AN ANALYSIS OF PLAGUE, INC.: EVOLVED FOR LEARNING

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Do you think you can design a pathogen that will eliminate all of humanity? That question is the premise of the game *Plague, Inc.: Evolved.* Developed by *ndemic Creations* and early-released in 2014, this game is the computer version of the popular app, *Plague, Inc.* The gameplay is simple: Choose a pathogen to play, collect DNA points, mutate the pathogen, and try to kill all humans before they develop a cure. The learning potential of the game includes problem-based learning, model-based reasoning and creativity. The first two are possible because the main gameplay follows the key components of rational constructivism (Newcombe, 2011; Xu & Griffiths, 2011); the last is possible because the scenario creator embedded in the game supports all four types of creativity as described by Elliot Eisner.

Gameplay

Currently, *Plague, Inc.: Evolved* is a single-player game, although multi-player capabilities are in development (Vaughan, 2014). The primary gameplay uses "god view", where one can manipulate the pathogen and monitor the world's reactions. To begin, one either selects the type of pathogen to play, such as

bacteria, or selects a scenario to follow, such as the black plague. The game then shows a map of the world, including major ports, airports, and travel routes. Around the border of the map are information boxes which lead the player to more information about the pathogen or the global response. As the pathogen infects more people and spreads to different countries, red and orange bubbles appear on the map. Popping these bubbles allows the player to collect "DNA points" to use towards mutating the pathogen. The game provides three categories for mutation options: "Transmission" to adjust how the disease spreads to other countries, "Symptoms" to adjust how the human body reacts to the disease, and "Abilities" to adjust the disease's hardiness in various environments. Some pathogens and scenarios have additional mutations specific to their aims. For example, the "necroa virus" includes mutations for creating and controlling zombies and the "frozen virus" scenario allows the pathogen to devolve humans into Neanderthals.

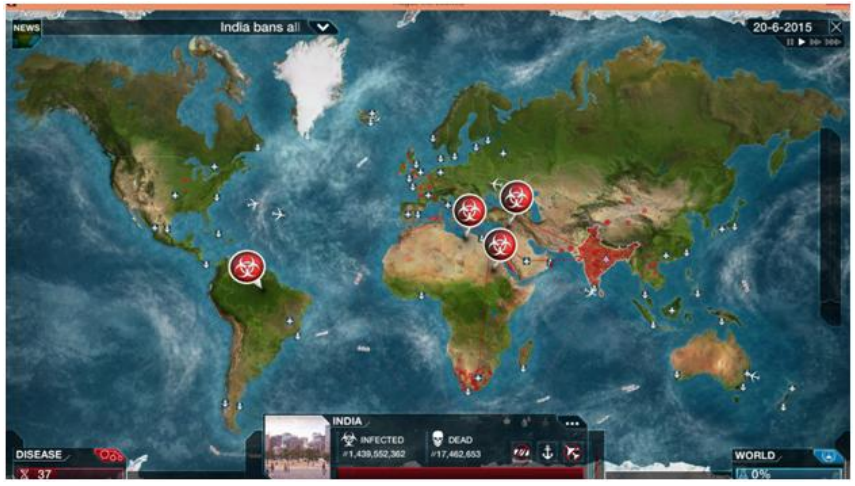

Figure 1. Main game screen showing travel routes, basic game information, and opportunities to collect "DNA points."

As the player develops the pathogen into deadly proportions, there are three main challenges to overcome. The first challenge

concerns the disease spread. Countries with less-traveled ports are difficult to infect. Countries with strong healthcare systems prevent the spread of the disease once it crosses the borders. As the disease becomes more deadly, countries begin closing their borders and isolating the infected. The second challenge is having too deadly of a pathogen. If the disease kills all of its hosts before it infects every human, it burns itself out and the player loses. The third challenge is the global cure effort. As the disease infects more countries and people, these countries begin researching a cure. Once the cure is developed, it is quickly deployed throughout the world. Unless the player has zombies from the "necroa virus" or aggressive apes from the "simian flu," the cure reaches all living humans before the pathogen can kill them.

Plague, Inc.: Evolved has also incorporated "mods" into its main gameplay. Instead of choosing a pathogen or scenario to play, the main menu allows the player to create a custom scenario and modify most of the aspects of the game. Set as various "labs," players can create their own mutations and progressions for mutations, change attributes for various countries, create and modify how governments will react to the pathogen, add events that can drastically alter game play, and include alternate win conditions. Visual aspects of the game may also be modified, such as adding custom graphics. Special skills, such as programming abilities, are not required because the look and feel of the scenario creator is similar to that of the game itself. Players select or add a game attribute then adjust its corresponding variables, which are listed and include the range of possible values. Although the user-friendly interface may restrict the possibilities for player modifications, it may also increase the number of players who want to try "modding" a game. Players may then play the custom scenario and/or upload it to the game community.

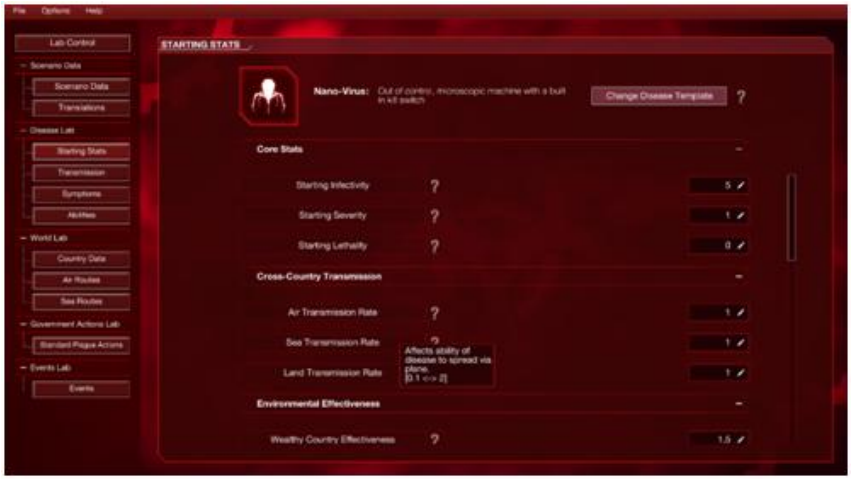

Figure 2. The scenario creator.

Community

Plague, Inc.: Evolved has two main gaming communities. The first, as mentioned above, is the community surrounding the custom scenarios. Player-created scenarios are uploaded to a common location accessible from within the game itself. These scenarios are often based on news stories, books, or movies. For example, one player-created scenario is based on the science-fiction movie, *The Day of the Triffids* (1963), where most of the population becomes blind and mobile plants attack them. Participants in this community rate each other's scenarios using a simple like/dislike system; results appear as a five-star quality rating system. No other feedback or discussion is possible in this community. In the *Steam* community, however, players engage in several discussions. The general discussions are separated into four sections, English, French, Russian and German, and typically address gameplay, questions for the developers, and the sharing of fun things players have done with the game. A separate section in the community is for discussing the scenario creator, where players share knowledge and questions about modifying the game. Participants in the discussions are identified by their

user name, but there is no designation of who is "expert" or "novice," although the game developers, who are active participants in the community, are identified as such. Also within the *Steam* community are areas where participants can share screenshots and fan-generated artwork.

Game analysis

To understand *Plague, Inc.: Evolved* in more depth, the *MDA Framework* (Hunicke et al., 2004) will now be applied to the game. The *MDA Framework* considers how games are consumed and decomposes them into three components: mechanics, dynamics, and aesthetics. The mechanics describe the rules, algorithms, and data management in the game. The dynamics describe the behavior of the game as a result of player inputs and game outputs. The aesthetics describe the player's experiences on an emotional level. Together, these three components describe the interactions between the player and the game.

The mechanics of *Plague, Inc.: Evolved* are algorithms based on real life which were then modified to create a game-like experience. Creator James Vaughan entered publicly available information on epidemiology and economics into a spreadsheet, where he determined their trends and interactions with other variables (Gera, 2013). He then modified the equations to create the game. For example, he weighted the game in favor of the pathogen. In order for the game to be playable, Vaughan adjusted the infection speeds, made every human vulnerable, and allowed simultaneous mutations (when the pathogen mutates, all infected people receive the mutation) (Rath, 2013). The most significant advantage to the pathogen that Vaughan added, however, is that the player controls the mutations rather than waiting for random events.

The dynamics of the game uses a simple real-time interface. The game shows the disease spread by plotting red dots on a map

of the world and by reporting the infection and death rates at the bottom of the screen. As the disease infects more people, red and orange bubbles appear on the map. Red indicates infection in a new country and orange indicates increased infection within a country. The player accumulates "DNA points" by clicking on these bubbles. The player may use these points to mutate the pathogen by opening a separate screen, selecting a mutation, and clicking the "Evolve" button. The global cure effort is summarized in a bar on the main screen as well. The player can find more detailed information about countries, the global cure effort, and governmental response to the plague through additional screens. This information enables the user to make educated decisions about which mutations to select. Additional information that may affect infection rates, such as a country closing its borders, or the cure effort, such as a government falling into anarchy, appear as news headlines.

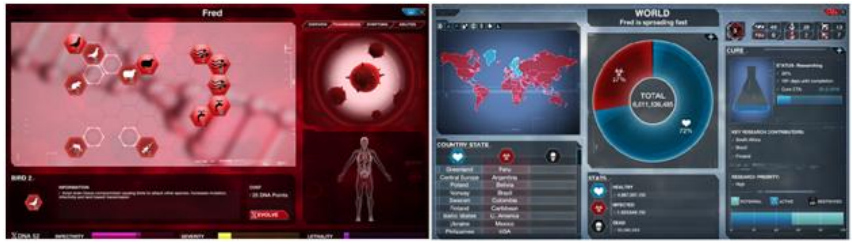

Figure 3. The mutation screen for a disease named "Fred" and the world screen showing the global response.

Being a strategy game, the primary aesthetics are challenge and discovery. The challenge arises from trying to select mutations in such a way as to maximize the infection rates while remaining undetected or while retarding the cure effort. If the pathogen spreads too quickly, governments close their borders and focus on developing a cure. If the pathogen becomes too lethal before infecting everyone, it dies out. The discovery aspect develops as the player experiments with different mutation combinations. Formal discovery happens when the player chooses certain

combinations of symptoms and receives clear and immediate feedback from the game. These combinations trigger a pop-up message, affect gameplay, and can potentially unlock an achievement badge. For example, choosing the insomnia and anemia symptoms results in the "Walking Dead – Insomnia and Anemia are causing people to walk around grey with tiredness." message, slows the cure effort, and unlocks the "Brainzzz" achievement. Informal discovery happens as the player tried to find the best combination of mutations to achieve short-term goals and needs to monitor the relevant data in order to determine if a goal was reached. The emotional response of the player fluctuates between challenge and discovery throughout the game as the player tries to achieve short- and long-term goals. For example, a player may decide to try and infect Greenland (challenge), realizes that Greenland has a shipping port (discovery), theorizes which mutations increase boat transmissions (discovery), only to learn that Greenland has closed its port (challenge).

Learning potential

When playing a video game, players attempt to develop a mental model that is similar to the actual programmed model of the game (Boyan & Sherry, 2011). These mental models are dynamic representations of situations in a real or imaginary world and may include spatial relationships, systems comprehension, deductive reasoning, and/or a representation of what the situation is about (Roskos-Ewoldsen, Davies, & Roskos-Ewoldsen, 2004). Players create mental models to account for the game's challenges and use trial and error to refine their model, so when the game's challenges include educational content, players create mental models of the educational content while creating a mental model of the game itself (Boyan & Sherry, 2011).

This process of refining mental models through trial and error may help explain some of the reported educational benefits of

Plague, Inc. The Center for Disease Control supports *Plague, Inc.: Evolved* as a tool for teaching people about outbreaks and disease transmission (Khan, 2013; Tirrel, 2013). Parents report an increased interest in hand washing and geography in their children who have played the game. Educators and PhD students are using the game as a tool for investigating infectious diseases and economic models (Rath, 2013; Tirrel, 2013). To further understand how people are learning from the game, I will analyze how I and two other players have learned from playing, apply a theoretical framework to this analysis, and extend that framework to describe the learning potential of this game.

My background is in mathematics and computer science, so the first thing I noticed while playing the game was the logistical growth curves happening as people became infected, as my disease spread to other countries, and as the cure effort got underway. Repeated playing of the game found me trying to adjust those curves by selecting various combinations of mutations that I thought would give me the best chance. My decisions were based on probabilistic reasoning; I found that focusing on symptoms increased the chance of the plague burning itself out while focusing on transmission decreased the chance of a country closing its borders before I could reach it. During this process, my geography knowledge, previously a weakness of mine, increased as I tried to reach particular countries. I was asking myself, "Where is Bolivia and what kind of climate does it have?" In a similar fashion, my science knowledge increased. Knowing the geography and science helped develop my mental model and increased my probabilistic reasoning, allowing my decisions to be more sophisticated.

I observed two other people play this game. One is a retired engineer and the other is in the golf industry. Both are self-described visual learners who think aloud while they play. They each began not with mathematical mental models but with spatial models; they quickly noticed the transportation paths on

the map and chose mutations to increase the probability that these paths would carry their plagues. They also learned science and geography as they engaged in repeated play and used this knowledge in their decision making. One of them also recognized some of the economic models in the game. As a result, I was able to observe them developing their mental models and reasoning in a similar fashion as I did even though their models were dissimilar to mine.

The theory that describes the learning that the three of us experienced is rational constructivism, sometimes known as neo-constructivism. It states that humans have a natural ability to compute probabilities, which they apply to a complex world in order to select or integrate multiple cues and to draw conclusions (Newcombe, 2011; Xu & Griffiths, 2011). Learning is a form of Bayesian inference, where the learner constructs a probability distribution over a set of hypotheses and use experiences to increase or decrease confidence in each hypothesis by constructing and adjusting mental models. Because experience affects the learner's probabilistic reasoning, action is crucial to learning; it helps develop domain-general knowledge into domain-specific knowledge (Xu & Kushnir, 2012).

In strategy games such as *Plague, Inc.: Evolved*, players strive for a condition known as the Nash equilibrium, a state in which each player choses an optimal strategy based on the actions of other players (Lonbørg & Weisstein, 2014). In order to achieve equilibrium, however, players must engage in repeated play. Doing so creates information that the player then uses in probabilistic decision making (Sanchirico, 1996). *Plague, Inc.: Evolved* enables this process by providing the player with a model that represents the scenario and that the player needs to actively interact with. This model is an *idea model* in that it illustrates key concepts and allows the player to create a mental model and use game play to develop deeper understandings of that model

(Squire, 2011). As the player accumulates information, like the key characteristics of Greenland, she is able to apply strategies that take advantage of that information, such as increasing the cold tolerance of the pathogen. This domain-specific knowledge happens through active participation with the game: looking at a nation's information screen, monitoring world data, investigating possible mutation combinations. The result is that repeated play of *Plague, Inc.: Evolved* creates more sophisticated mental models which enable stronger probabilistic decision making, which is the foundation of rational constructivism. With each game taking about an hour to complete, repeated play is easy to achieve.

Plague, Inc.: Evolved supports problem-based learning. Although the game has only one win-condition, kill humanity, there are multiple paths possible for achieving that win condition. The enjoyment comes from trying to discover creative ways to reach that condition, something possible only from learning the underlying properties of the system itself (Squire, 2011). This game also supports model-based reasoning. The data produced by the underlying algorithms are easily available to the player, encouraging them to produce mental models of the system, such as the logistic growth curves, even when they do not know the formal terms for their models. Educators are already using this game for model-based reasoning in economics and biology (Khan, 2013; Tirrel, 2013); extending the applications of this game into mathematics could also help students better understand exponential and logistic growth.

The scenario creator

The potential for learning within the scenario creator for *Plague, Inc.: Evolved* is different than that found in other video games' modding environments. The modding engines provided with *Civilization, The Sims,* and *Warcraft III* have been shown to be useful tools for introducing players to introductory computer

science topics and programming (El-Nasr & Smith, 2006; Hayes & King, 2009; Squire, 2008). The scenario creator in *Plague, Inc.: Evolved* is not as useful of a tool for learning computer science. Most of the modifications allowed are simple variable adjustments; the user chooses which attribute to modify then changes the values of the variables that the scenario creator provides for that attribute. The "Events Lab" section of the scenario creator offers users more flexibility by allowing them to create events using a very simple scripting tool, but the tool is too simple to be used as a means of learning basic programming.

Kurt Squire's (2008) work with *Civilization* has also shown that modding that game allowed players to deepen their knowledge about a particular culture or event in history. In a similar fashion, the scenario creator in *Plague, Inc.: Evolved* can be used to explore biology, economics, and geography. For example, players quickly learn that Canada is a difficult country to fully infect with a pathogen. Modifying the variables associated with Canada in the game allows players to explore whether the country's climate, population, or wealth has a higher impact in preventing disease spread. The scenario creator is simple to use for anyone familiar with the game itself, which may increase the number of players who experiment with designing. The level of realism possible in a custom scenario is limited, however, because of the limited number of variables one can change. For example, a recent discussion thread on the game's *Steam* community concerned possible "work-arounds" to simulate population growth.

Although the main game play has limited opportunities for creativity, the scenario creator affords several opportunities for several types of creative expression. Elliot Eisner (1966) describes four types of creativity: boundary pushing, inventing, boundary breaking and aesthetic organizing. Boundary pushing, the process of extending or redefining the limits of a system or object, happens in the scenario creator when the player extends the effects of various symptoms or redefines the capabilities of a

particular pathogen. Inventing, the process of restructuring the known in order to create something new, happens when the player creates mutations and events that were not previously found in the game or in the real world. Boundary breaking, the rejection or reversal of accepted assumptions, can happen when the player modifies the game world, like changing the win conditions or the climate of different countries. Aesthetic organizing, the process of placing order and harmony on a system, can happen when the player designs the scenario to tell a story or recreate an event. In addition to Eisner's four types of creativity, artistic and written creativity are possible in the scenario creator; players can include their own images and text in their creation. Therefore, creative expression is likely the strongest learning potential found within *Plague, Inc.: Evolved*'s scenario creator.

Conclusion

Being a strategy game, *Plague, Inc.: Evolved* is a natural environment for problem-based learning. It allows multiple solutions for reaching the win condition. By providing a visual model in real-time as well as ample data about the plague and the world's reactions, this game also supports model-based reasoning. Like the app it was developed from, *Plague, Inc.*, this game provides a good example of rational constructivism, the use of mental models and probabilistic reasoning. By adding the scenario creator to the computer version of the game, it has extended the learning potential to include creativity. Players can develop scenarios by using any of Eisner's types of creativity. The multi-player capabilities should be released in 2015. It is to be expected that this upgrade will extend the learning potential to include aspects of social constructivism as well.

References

Boyer, A. & Sherry, J. (2011). The challenge in creating games

for education: Aligning mental models with game models. *Child Development Perspectives, 5*(2).

Eisner, E. (1965). Children's creativity in art: A study of types. *American Educational Research Journal, 2*(3), 125-136.

El-Nasr, M. & Smith, B. (2006). Learning through game modding. *ACM Computers in Entertainment, 4*(1).

Gera, E. (2013). How to design a plague. *Polygon.* Retrieved from http://www.polygon.com/features/2013/11/10/4864278/plague-inc-james-vaughan.

Hayes, E. & King, E. (2009). Not just a dollhouse: What The Sims2 can teach us about women's IT learning. *On the Horizon*, *17*(1), 60 – 69.

Hunicke, R., LeBlanc, M. & Zubek, R. (2004). MDA: A formal approach to game design and game research. *Proceedings of the AAAI Workshop on Challenges in Game AI*.

Khan, A. (2013). Plague, Inc. *Center for Disease Control and Prevention: Public Health Matters Blog.* Retrieved from: http://blogs.cdc.gov/publichealthmatters/2013/04/plague-inc

Lonbørg, A. & Weisstein, E. (2014) Nash Equilibrium. *MathWorld—A Wolfram Web Resource*. Retrieved from http://mathworld.wolfram.com/NashEquilibrium.html

Newcombe, N. (2011). What is neoconstructivism? *Child Development Perspectives, 5*, 157-160.

Rath, R. (2013). The pathology of Plague Inc. *The Escapist.* Retrieved from: http://www.escapistmagazine.com/articles/view/video-games/columns/criticalintel/10333-The-Pathology-of-Plague-Inc

Roskos-Ewoldsen, B., Davies, J. & Roskos-Ewoldsen, D. (2004).

Implications of the mental models approach for cultivation theory. *Communications, 29,* 345-363.

Sanchirico, C. (1996). A probabilistic model of learning in games. *Econometrica, 64*(6), 1375-1393.

Squire, K. (2008). Open-ended video games: A model for developing learning for the interactive age. *The Ecology of Games: Connecting Youth, Games, and Learning*, 167-198.

Squire, K. (2011). *Video Games and Learning*. New York: Teachers College Press.

Tirrel, M. (2013). iPhone app wipes out population to show contagion risks. *Bloomberg.* Retrieved from: http://www.bloomberg.com/news/2013-11-11/iphone-app-wipes-out-population-to-show-contagion-risks.html

Vaughan, J. (2014). Plague, Inc.: Evolved announcements. *Steam Community.* Valve Corporation. Retrieved from http://steamcommunity.com/app/246620/announcements.

Xu, F. & Griffiths, T. (2011). Probabilistic models of cognitive development: towards a rational constructivist approach to the study of learning and development. *Cognition, 120* (2011), 299–301.

Xu, F. & Kushnir, T. (2012). Preface. *Advances in Child Development and Behavior, 43.* pp. xi-xiv.