Geniverse: Science Practices In a Web-Based Game Environment for High School Genetics

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Introduction

With a five-year grant from the National Science Foundation, we have designed and developed *Geniverse*, a game-based environment for high school genetics. Genetics, a core topic of biology in both middle and high school, is difficult to teach and learn (e.g., Duncan & Rieser 2007). The causes of difficulty in genetics include the invisibility of many of the structures (chromosomes and genes); the many different levels involved (genes, proteins, cells, traits); and the difficulty of reasoning across different organizational levels (Horwitz, 1996; Stewart, 1990). Moreover, genetics experiments are difficult to do in schools due to limits on time, facilities, and budget. Multi-generational experiments, the hallmark of genetic science, are nearly impossible in this context. These difficulties can be addressed with computer simulations that bridge the gaps between macro- and micro-worlds, and condense timescales from weeks or years to moments.

Geniverse Narrative

In *Geniverse*, students are introduced to a world where dragons roam, and where a protagonist of their own choosing befriends a dragon that eventually falls ill. Learning of a distant Guild for studying drakes, the model species for dragons, a long and arduous journey with the dragon is undertaken. Arriving at the Guild, the student embarks on a course of study to understand the dragon's disease. Through a series of 32 challenges across four levels of difficulty, students work their way up through the Guild ranks. Each challenge presents the student with an objective to achieve and a multi-level simulation that supports experimentation.

Integrating genetic concepts

Students encounter two different types of challenges in *Geniverse*. In "target drake" challenges, their goal is to breed a drake with specific traits. They can only discover how a trait is inherited by experimenting to reveal the genetic mechanisms at play; then they can breed to achieve the target. They are awarded up to 3 stars based their skill in meeting the challenge, and can repeat challenges to improve their star rating. The game mechanic here represents what Clark and Martinez-Garza (2013) term a "conceptually integrated" game, that is, the concepts of genetic inheritance are integrated into the core mechanic. As we were developing *Geniverse*, we recognized the advantage of engaging players with the science concepts directly and intrinsically, but were concerned that the understanding developed would be tacit rather than explicit. (In this regard, our concern closely mimics the concerns of Clark and Martinez-Garcia (2013) regarding conceptually integrated games.) As a result, we developed a second type of challenge designed to bring tacit understanding to the surface, using scientific argumentation as a means for students to make the targeted concepts explicit to themselves, their classmates, and teachers. We embedded a class-wide "Journal of Drake Genetics" into the game with a CER framework: students post *c*laims supported by *e*vidence (data from their experiments) and connect them with *r*easoning.

Research design and results

Our research study into the effects of Geniverse on student achievement involved 48 teachers: 24 using the Geniverse materials, and 24 using their business-as-usual (BaU) genetics materials. In this quasi-experimental design, control group teachers were matched to treatment teachers based on student demographic variables. Outcome measures include tests of students' genetics understanding, open-ended assessments that examine their abilities to engage in scientific argumentation, as well as motivation surveys.

On the science content assessment, our current analyses show significant growth between the pretest and posttest in both groups, however there was no statistically significant difference between the performance of students in the *Geniverse* condition and in the BaU condition. The treatment coefficient is positive in favor of *Geniverse*, but the p-value (.476) is not significant.

For the argumentation research, students in both the *Geniverse* treatment group and in the BaU group were asked to "provide a scientific argument or explanation" for a given specific experimental result. The gains in the Geniverse group are higher than those in the comparison group in each of the three aspects of argumentation.

This treatment difference is approaching significance at the total argumentation score level.

Discussion

Annetta et al. (2009) also found commensurate genetics learning gains in a comparison between a teacher-designed digital game and BaU. With respect to content learning across the disciplines, studies comparing game-based and traditional approaches have produced a wide variety of results. Meta-analyses (Clark et al, 2014; Sitzmann, 2011; Wouters et al., 2013) suggest that overall, somewhat greater learning gains can be produced by games than by traditional methods, particularly if the non-gaming teaching style is passive rather than active. Since we did not observe the BaU classrooms, we are not able to assess the degree to which their methods were active or passive.

Previous work on scientific argumentation associated with games has shown evidence for developing scientific “habits of mind” in place-based augmented reality (Squire & Jan, 2007) and specific examples in the forums of off-the-shelf commercial games (Steinkuhler & Chmiel, 2006). Our comparison between BaU and Geniverse shows a strong trend to support the basis for game-based learning of argumentation. However, we note from teacher surveys and classroom observations that the argumentation challenges are perceived by students as less fun than target challenges, and increasingly burdensome as the challenges increase in difficulty. More complete scaffolding of argumentation using principles of prediction, observation, and explanation as suggested by Clark and Martinez-Garza (2013) could support students more fully, but finding a way to connect argumentation to better performance on target challenges may also help to incentivize this aspect of *Geniverse*.

An additional finding that we are currently exploring involves the relationship between how far through the Geniverse materials students progressed, and their scores on the content assessment. Interestingly, students’ progress through the materials as measured by the software was a significant predictor of their achievement, but the teacher’s *reports* of how far classes progressed was not. That is, the further through Geniverse students got, the more they learned, but teachers’ perceptions of how far their students were progressing based on whole class progress were not accurate.

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