Beetle Breeders: The Student Experience of a Mobile Biology Game

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Abstract: Research shows that educational games can help students build content knowledge and skills, but it can be difficult for teachers to effectively integrate game-based learning into their existing curriculum. UbiqGames are browser-based, casual games that relate directly to the curriculum but can be played outside of class time. Designed for mobile devices, the games can be accessed anywhere, anytime and discussed or analyzed during class. *Beetle Breeders,* focused on the topic of genetics, is one of four games designed to teach intro biology concepts and developed as part of a research study looking at the implementation and effects of UbiqGames. This paper will examine the student experience of the *Beetle Breeders* implementation, including how players integrated the game into their lives both in and out of school, as well as the appeal and effectiveness from a student's point of view.

The UbiqGames Genre

As the field of educational games research develops, we have come to understand that games can be powerful tools for engaging and motivating students, and are a rich environment for teaching problem-solving skills and content knowledge (Prensky, 2001; Gee, 2003; Shaffer, 2006; Squire 2011). However, effectively integrating game-based instruction into existing curricula remains a challenge for teachers. Classroom time is limited and overcommitted, and access to school-based technology is inconsistent at best. To address these issues while maintaining the value of quality educational games, the MIT Scheller Teacher Education Program has been researching a new model of mobile games for formal education.

Ubiquitous Games (UbiqGames) is a genre designed with unique characteristics that enable students to have a deep learning experience outside of class time, which is then easily connected back to the curriculum. This type of game is designed for the small screens of smartphones so students can use them anytime and anywhere, but its browser-based nature means it can be played on any device. UbiqGames are casual games, meaning they are quick to learn and can be played in relatively short durations of 5-10 minute sessions. This works well for learning games since students can play in frequent, short bursts, during interstitial moments of their day, without taking up precious class time. These games are closely tied to the curriculum and focused on a specific topic. Additionally, they are often simulation-based, giving students the opportunity to engage with the content and explore at their own pace. Player logins enable game data and progress to be stored on a server, which feeds into another key feature of UbiqGames: the Teacher Portal. This unique resource is a web site teachers use to track student progress by viewing player information collected by the data-logging system. Along with game data (score and level), the games also log other types of data that describe play patterns such as how long players spend in each area of the game, how many times they log in, and how well they are progressing in the game.

Equally important to the games themselves is the surrounding implementation model, in which teachers let students experience the game during their own time, then use class time to connect the concepts in the game back to the curriculum, and facilitate discussion around those ideas. Due to their unique design, UbiqGames are meant to engage players and facilitate deep learning, while providing a feasible way for teachers to integrate them into their curricula and lesson plans.

The UbiqBio Project

The Ubiquitous Games for Biology (UbiqBio) project, funded by a grant from the NIH, is a suite of four games in the UbiqGames genre described above, designed to help high school introductory biology students understand important biology concepts that can be difficult to master. The project encompassed development of four UbiqBio games, covering the topics of Mendelian genetics, protein synthesis, evolution, and food webs, as well as research on the week-long implementation of each game. Biology teachers were consulted throughout the design process to identify misconceptions that students often have, help design standards-aligned games that address those misconceptions, and

develop curriculum materials that facilitate transfer and support other teachers in implementing the games.

The research questions explored in this project pertained to student learning and engagement, as well as teacher adoption and usability. This paper focuses on the student-centered outcomes of one particular game, including:

1. Did students find the game appealing and engaging?
2. What benefits did students perceive in terms of biology content learning?
3. What kind of student-to-student interactions did the game facilitate?
4. Is the UbiqGames model a feasible method for game-based instruction?

Studying these aspects has helped researchers gain insight into the overall student experience of UbiqBio, while also learning more about best practices for the design and implementation of mobile learning games in schools, both now and in the future.

Beetle Breeders

One of the UbiqBio games developed during the project, *Beetle Breeders* (see Figure 1), focuses on the concepts of Mendelian genetics and inheritance patterns. In this game, players are running a beetle pet shop. Customers want to buy beetles with certain traits and it's the players' job to breed them. They choose the contracts they want to work on, then mate the right beetles to produce the desired offspring. They must use their knowledge of Mendelian genetics to work with increasingly difficult patterns of inheritance and maximize their profits.

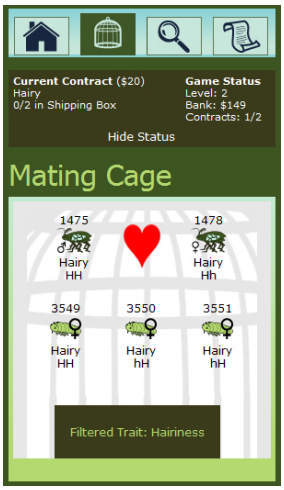

***Figure 1*: Beetle Breeders screen shot.**

Beetle Breeders contained a significant amount of biology content, as players were asked to work their way up through a variety of inheritance patterns including simple dominance, codominance, incomplete dominance, sex-linked traits, and polygenic traits. One of the most valuable experiences in the game was that of breeding beetles of certain genotypes and the ability to immediately see the offspring's resulting genotypes—a puzzle-like exercise that lets players experiment independently with the biology content. In addition, the game reinforced the concepts of probability and randomness by having players fill in Punnett squares and then selecting one genotype at random for each offspring. Overall, the game was designed to draw players into the story and puzzle aspects of the game, while both giving them exposure to new biology concepts and practice with familiar ones.

Methods

During the spring semester of 2011, a large-scale controlled study of the UbiqBio games and implementation approach was conducted. Participants included six teachers from three different schools in the Boston area, with a total of 177 Intro Biology students. The participant group was comprised of 53% boys and 47% girls. Due to the urban schools chosen as study sites, there was a large minority population, with students self-identifying as 47% Hispanic, 14% African American, 9% mixed race, 7% White, 3% Asian, and the rest unspecified.

The six teachers attended professional development sessions for each game, in which they learned about the gameplay, became comfortable using the smartphones involved, and were trained on the associated curriculum materials. For each relevant unit, teachers loaned Android smartphones (provided by MIT) to their students and assigned as homework for the students to play either a certain amount of time or a certain number of levels. Throughout the week or so of gameplay, they used the Teacher Portal to monitor student progress and tied the game back into their lesson plans where appropriate. Near the end of the unit, they collected the phones back from the students and conducted relevant wrap-up activities to facilitate transfer and help students reflect on their UbiqBio experience. During and after the implementation of each of the four games, researchers used a variety of data collection methods to examine numerous aspects of the students' experience with UbiqBio and *Beetle Breeders*.

Content knowledge gains were measured by an assessment based on existing MCAS (Massachusetts standardized assessment) questions and compared to scores from a control group of students assessed at the same point in the school year, one year prior to the study. Play pattern data was recorded by the back-end data logging system and can be analyzed to reveal when students typically played and how far they advanced in the game. Analyses of these data will be offered in other papers, while this paper will focus on the student experience as described primarily through surveys and interviews.

Upon completion of the *Beetle Breeders* biology unit, teachers administered a brief written post-survey which consisted of 17 closed-response items, the majority of which probed students using a five-point Likert scale. The survey questions gauged students' opinions about *Beetle Breeders*, as well their experiences playing the game.

In addition to the quantitative survey data, student interviews were also conducted for the purpose of collecting supplementary qualitative data. This was done on a much smaller scale, with a handful of students who had played the games and were available to be interviewed throughout the semester. These interviews provided anecdotal data to corroborate and explain from a student's point of view the trends that may be seen in the quantitative data.

Findings and Discussion

Experience Playing *Beetle Breeders*

In the UbiqGames model, students not only play games because they are "assigned" by their teacher. Ideally, students play because they find the games engaging and useful. To assess student perceptions, students were asked specific survey questions along these lines. When asked whether or not *Beetle Breeders* was an effective learning tool, the majority of students (76%) felt the game helped them learn genetics. This is not surprising given that the game covers a range of genetics-related biology concepts, and contains content which students can readily see as relevant to their course work. One student commented, "With the Punnett Squares I think that helped me get better with that, to understand it. Because I really didn't get... I've taken this class before and I haven't gotten [it]."

However, only slightly more than half (56%) described *Beetle Breeders* as fun, and nearly half (46%) agreed that the game was confusing. The authors of this paper feel that the design and implementation of *Beetle Breeders* significantly contributed to these mixed responses. Most notably, the technical implementation of the game made the gameplay often tediously slow, and this frustrated students. As one boy commented, "It's just that the phone would go slow when you're playing and I was just like 'oh, forget this,' and I'd just go do something else." Additionally, the game requires players to go through a somewhat complicated series of steps to complete the game tasks, and to be successful in the game, students need to leverage their knowledge of various genetics patterns of inheritance which many students find challenging. The combination of challenging content along with a somewhat intricate (even tedious at times) user interface may account at least in part for why students did not rate the game as more enjoyable. One student explained, "It was really complicated like with the contracts, types of different Beetles mating, like I didn't know if I had to sell it or if I had to keep it. How much money I would get. It was pretty complicated."

The UbiqGames model attempts to provide challenges at an appropriate level of difficulty for the individual student. As students complete levels and demonstrate mastery of concepts, the game

"levels up" and introduces increasingly complex content. Students rated their perception of the game's level of difficulty for them. While 49% rated this as "just right", another 31% reported that the game felt too difficult. Again, the authors felt that this was due to the combination of a somewhat intricate series of game mechanics, as well as the content itself. The combination of improved user interface, additional in-game feedback assisting students where they appear to "get stuck", and where possible, additional peer-peer or teacher-student discussion might improve students' perceptions. Ideally, games would be, as Papert writes, "hard fun" (Papert, 1996)—challenging enough to maintain focus and engagement, but not so difficult as to overwhelm the student, fail to assist the learning process and divert the student with frustration.

The UbiqGames approach also aimed to strike a difficult balance. On the one hand, the games were to be readily adopted by teachers, fit into students' lives, and feel relevant to their concurrent school "work". On the other hand, UbiqGames sought to engage students with a games-based approach (less frequently seen in schools) that effectively utilized technology to personalize the learning experience. Along these lines, students' opinions were, interestingly, split in their views of *Beetle Breeders*, feeling that *Beetle Breeders* did (45%) or did not (40%) feel like "school." Similarly, students reported that *Beetle Breeders* did (46%) or did not (29%) feel like "a game." Given the design and approach of *Beetle Breeders*, these findings are not surprising.

Often, traditional schoolwork (problem sets, individual homework) lacks a social component. Researchers were curious whether or not students discussed *Beetle Breeders* among their classmates. Survey data suggests that students were fairly mixed in the amount they discussed the game with their peers, as displayed in Figure 2.

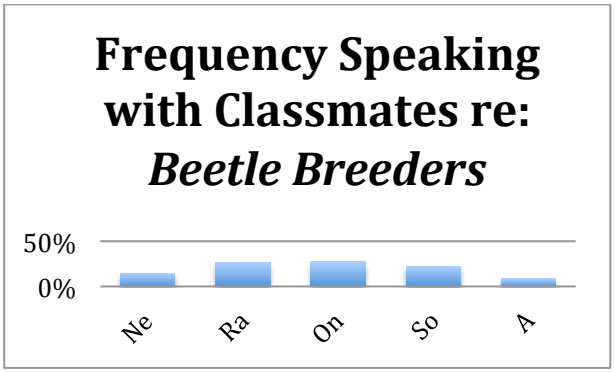

***Figure 2*: Frequency Speaking with Classmates.**

When asked about the content of their peer-to-peer discussions (See Fig. 3), the vast majority of discussion focused on either "game tasks" such as how to search and mate beetles, or how much money they had earned, which is the quickest way to assess student "achievement" in the game. While these are valid topics of conversation, the designers of UbiqGames aim to also foster discussion of the game content and strategies for success. Experimentation with "teams" and the positive or negative impacts of a competitive environment, for example, are interesting next areas to explore in the research around fostering student discussion.

***Figure 3*: Topics of Peer-to-Peer Discussion.**

UbiqGames are unique in that they are web-based mobile games allowing them to be played across iOS and PC platforms, on desktop and mobile devices. The "casual" game style also permits students to play in short, frequent bursts of time rather than extended sessions, freeing them to potentially play in a variety of locations, which some students did report doing for *Beetle Breeders* (Fig. 4).

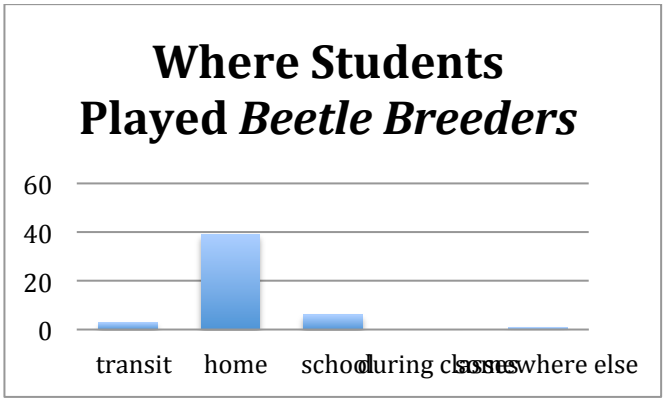

***Figure 4*: Where Students Played.**

While the majority of students reported playing at home, a few students mentioned playing in other locations. Interestingly, no students reported playing "during classes" in their written surveys. However, during interviews a few students who were trying to beat their classmates admitted to playing briefly during class, even though students were explicitly forbidden to play during class time. Ideally, the designers of UbiqGames hoped that the flexible play patterns would reduce barriers to use. When asked whether they felt "too busy to play", only 20% reported that this was an issue "frequently" or "all the time" with the vast majority (80%) maintaining that finding time to play was not problematic to any great extent.

With many technology-based educational interventions, there is the possibility that users will run into technical or logistical challenges. This was a concern for designers of the UbiqGames, especially since nearly all students used borrowed cell phones. This meant that the majority of players were both unfamiliar with the hardware/software and unaccustomed to charging, caring for and remembering to carry their UbiqGames device. However, only 5% reported frequent problems with their phone working properly (within which it is unclear if this was due to user error, faulty hardware/software or a combination of the two). The vast majority (83%) reported little or no problems with their devices. Similarly, a mere 4% indicated that they frequently forgot to carry their phones, with 87% reporting little or no problems remembering to bring their devices. Of course, as smart phones become the norm among students these issues will simply fade into the typical patterns of students remembering textbooks, backpacks, and calculators. In fact, one could convincingly argue that the last thing a teenage student will forget would be his or her cell phone.

Conclusions

UbiqGames generally, and the *Beetle Breeders* UbiqBio game in particular, were designed to investigate whether or not a casual game model could be readily embedded into fairly traditional biology curricula. Results from this study demonstrate that teachers were able to include *Beetle Breeders* with minimal technical and logistical difficulty for teachers and students. Students were generally able to readily use the technology on a practical level.

Beetle Breeders was intended to foster student engagement with key genetics concepts beyond those possible with standard paper-and-pencil exercises. Students perceived the game as a useful tool. However, significant challenges including a confusing user-interface and sometimes tedious game mechanics affected the game's appeal and potentially its value as a learning tool. In future UbiqGames, improvements in user-interface and game designs may provide students with more feedback and therefore reduce confusion and frustration, ideally increasing quantities of time spent playing the games and improving learning outcomes.

Furthermore, the "ecology" of student learning (Klopfer, 2011) consists of in-class instruction, homework, personal interest, class peers, teachers, and everything else in students' lives (such as

things that distract them from doing their homework). Utilizing a game-based component of learning can nicely dovetail within that ecology. Designs for UbiqGames and related curricula that can leverage multiple facets of that ecology may have an even greater impact on student attitudes and learning outcomes. Future work investigating ways in which UbiqGames successfully permeate this ecology offer many potential lessons for educators seeking to engage students in novel ways.

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