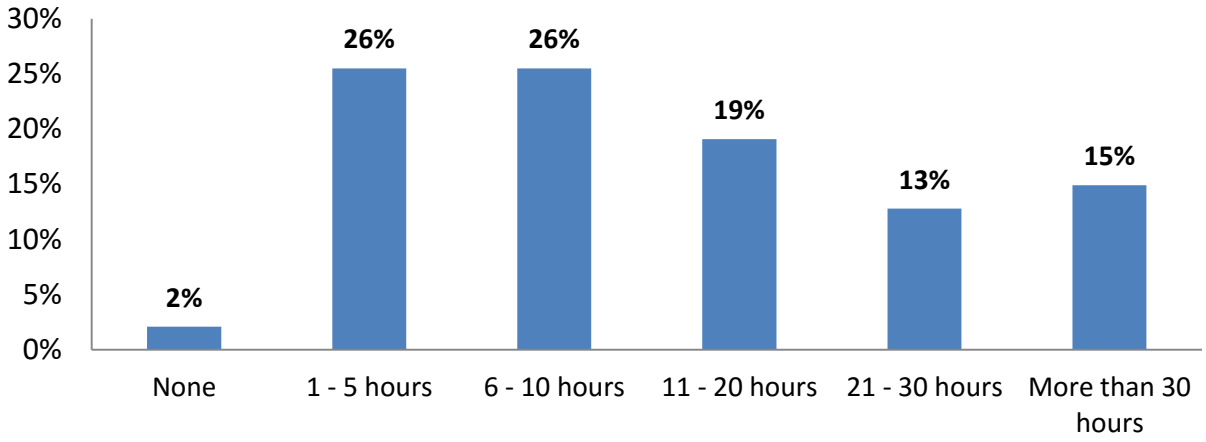
Within the controlled study, two-thirds of players were male.

Table 9: Gender- Controlled Study

	Percent	n
Male	66.0%	31
Female	29.8%	14
Transgender	4.3%	2

Our study population was ideal in some other respects, as these individuals tended to spent a considerable portion of time playing games. Over one-quarter (28%) spent more than 20 hours a week playing games, and 73% of those in the study population spent at least 6 hours a week playing games.

Figure 5: Hours Spent Gaming per Week



In other respects, the study population was not our target audience of casual game players. Slightly less than half of the individuals regularly played casual games, with more individuals playing role-playing games, story-based games, or puzzle games.

Table 10: Study Population was not the Typical Casual Sporadic Game-Player

	Percent	n
Role-Playing Games	55.3%	26
Story-Based Games	48.9%	23
Puzzle Games	46.8%	22
Casual Games	44.7%	21
Other	34.0%	16

What was the nature of game play?

Casual game play is characterized by a high drop-off rate in initial play, followed by a long period of continued play by a smaller proportion of individuals. Some of the players who continue to play, play intermittently over a sustained period of time, encapsulating the phenomenon known as the "long tail". Starchitect is no different, as just over 80% of individuals play Starchitect once. However, within that single play, approximately 6% of individuals play for more than one session, meaning they played more than 30 minutes during that first and only session.

Table 11: 20% Play More Than Once

	Percent	n
Drop out after first time playing	72.0%	9,762
Only play one time, but play	6.3%	658

multiple sessions		

In a traditional computer game, key metrics would include how often the individual played and how long the average gaming session lasted. Games that are intended to be played once track how long the individual plays for that one session. For a sporadic game, there are limits on how long an individual can play in any one session, as the game is explicitly designed to span multiple sessions and to encourage an individual to return to play. Large gaming corporations who design sporadic games spend significant effort testing various elements of game appeal to determine how to prolong individual game play over multiple sessions , looking at appeal of type of content, player ability to understand the game, and timing the game play conveniently for individual return.

Time is difficult to measure in online gaming, as games can be running on a background browser as players multi-task with little to no interaction from the individual. For the purposes of this study, we defined time through "sessions". Each session is a play session of continuous minutes during when game activity occurred. indeterminate length, meant to measure how often you initiate play with the game. A session will time out atafter 30 minutes, so if of inactivity. While in many games, long play in a player is inactive for 30min, then comes back to it, they will be starting their second session. So a single session reflects how many times did may be a marker of success, for casual sporadic games, how often you engage with the game is a player interacts with the game. This metric is designed to capture repeated play over time.

Table 12: Number of Sessions Played

	Percent	n
1 session	72.0%	9762
2 – 10 sessions	22.5%	3052
11 – 50 sessions	4.0%	549
51 – 100 sessions	1.0%	139
More than 100 sessions	0.5%	65

Ten sessions could have been played over the course of a single day, or spread out over days and even months.

Table 13: Sessions and Days

	1 day played	2 days played	3 days played	4 days played	5 days played	More than 5 days played	Total
1 session	9,762	0	0	0	0	0	9,762
2 – 10 sessions	646	1,483	492	204	113	114	3,052
11 – 50 sessions	0	1	12	17	33	486	549
51 – 100 sessions	0	0	0	0	0	139	139
More than 100 sessions	0	0	0	0	0	65	65
Total	10,408	1,484	504	221	146	804	13,567

Figure 6 Sessions and Days

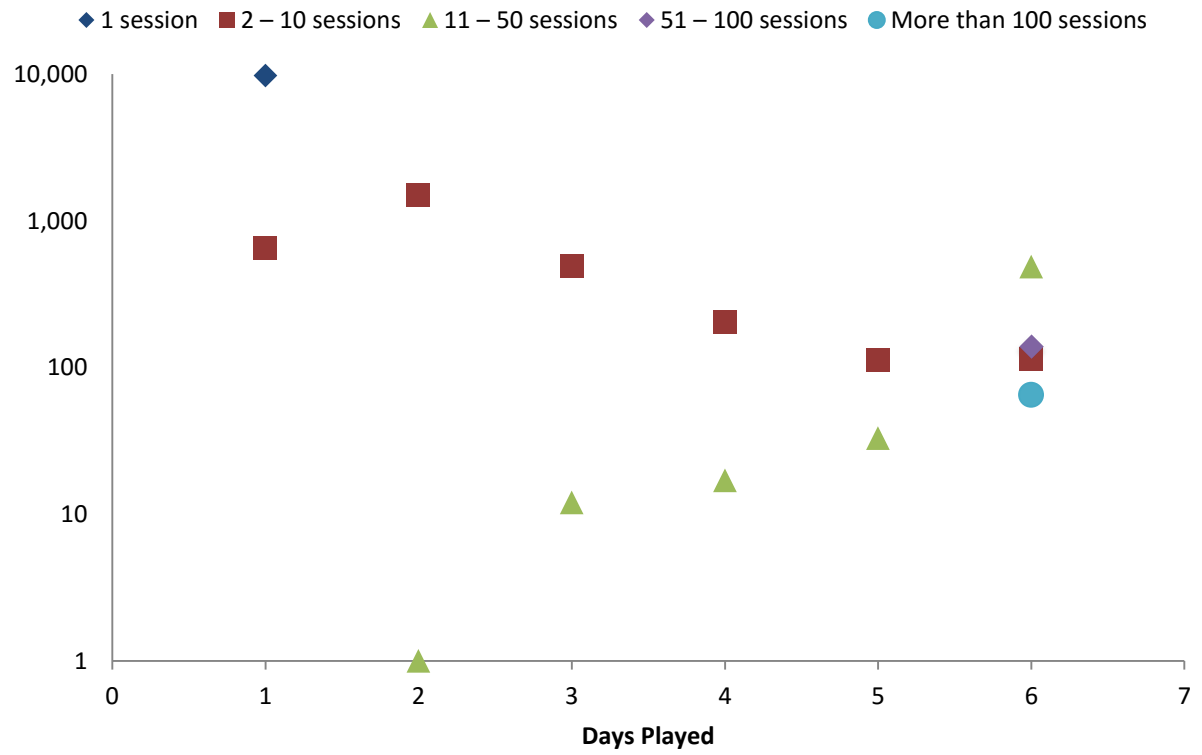
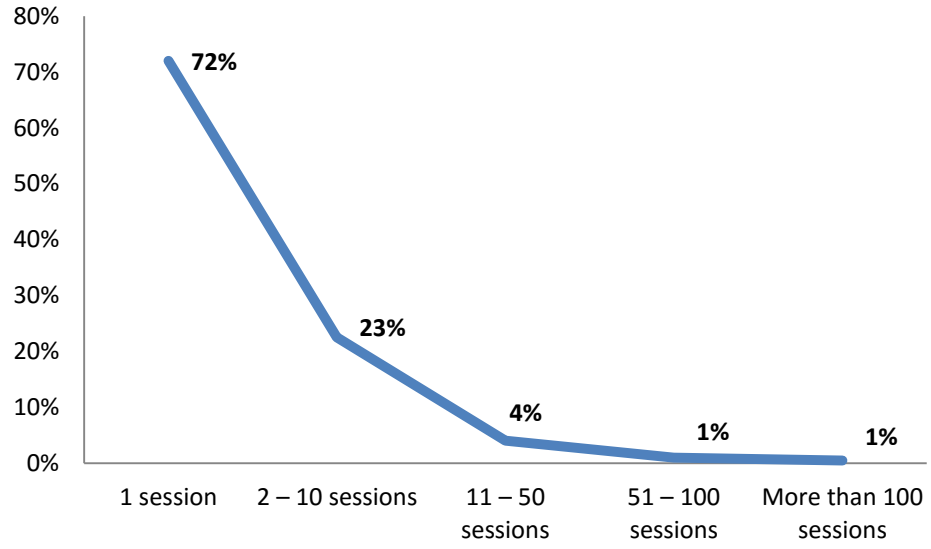


Figure 7: Number of Sessions Played

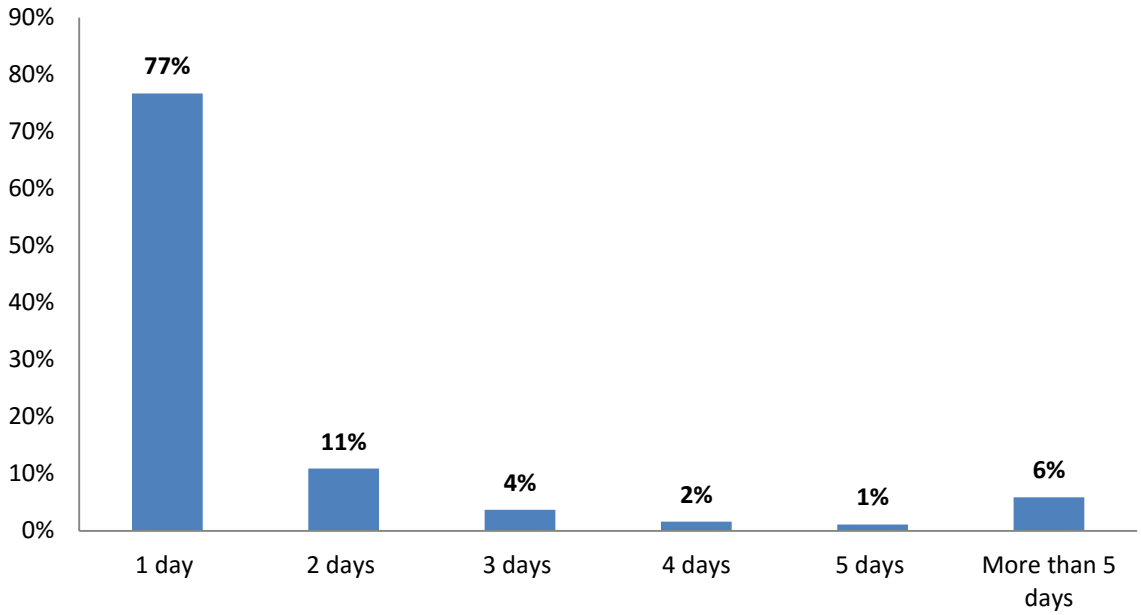


The data above is echoed by an analysis of the number of days an individual played. The caveat here is that the day is measured according to time in Colorado, where the Starchitect servers are based. It is conceivable that someone playing on the East Coast of the United States may have played up both prior to and after midnight East Coast time, and have that counted as a single day with the game database. Based on that information, roughly 74% of the individuals played for a single day, with the amount playing dropping off each day significantly, to 11% on the second day, 4% on the third day and 1% by Day 5. The long tail is apparent in those that play far more than 5 days. Nearly 8% of the individuals who played during our analysis played more than 8 days.

Table 14: Number of Days Played

	Percent	n
1 day played	76.7%	10408
2 days played	10.9%	1484
3 days played	3.7%	504
4 days played	1.6%	221
5 days played	1.1%	146
More than 5 days played	5.9%	804

Figure 8: Number of Days Played

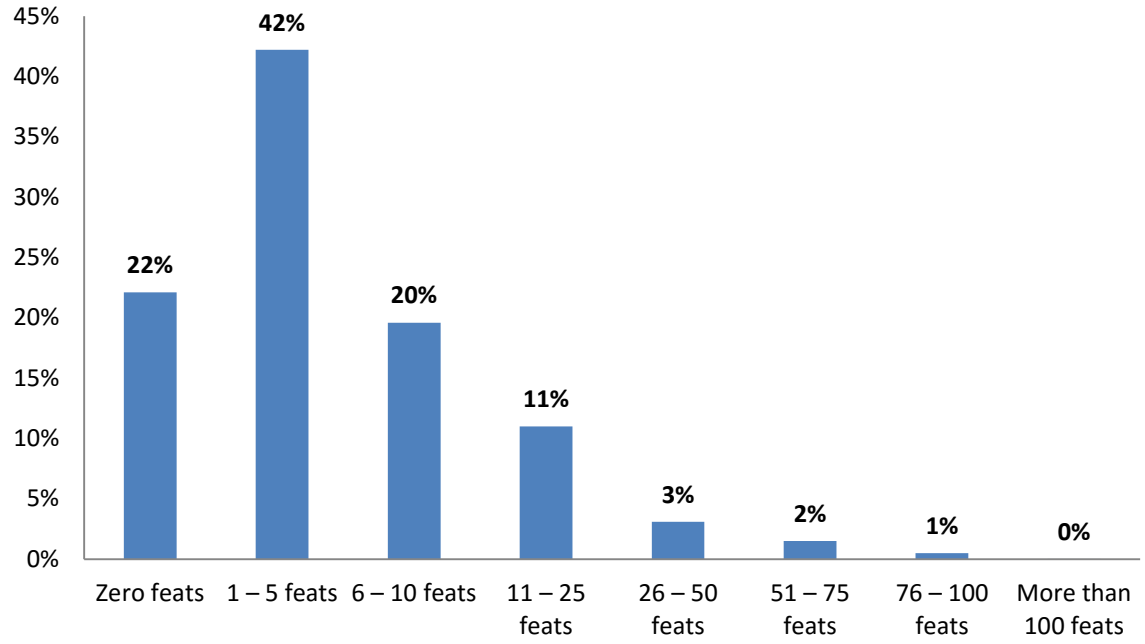


Feats are challenges within the game that need to be successfully completed order for the player to progress through the game. They are tied to the achievement of certain levels within the game, though not on a one-to-one basis. As in many casual games, feats that planned to occur early within the game play are often accumulated more rapidly, in order to give individuals momentum and motivation to continue. We can see this play out below, as over 30% of those that played achieved 6 or more feats.

Table 15: Number of Feats

	Percent	n
Zero feats	22.1%	2,994
1 – 5 feats	42.2%	5,723
6 – 10 feats	19.6%	2,654
11 – 25 feats	11.0%	1,499
26 – 50 feats	3.1%	426
51 – 75 feats	1.5%	199
76 – 100 feats	0.5%	70
More than 100 feats	0.01%	2

Figure 9: Number of Feats



Just a slim portion of those that played reached the very top levels, defined at the time as more than 25 levels.

Table 16: Number of Levels Played

	Percent	n
1 level	35.9%	4,865
2 – 5 levels	55.1%	7,477
6 – 10 levels	5.1%	697
11 – 25 levels	3.4%	462
More than 25 levels	0.5%	66

Figure 10: Number of Levels Played

Within Starchitect, the team placed questions to be answered by the players. The questions were pop-ups that occurred occasionally during game play, and players were allowed to close the pop-up without answering. While from a data perspective, it would have been better to require players to answer, we decided we would prefer that individuals who did not want to answer questions continued to play rather than stop playing. Players who played longer or more often would naturally encounter more questions. Most players only answered 1 or 2 questions, but following the curve of the

amount of play, there is a long tail, in that 3% of the players answered more than 15 questions. (See **Table 17**.) Specific questions were considered "triggered" questions, defined as questions linked to specific content which reaching that point in Starchitect might teach. For example, a question about what elements impact whether life would evolve on a planet, some individuals were asked prior to encountering that phase of the game, and others were asked after encountering that phase of the game.

Table 17: Number of Questions Answered

	Percent	Players
0-1 questions answered	89.8%	12,189
2-5 questions answered	5.5%	743
6-10 questions answered	1.4%	191
11-15 questions answered	0.7%	93
More than 15 questions answered	2.6%	351

When looking at who was accurate about the questions they were asked, nearly 40% of the individuals were accurate 90% or more of the time. No doubt this number is large partially because most individuals only answered one question, nonetheless, these players stand out as an space-educated audience.

Table 18: Percentage of Correct Answers

	Percent of Individuals	
0%-25% correct	19.8%	472
26%-50% correct	14.7%	349
51%-75% correct	19.1%	454
76%-90% correct	7.2%	172
More than 90% correct	39.2%	934

Despite the fact that most players were previously quite knowledgeable in science, we did see an overall change in amount of correct answers from those that were asked about a topic prior to encountering it in the game, and those that were asked about a topic after encountering it in the game. The amount of change in correct answers varied by question, and was not concentrated within one phase of the game but spread across the different points in time throughout Starchitect. (See **Table 19**.)

Table 19: Change in Correct Answers Over Time

	Percentage of Correct - Pre	Percentage of Correct -Post	Difference
A planet is more likely to be habitable if it is:	85%	91%	6%

a. close to its star b. far from its star not too close, but not too far c. the distance from the star doesn't matter that much			
What factors can influence how rings look? a. the size of the moon that formed them b. whether there are moons outside the rings c. the age of the rings d. all of the above	72%	76%	4%
Which is a possible color for a star? a. red b. white c. blue d. yellow e. [more than one of the above] CORRECT	68%	85%	17%
What can prevent a moon from forming? a. being too close to the planet so that it never forms b. being too far from the planet to stay in orbit c. being too close to another moon so that d. one orbit becomes unstable e. all of the above	66%	83%	18%
What elements influence whether life evolves on a planet? a. the planet's size b. the planet's distance from the star c. the age of the solar system d. all of the above	57%	80%	23%
Which statement is true: a. high mass stars live longer b. how long stars live doesn't depend on c. their mass (but they do die eventually) d. stars live forever	47%	53%	6%
For giant planets, which of these can influence the appearance (colors, banding) of the planet: a. the planet's distance from the star b. the planet's size c. both a planet's distance from the star and d. the planet's size e. none of the above	47%	65%	18%
Which stars are the hottest? a. high mass stars b. low mass stars c. the temperatures of stars varies, but it doesn't depend on the mass d. all stars are about the same temperature	45%	52%	7%
If you were looking for life in other solar	36%	35%	-1%

systems, would it be better to look for: a. low mass stars b. high mass stars c. either low mass or high mass stars would do d. it doesn't matter, life is unique to Earth			
Which is likely to take longest for a habitable world? a. the time from the start of the solar system to the formation of the planet b. the time between formation of the planet and the first simple single-cell life c. the time between the first simple-cell life and early multi-cell life d. the time between early multi-cell life and intelligent life	18%	17%	-1%

FINDINGS: Controlled Study

As the nature of the project made it difficult to have a truly controlled pre-post examination of the data, we conducted a more controlled study with recruited individuals. This allowed us to examine how game play might impact the larger populations' interest in and knowledge of space science.

Science Confidence

The initial questionnaire showed a high sense of confidence with some aspects of science. Nearly 90% of individuals felt they were good at understanding science topics, with nearly 40% strongly agreeing. Over 80% felt they were more likely to quickly understand new science topics compared to others their age. Participants were far less confident in their ability to explain science topics to others, with only 6% strongly agreeing that they were confident in this area, and over a quarter neutral in this area.

Table 20: Science Confidence- Pre-Questionnaire

(n=47)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think I'm pretty good at understanding science topics.	0.0%	0.0%	10.6%	51.1%	38.3%
Compared to other people my age, I think I can quickly understand new science topics.	0.0%	0.0%	17.0%	46.8%	36.2%

I feel confident in my ability to explain science topics to others.	0.0%	8.5%	25.5%	59.6%	6.4%
It takes me a long time to understand new science topics.	36.2%	53.2%	4.3%	6.4%	0.0%

Table 21: Science Confidence – Post-Questionnaire

(n=44)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Compared to other people my age, I think I can quickly understand new science topics.	0.0%	2.8%	9.1%	54.5%	34.1%
I think I'm pretty good at understanding science topics.	0.0%	4.5%	6.8%	61.2%	27.3%
I feel confident in my ability to explain science topics to others.	0.0%	11.4%	27.3%	38.6%	22.7%
It takes me a long time to understand new science topics.	34.1%	47.7%	11.4%	6.8%	0.0%

There were no statistically significant differences in science confidence for the individuals within the controlled study prior to playing Starchitect, and after playing for two months. Science confidence is a fairly stable construct, and it evolves over time, it is not unsurprising that game play alone does not change identity. As the initial ratings were quite high for science identity, change is more difficult to detect (ceiling effect).

Our study population was strongly interested in science prior to playing Starchitect. Nearly 90% were interested in learning more about space science. Over 90% enjoy learning about new scientific discoveries or inventions. Over 50% said other individuals would describe them as a "science person".

Table 22: Interest in Science – Pre-Questionnaire

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I want to learn more about space science topics.	0.0%	0.0%	10.6%	44.7%	44.7%
I enjoy learning about new scientific discoveries	0.0%	2.2%	6.4%	51.1%	40.4%

or inventions.					
I like to star watch.	0.0%	8.5%	12.8%	38.3%	40.4%
I want to understand how a scientific process works (e.g. how stars are formed, what causes solar flares.)	0.0%	4.3%	6.4%	55.3%	34.0%
I am interested in learning more about the physical sciences (chemistry, physics, and geology).	4.3%	4.3%	14.9%	44.7%	31.9%
I enjoy reading about science-related topics.	2.1%	2.1%	6.4%	51.1%	38.3%
I like to engage in science-related hobbies in my free time.	0.0%	4.3%	29.8%	44.7%	21.3%
I enjoy talking about science topics with others.	2.1%	2.1%	27.7%	42.6%	25.5%
Other people would describe me as a "science person."	4.3%	14.9%	27.7%	29.8%	23.4%
I often visit science-related web sites.	2.1%	10.6%	27.7%	44.7%	14.9%
I enjoy looking at information presented in scientific tables and graphs.	2.1%	8.5%	25.5%	55.3%	8.5%

Table 23: Interest in Science – Post-Questionnaire

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I want to learn more about space science topics.	0.0%	0.0%	4.5%	50.0%	45.5%
I enjoy learning about new scientific discoveries or inventions.	0.0%	2.3%	4.5%	45.5%	47.7%
I like to star watch.	0.0%	4.5%	22.7%	36.4%	36.4%
I want to understand how a scientific process works (e.g. how stars are formed, what causes solar flares.)	0.0%	2.3%	6.8%	59.1%	31.8%
I am interested in	2.3%	9.1%	9.1%	52.3%	27.3%

learning more about the physical sciences (chemistry, physics, and geology).					
I enjoy reading about science-related topics.	2.3%	0.0%	13.6%	45.5%	38.6%
I like to engage in science-related hobbies in my free time.	0.0%	6.8%	22.7%	43.2%	27.3%
I enjoy talking about science topics with others.	2.3%	2.3%	22.7%	50.0%	22.7%
Other people would describe me as a "science person."	4.5%	13.6%	25.0%	29.5%	27.3%
I often visit science-related web sites.	2.3%	11.4%	31.8%	31.8%	22.7%
I enjoy looking at information presented in scientific tables and graphs.	2.3%	4.5%	29.5%	43.2%	20.5%

No Change in Astronomy Interest

Individuals were not just interested in science, but were highly interested in astronomy specifically. On a scale of 1 to 7, with 7 representing being extremely interested in astronomy, the median score for both the pre and post questionnaire was 6. No one, before or after playing the game rated themselves below a 3 on the 7-point scale. This high initial score may have contributed to the reason that interest in astronomy did not change during play of Starchitect.

Table 24: No Change in Interest in Astronomy

	1 - I'm not at all interested in Astronomy	**2**	**3**	**4**	**5**	**6**	**7 - I'm extremely interested in Astronomy**
Pre-questionnaire (n=47)	0% (0)	0% (0)	6.4% (3)	10.6% (5)	25.5% (12)	21.3% (10)	36.2% (17)
Post-questionnaire (n=44)	0% (0)	0% (0)	6.8% (3)	11.4% (5)	11.4% (5)	31.8% (14)	38.6% (17)

Table 25: Interest in Astronomy- Median

	Mean	Median
Pre-questionnaire	5.70	6
Post-questionnaire	5.84	6

Self-perception of Knowledge

While individuals felt they were highly interested, they were less confident in their knowledge. Only 6% rated themselves as extremely knowledgeable in the pre-questionnaire, and 0% did so in the post. The median score was 4.

During play of Starchitect, self-perception of astronomy knowledge of astronomy did not change. On the scale of 1 to 7, approximately 36% of the study participants rated themselves above neutral (4) in astronomy knowledge, and approximately 38% did so in the post-play questionnaire. There was no significant differences between pre and post.

Table 26: Knowledge of Astronomy

	1 - I don't know anything about Astronomy	2	3	4	5	6	7 - I'm extremely knowledgeable about Astronomy
Pre-questionnaire (n=47)	0.0% (0)	8.5% (4)	21.3 % (10)	31.9 % (15)	19.1 % (9)	12.8 % (6)	6.4% (3)
Post-questionnaire (n=33)	0.0% (0)	6.8% (3)	9.1% (4)	45.5 % (20)	25.0 % (11)	13.6 % (6)	0.0% (0)

Table 27: Knowledge of Astronomy

	Mean	Median
Pre-questionnaire	4.26	4
Post-questionnaire	4.30	4

Measured Knowledge

Many of the individuals within our study would have passed an Astronomy Quiz prior to playing the game. Over one quarter had correct answers 75% of the time or greater. This score increased significantly in the post-play questionnaire, were nearly half of the individuals had a 75% or more of the questions correct.

Table 28: Astronomy Misconceptions – Percentage of Questions Correct

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
0% - 25% correct	0.0%	0.0%
25.1% - 50% correct	19.1%	4.5%
50.1% - 75% correct	53.2%	52.3%
75.1% - 99.9% correct	25.5%	40.9%
100% correct	2.1%	2.3%

These questions are listed in descending order of number of post-questionnaire respondents who got the answer correct. So the first question was answered correct by the highest percentage of people (therefore it's the easiest question), the second question was answered by the second highest percentage of people, until the last table, which was answered correctly by the smallest number of people. The correct answer is always listed first in the shaded box.

Table 29: A planet is more likely to be habitable if it is:

	Pre-questionnaire Percent (n=47)	Post-questionnaire Percent (n=44)
not too close, but not too far	95.7%	100.0%
the distance from the star doesn't matter that much	2.1%	0.0%
close to its star	2.1%	0.0%
far from its star	0.0%	0.0%

Table 30: What can prevent a moon from forming?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
all of the answers below	97.9%	100.0%
being too close to the planet so that it never forms	2.1%	0.0%
being too far from the planet to stay	0.0%	0.0%

in orbit		
being too close to another moon so that one orbit becomes unstable	0.0%	0.0%

Table 31: Which is the possible color for a star?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
more than one of the answers below	100.0%	97.7%
White	0.0%	2.3%
Red	0.0%	0.0%
Yellow	0.0%	0.0%
Blue	0.0%	0.0%

Table 32: What elements influence whether life evolves on a planet?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
all of the answers below	83.0%	93.2%
the planet's distance from the star	17.0%	6.8%
the planet's size	0.0%	0.0%
the age of the solar system	0.0%	0.0%

Table 33: What factors can influence how rings look?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
all of the answers below	91.5%	90.9%
the size of the moon that formed them	4.3%	4.5%
whether there are moons outside the rings	2.1%	2.3%
the age of the rings	2.1%	2.3%

Table 34: Astrology is:

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
not the same as astronomy	78.7%	88.6%
a science related to astronomy	19.1%	11.4%
basically the same as astronomy	2.1%	0.0%

Table 35: Which stars are the hottest?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
high mass stars	59.6%	77.3%
the temperatures of stars varies, but it doesn't depend on the mass	39.8%	20.5%
low mass stars	8.5%	2.3%
all stars are about the same temperature	2.1%	0.0%

Table 36: Which statement is true?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
low mass stars live longer	63.8%	75.0%
high mass stars live longer	19.1%	11.4%
how long stars live doesn't depend on their mass (but they do die eventually)	17.0%	13.6%
Live forever	0.0%	0.0%

Table 37: For giant planets, which of these can influence the appearance of the planet?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
both a planet's distance from the star and the planet's size	61.7%	72.7%
none of the above	31.9%	25.0%
the planet's size	4.3%	2.3%
the planet's distance from the star	2.1%	0.0%

Table 38: Comparing two star systems, one with a high mass star and one with a low mass star, where would you expect to find habitable worlds?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
closer to the low mass star than the high mass star	68.1%	68.2%
habitable worlds are equally likely to be found anywhere in a solar system	12.8%	18.2%
about the same distance from both	6.4%	2.3%

high and low mass stars		
closer to the high mass star than the low mass star	12.8%	11.4%

Table 39: Astronauts in orbit are:

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
apparently weightless because they are in free fall	46.8%	63.6%
both truly weightless because they are in a vacuum and because there is no gravity in space	6.4%	4.5%
truly weightless because there is no gravity in space	23.4%	13.6%
apparently weightless because they are in a vacuum	6.4%	2.3%
truly weightless because they are in a vacuum	17.0%	15.9%

Table 40: On Earth, what causes summer to be hotter than winter?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
both the daylight period is longer and the Sun is higher in the sky in summer	46.8%	59.1%
all of the other answers	21.3%	31.8%
the Earth is closer to the Sun in summer	17.0%	9.1%
the daylight period is longer in summer	10.6%	0.0%
the Sun gets higher in the sky in summer	4.3%	0.0%

Table 41: If you were looking for life in other solar systems, it would be better to look for…

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
low mass stars	46.8%	56.8%
either low mass or high mass stars would do	42.6%	34.1%
high mass stars	6.4%	6.8%

it doesn't matter, life is unique to Earth	4.3%	2.3%

Table 42: **What causes the phases of the moon?**

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
none of the below—no shadows are involved	31.9%	38.6%
Earth's shadow on the Moon	55.3%	50.0%
the Sun and Earth's shadows on the Moon	8.5%	9.1%
the Moon's shadow on Earth	4.3%	2.3%

Table 43: Which stage of the four below is likely to take the longest for a habitable world?

	Pre-Questionnaire Percent (n=47)	Post-Questionnaire Percent (n=44)
the time between the first simple-cell life and early multi-cell life	10.6%	2.3%
the time between formation of the planet and the first simple single-cell life	53.2%	54.5%
the time from the start of the solar system to the formation of the planet	23.4%	27.3%
the time between early multi-cell life and intelligent life	12.8%	15.9%

Learned from the Game

Table 44: 64% Learned New Things about Space Science

1 – I learned nothing new about Space Science	**2**	**3**	**4**	**5**	**6**	**7 – I learned many new things about Space Science**
0% (0)	4.5% (2)	13.6% (6)	18.2% (8)	29.5% (13)	13.6% (6)	20.5% (9)

Table 45: Learned New Things about Space Science - Median

	Mean	**Median**
Post-questionnaire	4.95	5

Of the 22 individuals who participated in the phone interview, 16 said they had an interest in astronomy before playing Starchitect. And 4 participants said they were actively seeking a game like Starchitect when they found it.

Motivation for Playing

Table 46: Why Participants Played Starchitect

	(n=19)
To build galaxies/ see it grow	11
Complete challenges	5
Pass the time	2
To learn more/ educational reasons	2
Facebook advertisement/ friend invitation	1

Note: Visitors could provide more than one response to this item.

Players most often (n=11) wanted to build galaxies and watch them grow.

> *I really wanted to see my galaxy grow. I wanted to start life on one of my planets.*

> *The progression of the game and being able to do different things on the game. Being able to develop different parts of the game myself. Doing different solar systems, developing different planets different ways.*

Some participants (n=5) were compelled to play Starchitect to complete the challenges.

> *It was the new challenges, seeing when you could get moons or get a new life form. Different planets, too.*

> *I am attached to my little solar systems and there are a couple of achievements I am still trying to reach so I give it another try every couple of days.*

Two participants played Starchitect to pass the time.

> *I'm not sure, just passing time, I guess.*

> *I had a lot of time on my hands, it was over summer, and it was really fun. You kind of have to play for quite a while to get anywhere in the game and it was fun going places with it.*

Two participants played to learn more about astronomy or the solar system.

I played for the educational benefit. I have an interest in astronomy. I am a college student and I am in the astronomy club at my school. It wasn't just "match the three candies." It was more interesting than that.

Mostly the different ways, the educational things that you learn from it, plus you get to build a galaxy and that is fun.

And one participant played because of a Facebook advertisement.

Facebook comes up with different games in the ads on the sides and that is why I play the games. There are some that I go back to if people ask me to join their groups and play their games.

Participants were asked what other games they have played similar to Starchitect. Of the 22 individuals who participated in the phone interview, 18 individuals said they had not played any game that was like Starchitect. Participants gave examples of games they play, some of which are like Starchitect.

Other Games Played By Participants

- Spore
- Role Playing Games
- Telescope
- Star Trek games
- Angry Birds
- Train Station
- Yo-ville
- Super Planet Crash
- First Player Shooter games
- Trivia games
- Planet Builder
- Universe Fanverse
- Sims
- Galactic Civilization
- X-Com
- Rogue Galaxy
- Star Citizen
- Puzzle games

Of the 22 individuals who participated in the phone interviews, all of them considered Starchitect to be an educational game.

Table 47: Why Players Believe Starchitect to Be Educational

	(n=22)
It helps you learn/ understand	13
The game is based on science	10
The fun facts	7

Note: Visitors could provide more than one response to this item.

Players most often said (n=13) that Starchitect helped them learn more about or better understand astronomy principles.

> *Because the game explains things. It breaks it down if you are trying to create a moon, which is really, really hard, it explains what is going on. It is not just a regular game, a science-fiction game. It teaches me.*

> *I like how it spells out a message. I was also interested to see the stars grow and try to settle the various planets in the habitable zone and how long they would last. Things like that.*

Some participants (n=10) thought the game was educational because it was based on science.

> *Aside from the whole small time-span, it is based on actual facts like how long star systems last, the type and sizes of planets that have to maintain life, how long it takes to maintain life. It is all based on factual information rather than something somebody made up.*

> *There is lots of educational stuff. It is a lot more scientific than most other things. The ways stars age, the scienfitic facts that pop up. The validity and when things can happen in the solar system. It was all based on scientific theories that we have.*

Some participants (n=7) felt the "fun facts" that popped up during game play made Starchitect educational.

> *I learned stuff every time I played it. They have the facts that pop up for you and you have to learn to go through the game.*

> *It helps you to understand how different solar systems were developed; it gives you trivia pieces and asks you questions and makes you think.*

Participants were asked if there were specific parts of Starchitect that they didn't feel were real Space Science, but were made up? And if so, what parts?

Table 48: What Players Perceived as Authentic or Fictional in Starchitect

	(n=22)
Not real	9
Appearance of life	*3*

Colors	*2*
Animation	*2*
Graphics	*1*
Time span	*1*
Development of planets	*1*
I thought it was accurate	9
Not sure/ I don't remember	4

Note: Visitors could provide more than one response to this item.

A little less than half of players (n=9) thought some aspects of Starchitect seemed fake or made up.

Three players mentioned the option to create life on the planet.

Only in the fact that it is a game where you can make habitable planets in any solar system. That seems a bit far-fetched, but that is the game play of course.

The way that you click a button and you get 65% for life to appear. The chances of life spontaneously appearing are highly unlikely, but life is horribly rare in real life and in the game you could have multiple plants with life. If you have ever studied life sciences, you know it is ridiculously unlikely.

Two players mentioned the colors used in the game.

The colors that were available for the planets. I wasn't sure if they just picked the colors or if it was based on what the planets would have been because of what was happening.

Some of the colors on the background that you could choose, I wondered about. I wasn't 100% sure it was true. Some of the things seemed far-fetched, but I think it is possible having three stars as the base of the solar system.

Two players mentioned the animation of the game.

Yes, some of the zoom, but they showed that it wasn't realistic.

The animation, the animation was at certain points when you had little raise and lower it, when you raised the animation it seemed like it wasn't real. With the animation, to make it real, during the bombardment part, have the astroids hitting the planets, show what is going on. When the stars actually explode, they don't show the stars exploding, which is not what happens in real life.

One player mentioned the graphics.

Mostly just some of the graphics. They seemed kind of cartoony.

One player mentioned the time span of the game.

I would have to say the time span, like I said, where it speeds it up to a million years in a minute, but then again, that is based on how long star systems take, so I am not sure there are any errors in the way it is done.

One player mentioned the development of planets.

The way some of the planets started to develop, I didn't think that was actually true form.

A little less than half of players (n=9) thought Starchitect accurately depicted creating a solar system.

Other than the fact that it is a game, and it is not real, it was pretty accurate. I had to Google some things here and there to figure out what I was doing, but it is very accurate. That is why I like it.

No, not really. I didn't play many of the mini games, so I don't know what those were like. The solar system seemed very realistic and true to life.

A few players (n=4) were not sure or could not remember how they felt about the accuracy of the game.

I can't remember.

I don't know that much about space to be able to make that call.

Table 49: What Players Wanted to Tell Designers

	(n=22)
More options/ more choices for things to happen	9
It was good/ it was fun	8
Improve the look of the game	4
More information/ better instructions	4
Pace of game	2
Multiplayer option	1
IP address/Facebook account	1

Note: Visitors could provide more than one response to this item.

Players most often (n=9) wanted to ask the game designers for more options and more choices during game play.

If they want people to play it longer, they need to have more things for people to do.

What they have is nice, but one you have done it, you are pretty much done. There are only so many times you can make a solar system or log in and check on your solar system, so once you have achieved that, there isn't much reason to keep playing. If the designers are interested in long-term playability, maybe the little people could do things once you created life on the planets or something like that.

I think it is a great game and I am very glad they made it. I would like to see a little bit more of, when you get intelligent life, what it does. Have some landmarks if they went to another moon or something like that, just to see what they are doing.

Great job, keep at it. The only other thing that I could say to them is I would love to see them touching on the idea of black holes or rogue black holes that are traveling through space. One of those could destroy an entire galaxy just in passing.

The one thing I really thought was not a great feature was how you could spend points to jump ahead in time, but then your energy bar didn't refill, so you weren't able to build anything right away. I think it would be better if you could jump ahead in time and build something right away.

Players (n=8) also wanted to tell game designers that Starchitect is fun.

It is awesome and keep up the good work because more people need to learn about science.

I don't have anything else to share. The game itself was well done and well put together.

Some players (n=4) felt the designers could improve on the look of Starchitect.

I would like to see more colors and stuff for the planets.

The other thing that was a little disappointing was the cloud patterns and stuff for the planets. It seemed cheaply animated. Mostly it was really cool and fun to learn.

Some players (n=4) would like to have more information or better instructions on how to play the game.

Have a little more in-depth information into developing planets and be able to utilize different areas in it where you can actually develop the planets in a little more detail.

Make the instructions a little bit easier to follow as far as different achievements to work toward, or throw in hints to help people along.

Two players mentioned the pace of the game.

It was rather slow, so the progression may need to be sped up a little bit.

It was really fun. There are times that I wish I could speed it up that I couldn't, and other times where I wish I could slow it down.

One player mentioned having a multiplayer component to Starchitect and frustrations with the current user login/connection method.

The interface for friends who play the game is kind of boring. There should be a little bit more, it should be more fun to play with other people somehow. Maybe you could challenge each other to the little mini games in there. More interaction with your neighbors. And of course the problem with the IP address and the game sticking to that instead of your Facebook account, that's a real issue."

Reflection on Lessons Learned from the Project

We began this project with a number of assumptions and inferences. Like all projects, the audiences, products, goals, and how we measured our achievement of those goals has evolved over time. In our case, the external context for the project also changed over time, such as the dramatic changes within the casual gaming market. We feel it would be beneficial reviewing how we initially conceived of the project, the path it has taken, and our adaptations not just for our own learning process, but also as a reflection for the field on informal science learning gaming.

Starchitect was conceived during the heyday of casual gaming, during 2008-2009. The release of the developer application for Facebook in May of 2007 fostered a sudden proliferation of casual sporadic games, led by Farmville. While the term "casual" within gaming has different meanings for different individuals, we were interested in specific aspects of this breed of game. First, while casual games are perceived as potentially less involved than Massively Multiplayer Online Games (MMOGs, such as The Sims Online), or Role-Playing Games (RPGs, such as World of Warcraft), the amount of time individuals spend on casual games, even on a single casual game, is enormous. Casual sporadic games can support learning content that has unfolding events in time, and scale in time, and understanding of cause and effect in time. Prior research has shown that the amount of time playing a game correlates with the learning that can occur. (Haley Goldman, Koepfler, and Yocco 2009)

Secondly, game statistics indicate that the majority of players abandon casual games within the first few rounds of play (typically days or weeks). Yet, casual games that build up assets over time, such as the increase in crops and features on a player's farm within FarmVille, encourage individuals to return to the game again and again, often over weeks and months, potentially years. While the numbers that continue to play extensively past the initial few rounds is smaller, these players can be extraordinarily devoted, both in terms of amount of play within a single day, such as multiple quick sessions throughout the day to harvest crops, and in terms of length of time (days, weeks, months) they continue to play the game.

This format of play— multiple 'touchpoints' throughout a day, plus engaged use over a period of weeks— is exactly the type of interaction research shows supports learning. (Hilton and Honey 2011) Player investment in something of their own creation can be substantial.

One of the elements we were experimenting with was audience, especially within our choice of platform. Prior informal science gaming has largely been disseminated in places where science-interested individuals will play, such as through science centers and museums, universities, STEM-based websites, education websites, etc. In using Facebook, we would be using a platform that reaches an enormous cross-section of the American public. Currently 65% of American adults use social media, including Facebook (Duggan 2015). We wondered if the game itself was compelling enough, or shared enough socially, if individuals who were not typically science-interested would play. In short, could a good game, disseminated where the general American public gathers (Facebook) overcome the perceived barriers of being an "educational" game, and teach space science to those who otherwise may not have sought out astronomy?

Facebook also encourages "stickiness", a player's willingness to return to play the game again and again. As Facebook continues to grow, 71% of American online adults have Facebook accounts, and nearly half of Americans are daily active users. (Duggan 2015) Casual sporadic games within Facebook are known to be "stickier" than such games elsewhere. This dynamic, plus the notification system built-in to Facebook, encourages players to check on their games regularly, up to multiple times a day. By going to where people were already gathering, we would nudge them to play the game more often.

Additionally, there were demographic factors in the choice of the type of the game. While 67% of all Americans play games, only 10% consider themselves "Gamers". Men are twice as likely to identify as a 'gamer". (Duggan 2015) Women make up 48% of the gaming population, compared to 15% for the "typical gamer", ie. a male aged 10-25. (Harwell 2014) During the period of the design of Starchitect, gender differences in types of gaming were seen as fairly binary, dividing between 'hardcore' or 'core' gaming titles and 'casual' games played for Moms. (Vanderhoef 2010) It is true that casual gamers are disproportionately female although it does not necessarily hold that females do not play other types of games. Pop Games research at the time of initial funding (2010) showed 55% of social gamers were women, with an average age of 43. This is not an audience that space science games typically reach. The potential of engaging with public who was not already part of the science-interested 'choir' was appealing.

Despite this emerging knowledge regarding the demographics of games, at the time much remained to be documented on who plays these games, why, and what can be gained from it. Our work would explore these factors.

What were our lessons learned?

1. Platform matters. Facebook was highly useful in attracting repeated play.

2.Independent of platform, the game attracts the choir. We don't have evidence that a compelling game will intrigue the non-science folks, as our players were superbly knowledgeable on space science when they started (compared to the American public). In our evaluation, the players felt they learned while playing, though we did not see extensive learning due to a ceiling effect.

Which isn't to say that perhaps 'catering to the choir' isn't useful. There are still players who get the general science questions wrong, it's just a smaller percentage than in the general public. The fact that Starchitect are better informed on average on space science doesn't mean that all of them are well informed. Interestingly, all of the telephone interviews considered Starchitect an educational game, and multiple Starchitect players told us in interviews that they had been seeking out a game such as Starchitect, where they could build solar systems according to the actual properties of space system origins.

3. The drop-off rate after initial first play is very high. In our case, 80% of the individuals played the game only a single day, though the content was designed to be played over a period of multiple days, As the casual game market has evolved, we know this to be consistent with other casual games, though it has implications for designing learning content.

4. Marketing is critical. Ad buys were key in reaching audiences. Targeting specific niches becomes harder and harder on the internet as the ad space is crowded. (After early years of losing money, Facebook has turned a substantial profit through advertising.) Google donates up to $40,000 of advertising credits per month to a non-profit organization, allowing them to buy ads and increase their audiences. The ad buying process at Google is a bidding one, where for-profits and non-profits both compete for the advertising space attached to certain search terms, bidding how much they will spend for that term. For a topic with high interest (for example real estate), the price for advertising will be quite high, likely higher than the credit Google offers. However, careful choice of keywords (for instance, "science game" as opposed to simply "game") can be highly effective at attracting players.

Facebook advertising was highly successful for Starchitect in recruiting players. Recruiting players was not necessary for the success of the game itself, as thousands of individuals did play Starchitect. Instead, the recruitment was important to ensure a robust sample size for the evaluation, as the evaluation needed individuals to complete both a pre-and post questionnaire.

Facebook does not give credits for non-profits, so the advertisements came at a direct budget cost. The team undertook this route based on anecdotes from game development professionals that suggested Facebook advertisement buys were the key ingredient in growth of the game.

Is building a casual sporadic game worth it?
Potentially, yes. As a game industry professional reportedly once said "Not all content is game-shaped." The art of any game development is finding the framework that fits. In this particular case, the idea of evolving solar systems over time was in principle a good fit to the sporadic play model.

Another consideration is that the development time for a casual sporadic game does not end. Seasoned players are constantly looking for the next level, the next feat, the next feature to unlock. In the case of Starchitect, one regular player noticed the presence of a new feat not yet unlockable, and emailed the Project Director to see when the feat would be available. Development continues as long as players are playing.

The design of a sporadic game has to be a long-term sustainable design if it is to keep match with player expectations. In a game such as Starchitect, where all of the game-play is based on actual space science, there is rich content material to mine for continued solar system development. For other content areas, this might not be true. For the long-term development process of a sporadic game to be worth it, the content has to be important and something that can't be delivered better in another medium.

Future designers should be prepared for the extreme drop-off in participation, and even the longest tail has the finite limit of your available development time. If the team wishes to hold on to players forever, then they need to constantly create new feats. "Finishing" or "beating" a game used to be the norm; it was not considered a let down. Phrased differently, do your educational goals really require the type of time a long-term game in order to gain the learning impact?

As the drop-off rate in this game, like other casual sporadic games and also social media platforms, is enormous, there are implications for game design for maximized learning. Considering that any casual sporadic game is likely to lose up to 80% of the audience within the first couple of sessions, the development team needs to make a choice. Do they attempt to make the game "stickier" and increase persistence within more players, thereby increasing the window of opportunity for learning? Or, do the game designers try and pack as much content as possible in that smaller window, ideally within the tutorial

itself, so that if players abandon the game fairly quickly, at least they will have gained some content? Or, the third option, does one attempt to do both?

In end-of-project discussions, we reflected that development of significant content for the small window of initial game play was similar to designing an exhibit interactive for a science museum. The majority of individuals will stay only a very short period of time at a single interactive, so the learning goals need to be clear, focused, and conveyable in a short period of time. Ideally, the exhibit interactive will have deeper content for those that choose to stay longer and engage more deeply. Nonetheless, the relative difference between amount of funding and development time for a single interactive versus a game that can be played and supported for years is substantial, and should be factored into the decision process for other future games.

In the commercial world of casual sporadic games, enormous effort is put into encouraging players to continue to play. Commercial games make their money with in-game purchases or adverts — giving players the ability to move ahead more quickly in the game in exchange for money. This dynamic builds attachment to the game in addition to the incoming funding. Perhaps we need to accept the steep decline in audience, and focus on the 'long tail' of participation. In this, we are using the concept of long tail developed through retail practices, where it refers the large number of products that sell in small quantities, and adapting it to participation to refer to a much smaller number of players, but ones who are exceedingly devoted and play for many times longer than the average player.

Was Facebook worth it?

Reflecting on the choice of Facebook as a platform, our experience was mixed. As noted above, Facebook as a platform has advantages for a number of specific types of games:

- Benefits of social media spread,
- Well-designed for sporadic games that require frequent short-duration play,
- Access to non-science interested people,
- Access to non-game players (For instance, if the target were only game-players, the STEAM platform might be a better choice.),
- Access to range across the age spectrum,
- Diversity. Facebook is as diverse as the internet itself, in terms of gender and ethnic origins, and
- Potential access to metrics on players.

Implications for research of using Facebook

One of the attractive elements of the choice of Facebook as a platform was the potential to dig deeper within the data. The ability to see the age, gender, and game playing behavior of our players would help us understand what audience Starchitect appealed to. By analyzing the Page Likes and Friending of our players, we could see if we were attracting individuals who were already interested in science. For example, we would assume that someone who followed "I F*$king Love Science" was pro-science, and sought out science-related information.

Our research, however, was limited by Facebook's rules. Their rules change, often unilaterally, and without notice. For example, access to age of our players in Starchitect was problematic. At the beginning of the project this was a basic piece of data readily available. Later on, we were only able to see age in categories, and then Facebook stopped provide age altogether. While we appealed and were able to gain back data on age of players, this leads to constant monitoring and long-term sustainability of the required follow-up can be substantial.

Facebook also regularly changed their metrics access. By the time for summative evaluation, we were unable to contact our players directly for interviews, unable to send them notifications, unable to individually analyze their Page Likes for science-related content, and more. Our dependency on Facebook for access to that data meant that our hands were tied in being able to provide greater insight into the game demographics or impact.

Bigger games within Facebook have greater access to more metrics and participation data. Starchitect was a very small game within the Facebook universe, so special dispensation to gather more data, contact players, and so forth was not available.

As noted above, for the right kind of game, Facebook could be a key factor in reaching an unconventional audience and encouraging participation. From a measurement perspective, it's troubling that access to that backend data could be changed or curtailed at a moment's notice. If one is approaching the project from a solely research perspective into how individuals play and learn from games, it would potentially be more effective to find a well-functioning game, gain access to their player data, and analyze that data for trends.

What would we do differently?

Starchitect could have played out differently. As the project director has noted, commercial games are significantly more willing to be more aggressive with their players— posting on player Facebook walls, sending invitations or notices to a player's Facebook friends, etc. These were all techniques aggressively used by one of the most prominent and popular Facebook game developers, Zynga. Unfortunately, their aggressive approach, while immensely profitable in the short-term, also led to many of the Facebook changes around gaming and notifications. Zynga, as a company, is now a shadow of its former self. That tenor of play was not something the project team wanted to emulate, but perhaps it slowed the adoption rate.

If we were to undertake this project again, we would be better positioned now to succeed, knowing what we know about the game span, drop-off rate, and platform affordances. At the same time, we acknowledge that our expertise can easily become outdated, as both the gaming world and the Facebook platform change rapidly. Casual sporadic gaming has changed enormously since the launch of the App Store in July, 2008 and the huge increase in mobile gaming such as the game Clash of Clans and and the demise of Zynga and other game companies has generated much conversation on how to create sustainable games that support players long-term.

Given that our expertise ages, we would recommend incorporating a very active developer in the gaming platform you are working in, or a very active data analytics person within the community, preferably from a for-profit company that focus solely on that platform. Finally, the 'wild west' attitude towards research privacy at Facebook has evolved (Harwell, 2014) and we should expect to see regular changes what data researchers are given access. Further, we would advise that future projects plan their game extensively for data redundancy in key data areas, so that if the access rules change, impact can still be fully measured.

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Appendix A: Pre Survey

Welcome to the Starchitect Study!

Welcome to the study about Starchitect! Funded by the Space Science Institute, NASA and the National Science Foundation, this study will research Starchitect players such as yourself. The study will try to understand who players are and what players think of the game.

You don't need to be knowledgeable about Astronomy or Science to participate!

The following survey should take approximately 10 to 15 minutes to complete. Some of the questions in the survey gather information about you, and other questions ask about your thoughts on Astronomy and Science. Please be assured all of your responses will be kept confidential. Any information you provide that could identify you as an individual will not be included in the presentation of survey results. We encourage you to take your time and answer all survey questions as honestly as you can.

If you decide to be part of the study, we ask that you play Starchitect as you normally would, as often as you like, for two months. When playing the game you may see pop-up questions, which you can answer or decline as you wish. We also ask that you take another survey at the end of the study.

You may be eligible for a $40 Amazon.com gift card after completing all surveys, playing Starchitect through the tutorial, and logging into Starchitect again after 12 hours. Amazon gift cards will be distributed to eligible participants after the study has ended. We will need you to provide your contact information in order to enroll you in the study. Only the researchers will have your contact information, and it will never be used outside of this study.

This is an entirely voluntary study. You have the choice not to participate in this project. You have the right to stop answering questions at anytime. You have the right to withdraw consent from this study and forfeit your gift card at any time.

1. If you would like to continue with the survey and be part of the study, please select "Yes" and then click "Next."

- o Yes, I agree to be surveyed and/or interviewed about my participation in playing Starchitect, and Starchitect in general. I understand I will be asked about my science and gaming activities, and my opinions and thoughts about Science, Astronomy and science-related games. I understand I am free to decline to participate at any time. I further understand that my answers will be confidential, assigned a number code, and available only to the project researchers.

- No, I do not agree to participate in the study about Starchitect.

If you have any concerns or questions about this project, you may contact Patricia Montano at Montano@AudienceViewpoints.com

This project has been reviewed and approved by Heartland Institutional Review Board, HIRB No. 140722-24;. Questions concerning your rights as a participant in this research may be addressed to: Heartland Institutional Review Board – Ph: 866.618.HIRB – director@heartlandirb.org

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2. What is your age?

- 13 - 17 years old
- 18 - 22 years old
- 23 - 30 years old
- 31 - 40 years old
- 41 - 50 years old
- 51 - 60 years old
- 60+ years old

3. What is your gender?

- Female
- Male
- Transgender

4. In what U.S. state do you live?

We'd like to know you a bit better as you join this study. The next questions are background questions to better understand you and your interests, especially your connection to games.

5. How many hours a week do you play online games or digital games, including app-based games like Candy Crush, Clash of Clans, etc?

- None
- 1 - 5 hours
- 6 - 10 hours
- 11 - 20 hours
- 21 - 30 hours

- More than 30 hours

6. What is your type of favorite game? (Check all that apply)

- Puzzle games
- Casual games
- Story-based games
- Role-playing games
- Other (please write below)

7. In the spaces below, please list your 3 favorite games.

Favorite Game #1

Favorite Game #2

Favorite Game #3

The next sets of questions are background questions to better understand you and your interests in Science and Astronomy.

8. On a scale of 1 to 7, where 1 is the lowest and 7 is the highest, please rate the following:

1 2 3 4 5 6 7

I'm not at all interested Astronomy I'm extremely interested in Astronomy

9. On a scale of 1 to 7, where 1 is the lowest and 7 is the highest, please rate the following:

1 2 3 4 5 6 7

I'm not at all knowledgeable Astronomy I'm extremely knowledgeable about about Astronomy

10. Please let us know how much you Agree or Disagree with the following statements.

I think I'm pretty good at understanding science topics.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Compared to other people my age, I think I can quickly understand new science topics.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

It takes me a long time to understand new science topics.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I feel confident in my ability to explain science topics to others.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. Astrology is,

- basically the same as astronomy
- a science related to astronomy
- not the same as astronomy

13. Astronauts in orbit are,

- apparently weightless because they are in free fall
- apparently weightless because they are in a vacuum
- truly weightless because they are in a vacuum truly weightless because there is no gravity in space
- both truly weightless because they are in a vacuum and because there is no gravity in space

14. What causes the phases of the Moon?

- the Moon's shadow on Earth
- Earth's shadow on the Moon
- the Sun and Earth's shadows on the Moon
- none of the above—no shadows are involved

15. On Earth, what causes summer to be hotter than winter?

- the Earth is closer to the Sun in summer
- the daylight period is longer in summer
- the Sun gets higher in the sky in summer
- both the daylight period is longer and the Sun is higher in the sky in summer
- all of the above

16. Which statement is true?

- low mass stars live longer
- high mass stars live longer
- how long stars live doesn't depend on their mass (but they do die eventually)
- stars live forever

17. Which stars are hottest?

- high mass stars
- low mass stars
- the temperatures of stars varies, but it doesn't depend on the mass
- all stars are about the same temperature

18. Comparing two star systems, one with a high mass star and one with a low mass star, where would you expect to find habitable worlds?

- closer to the low mass star than the high mass star
- closer to the high mass star than the low mass star
- about the same distance from both high and low mass stars
- habitable worlds are equally likely to be found anywhere in a solar system

19. A planet is more likely to be habitable if it is:

- close to its star
- far from its star not too close, but not too far
- the distance from the star doesn't matter that much

20. Which is a possible color for a star?

- red
- white
- blue
- yellow
- more than one of the above

21. What can prevent a moon from forming?

- being too close to the planet so that it never forms
- being too far from the planet to stay in orbit
- being too close to another moon so that one orbit becomes unstable
- all of the above

22. Which stage of the four below is likely to take the longest for a habitable world?

- the time from the start of the solar system to the formation of the planet the
- time between formation of the planet and the first simple single-cell life
- the time between the first simple-cell life and early multi-cell life
- the time between early multi-cell life and intelligent life

23. What factors can influence how rings look?

- the size of the moon that formed them
- whether there are moons outside the rings
- the age of the rings
- all of the above

24. What elements influence whether life evolves on a planet?

- the planet's size
- the planet's distance from the star
- the age of the solar system
- all of the above

25. For giant planets, which of these can influence the appearance of the planet?

- the planet's distance from the star
- the planet's size
- both a planet's distance from the star and the planet's size
- none of the above

26. If you were looking for life in other solar systems, would it be better to look for:

- low mass stars
- high mass stars
- either low mass or high mass stars would do
- it doesn't matter, life is unique to Earth

27. Name potential extinction events.

28. Put these life stages in the correct order from first to last to evolve.

- Single-Cell Life
- Multi-Cell Life
- Land
- Ocean

Welcome to the Starchitect Study!

Though you will not be able to participate in the study about Starchitect, you can still play the game as much as you like.

Thank you so much for your time and have fun creating your own planetary systems!

Welcome to the Starchitect Study!

To continue participating in this study we will need your contact information such as your name, email and telephone number. Your information will only be used for this study and will only be available to the researchers. Your contact information will be disposed of at the end of the study.

Your information will be used to email you about the study, to possibly reach you for a telephone interview about your thoughts on Starchitect, and to email you an Amazon gift card in appreciation

of your participation.

You may be eligible for a $40 Amazon.com gift card after completing all surveys, playing Starchitect through the tutorial, and logging into Starchitect again after 12 hours. Amazon gift cards will be distributed to eligible participants after the study has ended.

29. Please fill your contact information below.

First Name Last Name Email Address Phone Number

30. If you would not like to provide your contact information, please click the selection below. I decline to give my contact information

Welcome to the Starchitect Study!

Thank you very much for completing the survey and for agreeing to be part of our study on Starchitect. We look forward to your participation!

Please play the game as you normally would, and as often as you like. When playing Starchitect you will see pop-up questions, which you can answer or decline as you wish. We will be contacting you again in about 2

months to ask about your thoughts on Starchitect.

If you have questions about the study, or about this survey, please contact Patricia Montano at Montano@AudienceViewpoints.com

Appendix B: Post Survey

Thank you for playing Starchitect and participating in our study!

Funded by the Space Science Institute, NASA and the National Science Foundation, this study will researches game play. We'd like to ask you a few questions about your thoughts and experiences playing the game. This survey is critical to understanding who plays Starchitect and what players think.

The following survey should take approximately 15 minutes to complete. Some of the questions in the survey gather information about you, and other questions ask about your thoughts on Astronomy and Science. Please be assured all of your responses will be kept confidential. Any information you provide that could identify you as an individual will not be included in the presentation of survey results. We encourage you to take your time and answer all survey questions as honestly as you can.

If you decide to be part of the study, we ask that you play Starchitect as you normally would, as often as you like, for two months. When playing the game you may see pop-up questions, which you can answer or decline as you wish. We also ask that you take another survey at the end of the study.

You are eligible for a $40 Amazon.com gift card after completing this survey, if you have played Starchitect through the tutorial, and logged into Starchitect again after 12 hours.

This is an entirely voluntary study. You have the choice not to participate in this project. You have the right to stop answering questions at anytime. You have the right to withdraw consent from this study and forfeit your gift card at any time. Only the researchers will have your contact information, and it will never be used outside of this study.

If you have any concerns or questions about this project, you may contact Kate Haley Goldman at HaleyGoldman@AudienceViewpoints.com

This project has been reviewed and approved by Heartland Institutional Review Board, HIRB No. 140722-24;. Questions concerning your rights as a participant in this research may be addressed to: Heartland Institutional Review Board – Ph: 866.618.HIRB – director@heartlandirb.org

1. Please confirm your email address. This is a necessary so we can match responses and so to send you the Amazon gift card.

2. What initially brought you to play this game? (select all that apply)

- **Google Ads**
- **Facebook Ads**
- **Through class work**
- **A friend or family member's recommendation**
- **Other (please specify)**

3. What was the most interesting part of the game to you?

4. What was the hardest part of this game?

5. What do you think the goal of the game is?

6. Did you have a specific goal you personally are trying to achieve within the game?

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7. How realistic do you think Starchitect is?

- **100% realistic – all of the game is based on actual Space Science**
- **90% realistic- most of the game is based on actual Space Science, with a few elements invented to make the game better.**
- **50% realistic- About half of the game play is based on actual Space Science, about half of it is invented**
- **10% realistic- Most of the game play is invented.**

Comments:

The next sets of questions are background questions to better understand you and your interests in Science and Astronomy.

8. On a scale of 1 to 7, where 1 is I learned nothing new and 7 is I learned many new things about Space Science? Do you feel like you learned anything about Space Science in playing this game?

1 2 3 4 5 6 7

I learned nothing new about Space Science **I learned many new things about Space Science**

9. On a scale of 1 to 7, where 1 is the lowest and 7 is the highest, please rate the following:

1 2 3 4 5 6 7

I'm not at all interested Astronomy **I'm extremely interested in Astronomy**

10. On a scale of 1 to 7, where 1 is the lowest and 7 is the highest, please rate the following:

1 2 3 4 5 6 7

I'm not at all knowledgeable about Astronomy **I'm extremely knowledgeable about Astronomy**

11. If you learned something new playing the game, what did you learn? (List up to 5.)

12. Please let us know how much you Agree or Disagree with the following statements.

I think I'm pretty good at understanding science topics.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

Compared to other people my age, I think I can quickly understand new science topics.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

It takes me a long time to understand new science topics.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I feel confident in my ability to explain science topics to others.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**

- **Strongly Agree**

13. Please let us know how much you Agree or Disagree with the following statements.

I want to learn more about space science topics.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I like to engage in science-related hobbies in my free time.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I want to understand how a scientific process works (e.g. how stars are formed, what causes solar flares.)

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I often visit science- related web sites.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I enjoy learning about new scientific discoveries or inventions.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

Other people would describe me as a "science person."

- **Strongly Disagree**

- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I enjoy reading about science-related topics.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I like to star watch.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I enjoy talking about science topics with others.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I am interested in learning more about the physical sciences (chemistry, physics, and geology).

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

I enjoy looking at information presented in scientific tables and graphs.

- **Strongly Disagree**
- **Disagree**
- **Neutral**
- **Agree**
- **Strongly Agree**

14. Astrology is:

- **basically the same as astronomy**
- **a science related to astronomy**
- **not the same as astronomy**

15. Astronauts in orbit are:

- **apparently weightless because they are in free fall**
- **apparently weightless because they are in a vacuum**
- **truly weightless because they are in a vacuum**
- **truly weightless because there is no gravity in space**
- **both truly weightless because they are in a vacuum and because there is no gravity in space**

16. What causes the phases of the Moon?

- **the Moon's shadow on Earth**
- **Earth's shadow on the Moon**
- **the Sun and Earth's shadows on the Moon**
- **none of the above—no shadows are involved**

17. On Earth, what causes summer to be hotter than winter?

- **the Earth is closer to the Sun in summer**
- **the daylight period is longer in summer**
- **the Sun gets higher in the sky in summer**
- **both the daylight period is longer and the Sun is higher in the sky in summer**
- **all of the above**

18. Which statement is true?

- **low mass stars live longer**
- **high mass stars live longer**
- **how long stars live doesn't depend on their mass (but they do die eventually)**
- **stars live forever**

19. Which stars are hottest?

- **high mass stars**
- **low mass stars**
- **the temperatures of stars varies, but it doesn't depend on the mass**
- **all stars are about the same temperature**

20. Comparing two star systems, one with a high mass star and one with a low mass star, where would you expect to find habitable worlds?

- **closer to the low mass star than the high mass star**
- **closer to the high mass star than the low mass star**
- **about the same distance from both high and low mass stars**
- **habitable worlds are equally likely to be found anywhere in a solar system**

21. A planet is more likely to be habitable if it is:

- **close to its star**
- **far from its star not too close, but not too far**
- **the distance from the star doesn't matter that much**

22. Which is a possible color for a star?

- **red**
- **white**
- **blue**
- **yellow**
- **more than one of the above**

23. What can prevent a moon from forming?

- **being too close to the planet so that it never forms**
- **being too far from the planet to stay in orbit**
- **being too close to another moon so that one orbit becomes unstable**
- **all of the above**

24. Which stage of the four below is likely to take the longest for a habitable world?

- **the time from the start of the solar system to the formation of the planet**
- **the time between formation of the planet and the first simple single-cell life**
- **the time between the first simple-cell life and early multi-cell life**
- **the time between early multi-cell life and intelligent life**

25. What factors can influence how rings look?

- **the size of the moon that formed them**
- **whether there are moons outside the rings**
- **the age of the rings**
- **all of the above**

26. What elements influence whether life evolves on a planet?

- **the planet's size**
- **the planet's distance from the star**
- **the age of the solar system**
- **all of the above**

27. For giant planets, which of these can influence the appearance of the planet?

- **the planet's distance from the star**
- **the planet's size**
- **both a planet's distance from the star and the planet's size**
- **none of the above**

28. If you were looking for life in other solar systems, would it be better to look for:

- **low mass stars**
- **high mass stars**
- **either low mass or high mass stars would do**
- **it doesn't matter, life is unique to Earth**

29. Name potential extinction events.

30. Put these life stages in the correct order from first to last to evolve.

- **Single-Cell Life**
- **Multi-Cell Life**
- **Land**
- **Ocean**

31. If you were drawing a realistic picture of the solar system on a piece of notebook paper, would the planets be:

- **large enough to make out details**
- **easily visible, but too small to see details**
- **only tiny dots at best**

32. Almost done! Do you have any comments or suggestions about the Starchitect game that you'd like to share with us?

Thank you very much for completing the survey and for being part of our study on Starchitect!

In the coming days the contact information you provided at the beginning of the study might be used to reach you for a telephone interview to ask about your thoughts on Starchitect.

After completing this survey you will receive a $40 Amazon.com gift card to be sent via the email you provided at the start of the study. Those eligible to receive gift card must have completed all surveys, played Starchitect through the tutorial, and logged into Starchitect again after 12 hours. Gift cards will be distributed to eligible participants a few three weeks after the study has ended.

If you have any questions about the Starchitect study or this survey, please contact Kate Haley Goldman at HaleyGoldman@AudienceViewpoints.com

Appendix C: Telephone Interview

Hello! My name is Erin/Emily/Kate, and calling to ask you a few questions about the Facebook game you played called Starchitect. The interview will take about 5-8 minutes.

1. What made you first start playing Starchitect?

2. Do you consider yourself to still be actively playing Starchitect? (Prompt: So you've stopped playing entirely?)

3. When you were playing, what kept you playing? Why did you play?

If yes:

4. How often do you play?

5. Do you think about your solar systems when you are not playing?

If no:

6. Do you remember when you stopped playing? How long ago was that?

7. Was there a particular reason you stopped playing?

For everyone:

8. What other sorts of games have you played that were like Starchitect?

9. Why did that remind you of Starchitect?

Were there particular elements that reminded you? (Probe on subject matter, style of play… space/astronomy vs. educational vs. Facebook vs. sporadic. Especially make sure to probe on sporadic vs. other types of games)

10. Do you consider Starchitect an educational game?

11. What about it makes it an educational game?

12. Are there any specific parts of Starchitect you didn't feel were real Space Science, but were made up? What parts?

13. What specific parts of Starchitect did you feel were realistic?

13. What would you want to tell the designers of the game?