Breeding Dragons for Learning Genetics: Redesigning a Classroom Game for an Informal Virtual World

Yasmin Kafai, University of Pennsylvania
Cynthia McIntyre, Concord Consortium
Trudi Lord, Concord Consortium
Paul Horwitz, Concord Consortium
Jennifer Sun, Numedeon Inc
Mark Dinan, Numedeon Inc
Daniel Kunka, Numedeon Inc

Introduction

Serious gaming research is leveraging the principles gained from playing digital games for learning games in schools (Gee, 2003). Hundreds, if not thousands, of educational games and simulations have been designed to support learning (e.g., NRC, 2011; Squire, 2011). A recently completed meta-review was cautiously optimistic about the benefits of digital games to promote competencies and pointed out the need to better understand particular gaming designs and scaffolds for learning (Clark, Tanner-Smith, Killingworth, & Bellamy, 2013). Virtual worlds can provide such designs in the form of environments that simulate historical or fantasy contexts to engage and support students, alone or in teams, in various aspects of science inquiry. Several of the virtual worlds designed for use in science classrooms have demonstrated promising learning and motivation outcomes when compared to conventional instruction (for an overview, see Dawley & Dede, in press).

Outside of schools, however, it's a different story when virtual worlds are used for learning purposes, not only because of the voluntary nature of participation, but also because of the significantly larger number of participants (Kafai & Dede, in press). Virtual worlds are among the fastest growing online communities, and younger players in particular have adopted virtual worlds such as *Club Penguin*, *Habbo Hotel*, *Minecraft*, *Neopets*, and *Whyville* as their new playgrounds, reaching hundreds of millions of participants, far more than their adult counterparts (Grimes & Fields, 2012). Research suggests that informal virtual worlds can provide rich learning opportunities for science inquiry and science conversations, for instance, when players not only experience, but also study epidemic outbreaks in real time (Kafai & Fefferman, 2010). While such epidemic simulations engage large numbers of participants, players also benefit from having access to tools such as simulators that support and direct further science inquiry. The challenge, then, is to figure out how to combine and leverage the best of both worlds: the structured and guided activities found in many school virtual worlds with the voluntary and social participation found in informal virtual worlds.

In this paper, we address this challenge by examining the redesign of an established classroom simulation called Geniverse for integration into an informal, virtual world called Whyville. In Geniverse students breed dragons to learn about genetics in a game-like environment that helps them to see biology as an active, inquiry-driven enterprise and enables them to interact as scientists and build essential skills and understandings both in genetics content and in the nature and process of science (Horwitz, Gobert, Buckley, & O'Dwyer, 2009). While the virtual word Whyville.net already offers many science games and activities to its currently more than 7 million registered users—predominantly girls (77%) between the ages of 8 and 16—the integration of Geniverse could provide additional opportunities for online players to engage in learning genetics. Our central research question was: Could the integration of an instructional tool developed for the more formal environment of classrooms be successful in the informal environment of a virtual world? To answer this question, we examined two levels—participation and play—in breeding dragons and learning about genetics in Whyville. The first level focused on understanding the nature of participation: *Do Whyvillians visit the dragon labs and lairs? Who comes? How much time do they spend using Dragons?* The second level focused on understanding the nature of play: *How many labs and lairs do they visit? How many dragons do they breed?* We used a combination of different data sources, including log files and pre/post surveys to examine how Whyvillians participated, played, and learned about genetics by breeding dragons. In the discussion, we address the quality of participation and learning about genetics in informal virtual worlds, how science inquiry software tools that previously only were used in teacher-scaffolded and supported classrooms can be redesigned for use in more informal virtual learning contexts such as Whyville, and next steps for further research.

Background

Virtual worlds enable participants to simulate economic, social, and scientific phenomena to explore various issues (Bainbridge, 2007). The immersive nature of virtual worlds also supports social interaction, identity exploration, and motivation because players can decide how to explore the environment, which avatars to interact with, and what to do rather than follow a pre-designed path (Boellstorff, 2008). Virtual worlds designed for use in science classrooms such as *EcoMUVE*, *Quest Atlantis*, and *River City* have incorporated many of these features and have demonstrated promising learning and motivation outcomes compared to conventional instruction (Barab, Scott, Siyahhan, Goldstone, Ingram-Goble, Zuiker, & Warren, 2009; Dede, 2009; Metcalf, Kamarainen, Grotzer, & Dede, 2012). These school-based versions, however, often lack some of the key features, in particular the voluntary and open-ended nature of participation and learning found in the massive informal communities, as well as the social and economic dynamics that are essential dimensions of interactions in informal worlds. In the case of *Whyville*, players can accrue virtual "currency" by playing science games successfully, currency that they then can use to accessorize their avatars and socialize with others (Kafai & Fields, 2013), thus combining social and educational play.

Most research on informal worlds has focused on science inquiry and learning by engaging players in educational science games or by initiating scenarios that invite scientific investigation and leverage the massive number of participants (Kafai & Fields, 2013). For instance, the launch of a virtual epidemic in *Whyville* provided a compelling context for players to learn about infectious disease inside of classrooms with the guidance of teachers (Neulight, Kafai, Kao, Foley, & Galas, 2007), as well as outside of classrooms using simulators and discussion forums to engage thousands of online players (Kafai & Wong, 2008). The epidemic simulators within *Whyville* allowed players to experiment with different parameters and make predictions about the spread of infection while they were experiencing in real time the outbreak among their avatars. A more in-depth study of a simulation tool also revealed that players on their own became engaged in systematic iterations rather than random experimentation (Kafai, Quintero, & Feldon 2010). This successful integration and use of epidemic simulators suggests that other instructional tools such as the genetic simulators previously only used in classroom settings could be integrated into virtual worlds.

Genetic simulators such as Geniverse build on a long legacy of educational technology developments, starting with GenScope in the early 1990s, that recognize the importance of teaching students about the relationships between phenotype and genotype (Horwitz, Gobert, Buckley, & O'Dwyer, 2009). Learning about genetics is an increasingly important area of K-12 science education for personal and political reasons with the availability of genetic testing for the public, the use of genetics for medical care and ethical considerations, and political discussions around genetically modified food. But teaching genetic principles is not so straightforward. Instructional interventions have focused on providing hands-on experiences, insofar as it is possible, or using simulation tools. For instance, Fast Plants allow students to study breeding and development within rapid cycles to help them better understand inheritance principles (Williams, Debarger, Montgomery, Zhou, & Tate, 2012), while online simulators such as Geniverse help students understand key principles of genetics and make the impossible possible by allowing students to peer into chromosomes, control meiosis, and change the alleles of virtual genes. As surprising as it may be, dragon breeding offers an authentic context for learning about genetics: for one, dragons are used as a simplified model organism, based on real genes, to examine different traits, and the fantasy context of dragons offers the narrative thread common in many gaming contexts. Students breed dragons and observe how the offspring's genotype affects its appearance, or phenotype. As they move through the Dragons game they must choose trait variants for parents that will result in a prescribed set of traits in the offspring. These initial activities familiarize students with the basic dragon traits and their mapping to genes, testing student understanding by having them manipulate the genes of one dragon to match a target dragon. In studies of high school classes, using Geniverse has been found to be successful in helping students learn about key genetic ideas (Reichsman & Lord, 2012). In all research done so far, a teacher trained in facilitating the use of Geniverse in the classroom has been present. In adapting Geniverse for Whyville, we considered the absence of a teacher and designed a game called Dragons that provided many, but not all, of the same features found in Geniverse with added support for independent use. To understand if, and how, these new features of Dragons were successfully integrated in Whyville, we examined two different levels of engaging with Dragons and learning about genetics in Whyville. The first level focused on the participants and Dragons the nature of their participation, while the second level focused on understanding the nature of play with.

Context, Participants, Data Collection, and Analysis

Our study was conducted in collaboration with Numedeon, Inc., the company that hosts Whyville, performed the technical integration of Geniverse, and collected the tracking data and online surveys. After pilot testing with a select group of experienced Whyville players, we launched the Dragons game in August 2013. We released Dragon

activities to the Whyville community in two stages. The first stage offered a subset of labs and lairs that focused on basic dominant/recessive traits; the second stage introduced more complex patterns of inheritance. Currently, Dragons offers 37 activities: 21 labs and 16 lair challenges (see Figure 1).

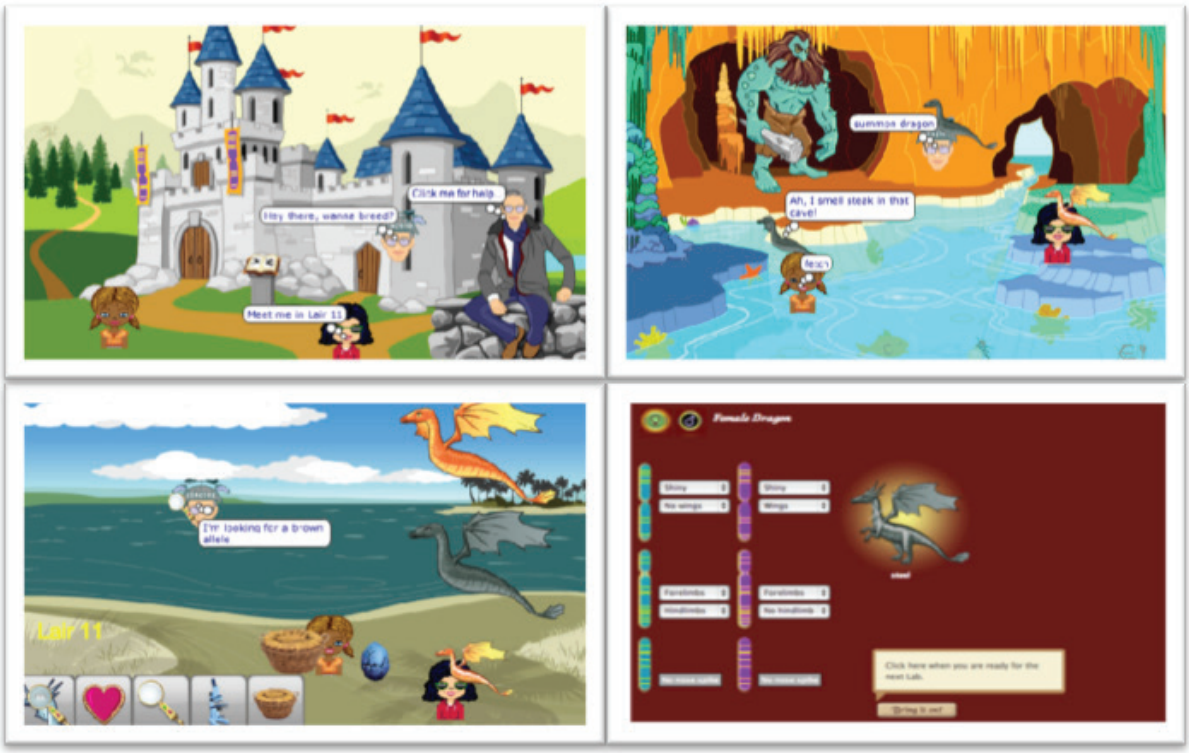

Figure 1: Clockwise from upper left: Dragon Castle where players can enter the lairs or labs, or check their progress in the Dragon Book. Players meet in the Grotto to fetch their treasures. Lab challenge illustrates how a change in genotype may affect the phenotype of the dragon. Players breed their dragons in a lair.

Players start Dragons with a tutorial that introduces them to the process of breeding dragons and the different interface elements. Through a series of guided challenges, players learn how to scope a dragon's chromosomes, reveal the alleles in an unhatched egg, hatch a dragon, and breed their dragon with other dragons. Once players have completed the tutorial, they are sent to the Dragon Castle where they can begin solving Dragon challenges in the lairs (where the wild dragons roam) or delve more deeply into dragon traits and inheritance through the Dragon labs. As players complete each challenge and lab, their progress is recorded in their Dragon Book, which includes all available Dragon activities. The Dragon activities are listed by level of difficulty, though players can attempt them in whatever order they choose. As players move through 16 challenges, they are presented with progressively more complex patterns of inheritance such as incomplete dominance, sex-linkage, and polyallelic traits. Each challenge focuses on a specific concept and has one or more labs associated with it. The labs provide highly scaffolded, game-like challenges that highlight genotypic to phenotypic relationships, the process of meiosis and fertilization, and the selection of parents based on the need for certain alleles in a pool of offspring. Labs provide players with both instruction and feedback as they introduce the new alleles and patterns of inheritance that players must understand to complete the lair challenges.

In Dragon challenges, players are asked to produce a dragon with a specific set of traits that will enable it to fetch treasure. For instance, to find a dragon that can fly to the top of a palm tree and grab the golden coconut, players must enter a lair where dragons have the alleles needed to produce wings and arms. While the labs are single-player activities, players can work alone or collaborate in the lairs to breed offspring that have the required traits as lairs are essentially Whyville "chat rooms" that support multiple player interactions. Within each lair, individual players can perform several actions. They can use the scope tool to examine the chromosomes of the parent dragons living in that lair, or they can scope an egg produced by two parents, before it hatches, to examine the offspring's alleles and determine if it will have the trait(s) they need. A player is not allowed to take a dragon once it has hatched and its phenotype is revealed. A player can also bring his or her own dragon (whose phenotype—and even genotype—they know) into a lair and breed with one of the resident dragons. This is especially helpful when

the challenge requires genetic material from dragons residing in more than one lair (not all alleles are present in the resident dragons of every lair). Finally, a player can breed his or her dragon with another player's dragon. In pilot testing, it was not uncommon to hear one player say to another, "Come to Lair 5 and breed with me, I have a nose spike!" Each challenge ends with fetching treasure that is hidden throughout the Whyville virtual world in popular chat rooms frequently visited by Whyvillians like the beach, grotto, or waterfall. Once in these locations, a player can summon their dragon and fetch the treasure. All actions performed in these public areas are viewable by other players, providing "advertisement" for the Dragons game.

Our data collection included a variety of different measures from the following sources: (1) log files that recorded all Dragon-based actions of Whyville players, including information about locations visited in the labs and lairs, and chat content, and (2) online pre- and post-surveys. In September 2013, we released a pre-survey consisting of 13 items with one question about prior experience with genetics in school, five questions about interest in genetics with five-point Likert scales, five multiple-choice questions that presented various scenarios involving specific parental genetic traits, chromosomes, and results of breeding, and one open-ended response question. Two of the genetics content questions used hypothetical scenarios. Whyville players received 120 "clams" (Whyville currency) for answering the pre- and post-surveys. While 4,379 Whyvillian players answered the pre-survey during September - December 2013, we focused our analysis on the 1,265 players who did one or more Dragon activities such as completing a lab or visiting a lair. Seventy-four percent of this sample (or 937) were girls, representative of the gender distribution in the larger Whyville population. A preliminary examination of the player data revealed that participating users ranged in age from 8 to 99 years (!), a rather surprising range given that Whyville is most popular with a tween audience. The wide spread of age, however, was likely to be explained by some players not identifying their actual age when having registered on the site. At the time the analysis was conducted, not all players had completed the post-survey (these were made available only to players who had completed at least six challenges or labs), thus this section of our findings is based on a subset of 81 players who had complete pre- and post-surveys.

Findings

In the following sections, we present first main considerations in redesigning the classroom-based simulation Geniverse into Dragons for the virtual Whyville, then report on the nature of participation in Dragons, the nature of play in Dragon labs and lairs, and finally, players' interest and understanding of genetics.

From Geniverse to Dragons: Redesigning a Classroom Game

The Dragons activities borrow several key elements from the classroom game Geniverse, but also differ in terms of content design and coverage, player features and incentives, and the connection to the larger Whyville community. Like Geniverse, the "labs" in Dragons challenge individual players to solve genetics puzzles of increasing difficulty. Indeed, the labs are the portion of Dragons most similar to Geniverse. Dragons created in the labs do not persist in the rest of Whyville and cannot be "owned" by players. However, to integrate Geniverse into Whyville as the Dragons game, the content was reduced, covering only two-thirds of what is addressed in Geniverse. The reading level of the text was also adjusted for a middle school rather than high school audience. In contrast to Geniverse, Dragons also features "lairs" where multiple players can adopt "pet" dragons by gathering and hatching eggs. Players can only "own" one dragon at a time, which they can summon in any other location in Whyville. Each lair is home to a small group of resident male and female dragons, which differ genetically from lair to lair. By visiting several lairs and breeding their dragon judiciously with the resident ones, players can acquire a genetically diverse range of dragons. If two players occupy the same lair, they can also breed their dragons with each other in order to produce a dragon with traits useful in the greater Whyville virtual world—either for its intrinsic value to "show it off" or for the extrinsic value of fetching treasure.

The addition of lairs and the multi-player feature are unique to the Dragons game as is the access to the rest of Whyville, where players can use their dragons to obtain various treasures, but only if the dragon possesses the appropriate set of traits. As mentioned, a dragon with wings can fly up into a tree and grab a coconut while an armored dragon can brave falling rocks and retrieve a diamond from behind a waterfall. The challenge of Dragons, then, is to breed many different kinds of dragons that can retrieve treasures from different "rooms" in the greater Whyville virtual world. When players summon their dragon for this purpose they are in full view of any other Whyvillian in that room. This exposes non-players to the fact a "dragon game" is going on in other parts of Whyville, and encourages them to participate. These changes in the design were intentional to give Dragons a more game-like feel with incentives that mirror other Whyville games, leverage the massive and collaborative nature of Whyville activities, and embed instructional elements such as visualizing traits in lair activities.

Participation and Play in Dragon Games

The Dragons games were launched at the end of summer 2013 with an announcement on the main Whyville portal, along with an invitation to players to complete a short pre-survey in exchange for earning 120 clams. The visits to the Dragon game took off and lairs were visited by multiple players at the same time. The examination of log files revealed that the lairs received a total of 10,655 visits and a total of 8,350 dragons were bred by Whyvillians during this time period. Certainly, the rise in increase of certain terms in chat, such as "dragon" and "gene," is due to the presence of the Dragons game. Our further analyses focused on a subset of 1,265 players who chose to take the pre-survey and thus provided us with information about their interest in and knowledge of genetics.

Who came to play Dragons? Over the course of five months, 1,265 players visited a lab or lair. Of those, 937 were girls (74%) and 328 (26%) were boys, representative of the Whyville community at large. With approximately 20,000 active player visits in Whyville per month, the Dragons games reached about 6.3% of those players, most likely coming from the group of "core users" in virtual worlds (Kafai & Fields, 2013). The average self-reported age of the Dragons players was 19.9 years old, and thus far older than the average Whyville player who is around 12.4 years old. Because we know that players differ so dramatically in frequency of their activities (Kafai & Fields, 2013), we divided the 1,265 Dragons players into two groups: heavy and light players. Heavy players were those who successfully completed at least one lair challenge whereas light players might have visited multiple lairs or labs, but were never successful in completing a lair challenge. Boys and girls represented both heavy and light players at approximately the same ratios as throughout Whyville.

What did players do in Dragons? Of the 1,265 players, 390 completed at least one lair challenge, successfully retrieving a treasure while 363 completed a lab. Note that players did not receive clams for completing lair challenges; instead they received a "treasure" (e.g., magic chalice or diamond), which appeared in their Dragon books as a record of their accomplishment. Both labs and lairs were popular activities. Labs are single-player activities while lair challenges can be completed alone or with other players. Some players preferred one mode of play over the other while others participated in both equally. On average, players completed 3.3 labs and 4.9 lair challenges. Breeding dragons—to solve the challenges or to create a different "pet" as the reward—was an engaging activity for most players. Light players bred 3.3 dragon pets on average. Heavy players bred an average of 18.7 dragons. The maximum dragons bred by one player was 173!

Interest and Learning in Genetics

After all this activity in *Dragons*, what impact did it have on players' interest in and understanding of genetics? The assessment was divided into seven survey questions focused on background, motivation and attitude toward learning genetics and another six test questions focused on genetics content. The answers from the pre/post survey revealed that interest in genetics was high to begin with, with an average of 3.65 on 5-point scale, and this level of interest did not change significantly after playing with Dragons. Not surprisingly, those players who completed the most Dragons activities started with a significantly higher interest in genetics. In addition, while 64% of all players stated in the pre-survey that they had some prior experience with genetics in their schools, we found that 72% of heavy players reported having prior genetics experience as compared to 61% of light players, a statistically significant difference at the p=.05 level. In addition, the heavy player group's motivation and attitude toward learning genetics was significantly higher than those of the light player group. All these findings indicate that the Dragon games were most attractive to those players who had already prior interest and also a background comparable to secondary biology class given their self-reported age.

Our assessment of players' understanding of genetics was hampered by the fact that of the 1,188 players who completed the pre-survey, only 81 players also completed the post-survey, and only 10 of those were light players. Not surprisingly, the pre-survey scores on content knowledge portion for those members of the heavy player group (3.2 of 5) was significantly higher than the pre-test scores of light players (2.8). Even though heavy players bred nearly six times more dragons than the light player group, they did not show a significant gain in content knowledge after taking the post-survey. To truly gauge players' content learning, we need an increased number of Whyvillians in the light player group to complete the post-survey. This suggests that we might need to provide additional incentives to increase participation in order to meet this goal.

Discussion

We started this paper with an overarching research question: Could the integration of an instructional tool developed for the more formal environment of classrooms be successful in the informal environment of a virtual world? We redesigned Geniverse, a simulation tool developed to help high school students learn about genetics, for use in the virtual world of Whyville with a predominantly middle school player group. Some of the design changes—

providing incentives and including multi-player options—were a nod to the traditions of virtual worlds at large and to achieve a better fit with the existing gaming activities within Whyville. We know from the number of visits and play that some players were more drawn to the single-player labs while others were more interested in creating dragons and solving lair challenges. There was also a large group of players who created dragons without completing any challenge, presumably for the "coolness" factor of having a dragon pet.

Further analysis is needed to examine to what extent individual players learn genetics content by engaging in systematic investigations of inheritance by breeding dragons in lairs or completing lab activities. This performance could be gleaned from multiple data sources. We could explore patterns of play for those players who fail challenges initially and improve over time as compared to those who succeed early in earning treasure. Additional research will attempt to detect growth in a player's understanding of genetics by analyzing actions that reveal evidence of genotypic thinking. For instance, we can look at whether players use the special "scope" tool to peer into a dragon's chromosomes to determine if an egg contains the alleles necessary to complete a specific challenge, and if they "hatch" that egg or reject it based on what they see. Such focused analysis of play patterns could reveal whether players engage in more intentional rather than random inquiry (Kafai, Quintero & Feldon, 2010).

Redesigning instructional games for informal virtual worlds is a promising first step to enrich learning opportunities for a wide variety of science topics outside of school. Children are drawn to massive online communities for multiple social benefits, including collaborative play. By adding science games to these environments, we can provide extended opportunities to engage with complex concepts such as genetics. With *Dragons* in Whyville, we have shown that players can become highly engaged in science outside of school. Reaching more children by making these tools accessible in informal contexts may be a key to engaging more children in science learning, but it is also no guarantee that many of these inherently complex concepts will be fully understood through play alone.

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