An Astronomy Education Game for Facebook: Learning From Those Games You Love to Hate

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Abstract: We have developed a stellar and planetary evolution game for Facebook as part of an informal educational project. The game uses the "sporadic play" model of games such as *Farmville*, where players may only take actions a few times a day, but may continue playing for months. This framework is an excellent fit for teaching about the evolution of stars and planets: systems evolve in scaled real time (a million years to the minute), so that massive stars supernova within minutes, while stars like our sun live for weeks. The game has now been live for over a year, and has attracted over 35,000 players. Using a mix of data and evaluation strategies, we discuss play duration and retention; player demographics; and content gains. We close with a summary of our current opinions on the perils and promise of developing educational games using this platform and game framework.

Background

In 2007 Facebook began allowing developers to create applications that interacted with core elements of their system. This generated a surge of new games that attempted to take advantage of the of the platform, whether through its social network, or simply as a space that made it easier for a game to stay in contact with its players. Some of these games were of a novel, and perhaps peculiar nature: rather than trying to draw the player in for an extended play session, they deliberately restricted play, forcing the player to return at a later time. These "sporadic" (also referred to as "passive") games were occasionally lambasted for having more in common with psychology experiments than with traditional skill development or problem solving games. They were also extremely successful, with Zynga's *Farmville* peaking at 80 million monthly active players before competition began to decrease its share (Chiang, 2010).

During this period our group of scientists, evaluators, and informal science educators felt that both Facebook as a platform, as well as the sporadic play game framework, might be of interest for educational games. Educational games have been of interest in science learning for some time because of their potential to address multiple goals, including motivation, conceptual understanding, and the nature of science (Honey and Hilton 2009). However, while there was significant research on gaming and learning, there was relatively little academic or publicly available research on Facebook games, especially sporadic games. (Richards, Stebbins, & Moellering, 2013). It was particularly these two features – Facebook and sporadic play -- that we found intriguing, for a number of reasons:

1. New audiences. These games were notable for attracting a broad demographic, both in gender and age. Some of this related to the subject matter of the game, but some was undoubtedly the result of the platform and game frameworks themselves: sporadic games could fill small niches in your schedule, and didn't (on the surface) require a significant time commitment. This was of particular interest for an informal education (a.k.a. "free choice learning") project hoping to have a broad reach. For instance, studies have shown that women over 40 play web-based games more frequently and for more time than other individuals, including both teenagers and adult males (Harwell 2014, Pearce 2008). In fact, while traditional informal science institutions (e.g., science centers) 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 number of hours that might appear to be more than "casual" (Kuittinen et al, 2007). Perhaps partially due to their lack of self-perception as gamers, these populations have also often been ignored by both the gaming industry and the academic study of gaming. (Takeuchi and Vaala, 2014).

2. Sporadic play seemed at least superficially aligned with the experiential learning cycle of acting, reflecting, developing a theory, testing that theory, and repeating (Mumford, 1997). Players waiting for their next session might remain “mind’s on” while considering their next action, and revisiting the game day after day could serve to reinforce the content.
3. Despite the informal education focus of the project, sporadic play could also be a good match for classrooms. While the traditional divisions between formal and informal education have been increasingly breaking down, classrooms continue to be heavily constrained in time and resources. Flexible activities that can be undertaken at home, but still tie to curricula, can help supplement the classroom experience. By extending the play period, the game can take little time on a daily basis, but still cover a significant amount of content over the course of a school term. This type of play bridges the informal and formal goals cited in Squire and Patterson (2009) with flexible, emergent, and voluntary attributes, yet still with largely defined educational goals.
4. The content of the proposed project – solar system evolution -- was a good match to this game framework. In general, systems that evolve over time (whether they involve crops or planetary systems) can fit nicely into the sporadic play model. In other words, if you can grow a farm, you can grow a solar system.

The project

With funding through the National Science Foundation and NASA, we produced *Starchitect*: an online, end-to-end stellar and planetary evolution game designed to teach players about a variety of astronomy and planetary topics (http://www.starchitect.net/). The team included the authors (J. Harold P.I., and K. Haley-Goldman as evaluator) as well as Dean Hines (Space Science Institute/Space Telescope Science Institute) as science advisor, Evaldas Vidugiris (Space Science Institute) as lead programmer, Ben Sawyer (Digital Mill) consulting on game design, and Nina Klymenko for graphic design. Note that the primary program goal was to produce an educational game for informal (non-classroom) audiences, not to perform a research study. However, the project did provide an interesting opportunity to examine an educational game in a social network, including the types of players it would attract, and the outcomes it could achieve.

Starchitect’s solar systems evolve at a million years a minute, so gameplay is naturally drawn out for days or weeks (for reference, at a million years a minute the Earth is approximately 3 days old, halfway through our solar system’s lifetime). With this scaling, massive stars will supernova almost immediately, while lower mass stars like our sun will live for weeks of game time, possibly evolving life before passing through a red giant stage and ending their lives as white dwarfs. While it was designed to probe various features of Facebook as an educational game platform, the game is also available externally so that children under 13 can access it. As an added benefit, this allows us to compare the play patterns of the Facebook and non-Facebook audiences.

Game features

Players begin with a simple tutorial that walks them through creating a star and a single planet. From there they can move on to add moons, planets, or create more systems. The player can also pursue life by placing a terrestrial planet in the habitable zone of the star (the location of which varies with star type).

We embed as much accurate astronomy and physics within the game as possible, while still trying to maximize player agency. Players can place planets anywhere, but they will destabilize if they are too close to each other. A player can “design” the look of their giant world, but the colors and patterns of those designs are based both on the planet’s location, and on research models (for instance, of band formations as a function of gas giant size). Rings can be added, but not directly: rings form when a player attempts to create a moon too close to a giant world (inside the Roche Limit). Ring gaps are generated programmatically based on the location of resonances resulting from other moons placed by the player (see Figure 1). Players can also take pictures of their systems, then post them so that others can vote on the most interesting systems. Besides the incentive to create those systems in the first place, other players can learn what’s possible in the game.

The game is built around a “Feats” achievements system, which is a typical approach for this class of games. However Feats also provide several specific advantages for us: they allows us to drive player behavior towards specific learning goals (e.g., “Place a terrestrial planet in the habitable zone”, or “Create a solar system similar to ours.”); they can tie to a system of “Unlocks” that allow us to scaffold the content of the game (e.g., players must succeed at a mini-game on scales before being able to "cheat" and display unrealistic planet sizes in the game); and they provide a tracking mechanism for player accomplishments.

Other game features include mini-games that can address content that might not fit naturally in to the gameplay; the ability to take pictures of your system and post them to your wall; and a separate application that lets visitors rank system pictures submitted by players.

Evaluation strategies

Evaluation of the project presents a variety of opportunities and challenges. The opportunities include the fact that the game provides a fairly large "N" (over 35,000 players to date), and that the in-game data is very rich when it comes to measuring activity and progress. Game activities can also be specifically designed to collect data (for instance, the quiz described below). With the addition of Facebook demographic data, we can study our players by (at minimum) gender and age. However, in-game data is still limited: both the PI and evaluator agreed that interview data would be necessary to fully probe the player experience. In addition, ongoing privacy concerns by Facebook users lead to periodic (and unpredictable) tightening of the rules governing the data available to developers.

Of the challenges, probably the most difficult lies in the nature of the game. The intent is for players to engage for long periods, which means that traditional focus groups are of limited use (though still useful for testing the general interface, playability, etc.) Furthermore, only a fraction of the players stays with the game for an extended period. This means that if we want to specifically address the effects of longer term play, we need to target those players after the fact in-game, and then encourage them to respond to surveys or interview requests.

All of this lead us to build an evaluation strategy around four primary data sources:

- Game data. The game is heavily instrumented in order to provide evaluation data at a variety of levels, including player counts, Feats achieved, time spent in game, etc. For Facebook players, this data is supplemented with age and gender information.
- Online surveys. Designed by our external evaluator, players were recruited for these surveys using popups from within the game. This allowed us to target specific audiences: for instance, a recruiting popup could be generated if a player came back for at least one day after completing the game tutorial.
- An in-game quiz. Designed to appear as just another part of the game, this quiz was populated with a mix of general science and pop culture questions; science survey questions with documented results for the general population (National Science Board, 2014; LoPresto, and Murrell, 2011); and questions that specifically targeted content knowledge that could be acquired through playing the game. These last questions could be triggered by the game based on a series of pre/post criteria, allowing us to look for potential content knowledge gains.
- Phone interviews. As with the online surveys, players were recruited using popups within the game, allowing us to ensure that they had actually played the game for a reasonable amount of time. Interviews require contact information, so these players were offered gift card incentives to participate in the interview process.

Results

Who's Playing

Facebook data indicates that about 3/4 of the players are male. The age distribution is quite broad, with a quarter of the players under 19, and 30% over 35. Since Facebook limits participation to users 13 and older, the non-Facebook contingent (approximately half the player population) may well skew younger. Results from the game's quiz questions on general science knowledge indicate that our players are significantly better informed about science than the general public. This last result is particularly relevant for an informal educational game, since our content gains are going to be influenced by our players' prior knowledge. For instance, news reports are fond of citing that a quarter of the American public doesn't know that the Earth revolves around the sun (National Science Board, 2014). However, virtually all of our players already know this coming into the game, so we can't expect content gains in this area.

In addition to being well informed about science, the online survey results indicate that players see themselves as science interested and literate. Nearly 90% were interested in learning more about space science, and enjoyed learning about new scientific discoveries or inventions. Over 50% said other individuals would describe them as a “science person”. This “science person” view is reinforced by the in-game quiz. Two of the quiz questions in particular are more accurately described as relating to “worldview”, rather than content knowledge: whether the universe began with the Big Bang, and whether humans evolved from simpler lifeforms. These questions have some of the largest differences between the general population and our players, suggesting that the game is selecting for science minded people, not just knowledgeable ones.

What are they doing?

Overall, a quarter of players come back for a second day, with a significantly higher rate for Facebook versus non-Facebook players (see Figure 2). That initial rapid drop-off is followed by a much flatter curve: of the group that returns, half come back at least a third day, and 20% at least 10 days. This type of progression appears to be typical for this class of game (Trefren, 2010). Play time can also be stretched out over a long period (relative to traditional education games): half of those who returned to the game at least once spent a minimum of 12 days between start and finish. Finally, there is also a significant difference between people who log in through Facebook, and those who do not: Facebook players on average return to the game at almost three times the rate.

Beyond simply measuring time spent playing the game, we can look at the number and type of Feats achieved to get a sense of engagement. For our purposes we use the “Goldilocks” Feat (place a terrestrial world in the habitable zone of a K0 star) as a threshold. This is somewhat arbitrary, but the concept of habitable zones -- the region of a solar system where planets could support liquid water and, presumably, life -- represents a core piece of content for the game. Succeeding at this Feat also indicates that a number of prior steps have been taken (20 Feats, on average). Around 20% of the players that complete the tutorial eventually complete the Goldilocks Feat, suggesting reasonably deep engagement with the game.

What are they learning?

A number of the in-game quiz questions were specifically designed to perform a pre/post assessment. For instance, for the question “what can prevent a moon from forming?”, players are either asked prior to attempting to place a moon (forming the “pre” cohort), or after successfully placing a moon (forming the “post” cohort). A given player is not asked a question twice. Since the conditions that define pre and post can create narrow windows when the question can be triggered, the number of players in each cohort varies dramatically. Nevertheless, this approach produces a number of interesting results:

- As mentioned previously, strong prior knowledge by the players can create a ceiling effect. This is most obvious in the “Does the earth orbit the sun” question taken from the Science and Engineering Indicators survey (National Science Board, 2014). Over 95% of players could correctly answer this question even in the “pre” cohort, leading to no significant difference in the “post” cohort.
- Gains of up to 20 percentage points were seen in questions directly relating to game content: e.g., “What is a possible color for a star” (+20%), or “What can prevent a moon from forming” (+21).
- Two questions specifically relating to time scales (“Which mass stars live longest”, and “What takes longest” in the evolution of a habitable world) produced little or no gains. It may be that players do not recognize that elapsed time in the game is representative of elapsed time in the real world, even in a relative sense of “which takes longer”. If so it’s unfortunate, since it was one of the more appealing elements of this game model. Future iterations of the game could place a greater emphasis on the elapsed time to focus on this issue.

Lessons learned (and would we do it again?)

From the perspective of a producing an educational game, the answer is qualified yes. The game showed reasonable success at meeting its goals. Players engaged for long periods, and some content gains were seen. Furthermore, the difference in play patterns between Facebook and non-Facebook players reinforces the idea that the Facebook creates specific affordances for certain types of games: to the extent that your content fits these game frameworks, it could be a productive platform.

There are a few caveats, however. First, these types of games tend to come with expectations of indefinite play. We periodically receive feedback from players who have completed every possible Feat and are requesting even more gameplay. For grant funded game development projects, this can be unrealistic. In addition, competing in environs such as Facebook can imply the use of specific strategies that may be seen as distasteful. Our team was unenthusiastic about many of the aggressive click-bait and advertising strategies often used to acquire players and visitors. Adopting a position of "Don't be evil" is laudable (and possibly a requirement of grant funded work), but it may restrict your game's growth.

The research and evaluation perspective is somewhat different. When we originally conceived the project, the idea of evaluating an educational game for Facebook promised a wealth of potential user data well beyond what is presented here. The developer is, however, entirely dependent on Facebook for that data. Over the course of the game development we found some of the data access rules tightening, and by the time the summative evaluation was in play it became clear that it would be a struggle to gain access to everything we might want. In principle these are solvable issues: shorter time scale development (so that data access requirements did not shift), or even using an existing game for research purposes, would decrease the risk of having data access problems.

We close with a note from the player interviews. Several of the players indicated that they were specifically looking for a game of this type: something science based that they could learn from. This "attracting the choir" effect may impact the content goals of the project, but it also indicates an active desire on the part of the public for educational games. Given that some developers argue for trying to sneak educational contest past players unawares, it may be helpful to reinforce the idea of games that openly declare their goals and invite the player to learn while they play.

Figure 1: Main game screen, showing a ringed planet. Ring gaps are generated programmatically based on the locations of the moons (visible at the upper right of the rings).

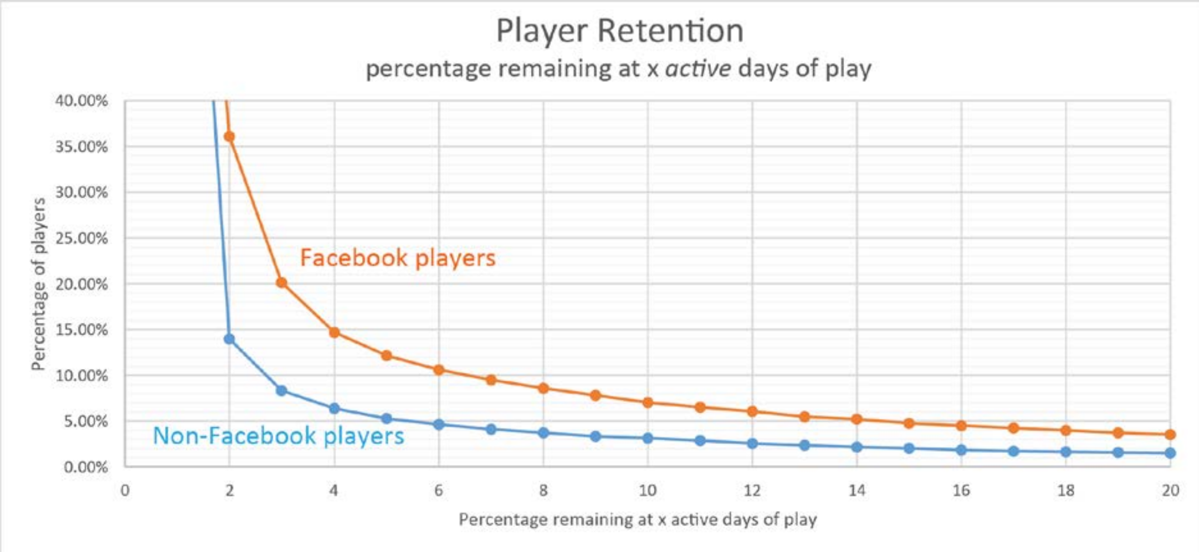

Figure 2: Player retention by time. This tracks only days in which the player touched the game, not total elapsed calendar time.

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