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Lessons From a Field Test

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Abstract

This paper describes efforts to test the promise of a digital game and accompanying materials designed to support the teaching and learning of genetics in middle school. The study is part of Possible Worlds, funded by the U.S. Department of Education's Institute of Education Sciences. The goal of the project is to develop and test game modules to displace common scientific misconceptions students often retain after direct instruction. In this study, we explored whether students' prior experience of gameplay supported teachers' efforts to make sense of genetics instruction, and to help students develop deep understandings of randomness and dominance. Our findings had mixed results that call into question a central assertion of the Preparation for Future Learning model (Bransford & Schwartz, 1999), the theory upon which our game modules are based.

Introduction

This paper will describe findings from Possible Worlds, a National Research and Development Center on Instructional Technology funded by the U.S. Department of Education's Institute of Education Sciences. The goal of the project is to develop and test a series of game modules to support middle-school students and teachers in displacing common scientific misconceptions and building accurate knowledge of complex scientific concepts. Each module consists of a game for the Nintendo DSi and accompanying curriculum materials. The modules are intended to serve as a complement to, rather than a substitute for, teacher-led instruction. Our instructional model builds on Bransford and Schwartz's (1999) "Preparation for Future Learning" (PFL) model, in which educational interventions are followed by a form of direct instruction in order to increase the likelihood of transfer.

In Possible Worlds modules, gameplay takes place at home, prior to instruction. Teachers then use class time to draw connections between game activities and the target scientific content. Now in the fifth year of the project, we have had extensive opportunities to refine our instructional model and see how it plays out in middle-school classrooms. In this paper, we discuss field tests of our second game module, which is designed to support the teaching of genetics by dislodging well-documented misconceptions about the concepts of randomness and dominance (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

The primary purpose of this field trial was to examine whether and how teachers' implementation of the genetics module was consistent with the instructional model advanced by Bransford and Schwartz (1999). More specifically, we looked at whether the prior experience of gameplay supported teachers' efforts to help students make sense of direct instruction, and helped students develop deep understandings of the target genetics concepts. The following research questions guided the study:

1. When and how do teachers and/or students make explicit references to the game?
2. Do students who use the module learn key concepts relating to genetics?

We infer from evidence of teachers or students referencing the game during instruction that it is an indicator of efforts to build knowledge – to establish a relationship between the game and target concepts. The context in which they make these references will offer insight into how the game may support the teaching of genetics, and the extent to which it fosters conceptual learning.

RoboRiot

The game for our genetics module, RoboRiot, takes place on Planet Azalon, which has a thriving robot population. Unfortunately, some robots have been infected by a computer virus. Players are in charge of a rescue squad; their mission is to deploy rescue robots to disable and reboot the rampaging bots. Players must be strategic about which robots they deploy because different robots have strengths and weaknesses that determine whether efforts to disable an infected robot will be successful.

When players pit a rescue robot against an infected bot, the outcome is determined by a "Rock-Paper-Scissors" type of scheme. Robots have two "alleles" and the expressed one is determined by allele dominance. So, for instance, the water allele is dominant over the fire allele, and the fire allele is dominant over the ice allele. The success of each rescue mission is determined by this dominance scheme.

Players can "recycle" members of their existing team to try to acquire a particular type of robot they need. They place two robots, each of which has two alleles, into the recycling machine, and one new robot is produced. The resulting robot contains a randomly chosen allele from each of the original robots, much like any offspring inherits alleles randomly and in equal quantity from each parent. Depending on which two of the four alleles the robot "inherits," the player may or may not end up with the type of robot he/she is hoping to get.

RoboRiot focuses on randomness of inheritance and the relationship between dominant and recessive genes, core genetics concepts that students persistently misunderstand. As students play, the designers intend for players to become aware of how randomness and dominance affect gameplay, and to rely on that awareness to make decisions that help them achieve their goals.).

The intervention

The study was conducted in March 2012 in one public middle school in Suffolk County. Four 8th grade science teachers and 95 of their students participated.

During a two-hour teacher training, a curriculum specialist prepared teachers for a specific implementation of the genetics module. The instructional sequence involved 1) at-home game-play, 2) regular instruction in target concepts supplemented by teaching materials that incorporate images from the game, and 3) the use of linking activities designed to help teachers and students draw connections between the game and science content. In this module, a Peppered Moth linking activity is intended to demonstrate concepts of natural selection, adaptation, and genetic dominance. Another linking activity allows students to explore the relationships between the RoboRiot robots and the effects of random ordering during robot encounters. A "Robopedia" presents the alleles that make up each type of robot and summarizes each bot's strengths and weaknesses.

Data collection and analysis

Researchers collected data via 1) daily classroom observations, 2) "Quick Writes" that asked students to reflect on relationships between the game, activities, and genetics concepts, 3) multiple-choice assessment probes and associated writing probes (Keeley, Eberle, & Tugel, 2007) administered at the end of the intervention to elicit students' ideas about randomness, dominance, and the meaning of the phrase "survival of the fittest," and 4) a one-on-one teacher interviews at the end of the intervention.

To answer Research Question 1, we extracted information from classroom observations and teacher interviews about when and how the teachers used and/or referred to RoboRiot or other module materials in the context of instruction or interactions with students. For Research Question 2, we drew from classroom observations, Quick Writes, and assessment probes. We tagged student comments and classroom interactions that offered insight into students' genetics knowledge, as well as how they grappled with the difficult concepts of randomness and dominance. From Quick Writes and assessment probes, we identified trends in how students expressed their understanding of the focal concepts.

Results

The teachers implemented the module daily over two weeks. They adhered to our instructional model by having students play RoboRiot prior to their genetics instruction. Contrary to our suggestion, however, students played the game during class time and/or during their "Extended Academic" period, which is typically reserved for lab investigations, supplemental classroom activities, and homework help. Teachers feared the Nintendo DS devices would be lost or damaged if students brought them home.

RQ1: When and how do teachers and/or students make explicit references to the game?

During interviews, the teachers said their instructional priorities for their genetics unit were to teach genetic terms, as well as the procedures needed to complete and interpret Punnett Squares. During instruction, the teacher referenced RoboRiot and used module components to advance these instructional priorities.

<u>Teaching genetics terms</u>

Teachers referenced the game to introduce genetic terms. For example, when defining terms such as "allele," "homozygous," "heterozygous," "recessive," and "dominant," they made use of the Robopedia. A teacher explained to students that understanding the genetics of the robots would help them understand human genetic inheritance. As another teacher reviewed questions from past Regents exams, she referenced RoboRiot to help define "independent assortment." In doing so, she draw an analogy between the method that Mendel used to mix the alleles in the pea plants and the method used by the recycler to mix the robots' alleles. By referencing a core visualization from the game, she drew on the shared experience of gameplay to make a difficult term more understandable to students.

Teachers also referenced RoboRiot to review genetics terms introduced in prior lessons and clarify distinctions between concepts. For example, having introduced the terms "recessive" and "dominant" in a prior lesson, one teacher emphasized the point that recessive genes, as opposed to dominant genes, remain latent in heterozygous traits and can reappear in future generations. Using the Robopedia and what they remembered from gameplay, she prompted students to determine which robot alleles were recessive and dominant. The teacher explained, "The sand robot was the dominant. When we do genetics, the dominant allele determines the trait, it's the gene that's expressed…Your recessive allele is the allele that's not expressed. It's covered up…But is it still there if it's covered up? Sure it is. You're going to see those alleles in another generation." This teacher went on to distinguish between homozygous and heterozygous traits, using the robots as examples to highlight this distinction. She then used those examples to define "genotype" and "phenotype."

Teaching genetics procedures

Among the teachers' highest priorities was to teach procedures for using a Punnett Square to determine the probability that a particular genetic trait is expressed in offspring. Traditional methods of teaching Punnett Squares often are successful at teaching the procedures involved, but less successful at helping students understand the underlying genetics concepts. Amidst a reliance on upper- and lower-case letters to designate genotypes and interpret genetic probabilities, the connection to actual traits easily gets lost.

Teachers who supplemented their teaching of Punnett Squares with allusions to RoboRiot appreciated opportunities to reference traits rather than letters during instruction. According to one teacher, "Robots were good because it shows it's not just letters, but actual traits." During instruction, several teachers drew students' attention to similarities between a Punnett Square and the recycler in the game, and one teacher referred to the recycler as "a giant Punnett Square." Another teacher asked, "Did you notice any similarities between what happens in the recycler and Punnett Squares? Remember the conversation about Punnett Squares and my family history with being short compared to my parents, and how many people in the family were short? When you put the robots in the recycler, what was being scrambled, what was coming out?...Some of you complained about how when you put robots in they didn't come out exactly how you want." This teacher previously attempted to use her own family history to get away from a reliance on abstract symbols and, instead, to illuminate the genetics concepts behind the Punnett Square. The game provided an additional point of reference to accomplish this.

Teaching underlying concepts

There were instances in which teachers referenced RoboRiot to pursue the goals that were our conceptual target for the module.

Randomness in genetic inheritance

Teachers' references to the game drew similarities between how robot alleles are randomly selected in the recycler, and the random way in which plants and animals inherit genes in the real world. The teachers explained that, in both scenarios, you could not "control" or "predict" what traits would result, or, as one teacher put it, "You never knew what you were going to get." To drive home these points, a teacher stated, "Did you notice that when you put your robots together, maybe you wanted fire but you got water?...The same thing happens with boys and girls."

Teachers also referenced the game to clarify that each "parent" (robotic, human, or plant) contributes the same amount of genes to an offspring, and randomness determines which alleles from each parent are chosen. Contrary to many students' beliefs (Driver, et al. 1994), even if an offspring only looks like one parent, he/she has an equal number of genes from both parents.

A teacher told us that, prior to using the module, she never realized that the concept of randomness was difficult for students. She said that, without the game and supplemental materials, "I never would've focused on it. I never realized kids have such a problem with it. I myself had some misconceptions about it." In this way, the module helped her better understand the mental models and challenges that teachers and students had to confront.

Dominance conceptions

A common misconception among students of this age group is that particular traits are inherently better than others, and this advantage is determined by dominance. We hoped teachers would use RoboRiot and related activities to help supplant this misconception with the idea that environmental circumstances determine which traits are advantageous. In RoboRiot, no robot is better than any other; a robot who wins against one robot will lose against another. At times it is better for a robot to have a recessive trait, while other times the dominant trait is better.

The Peppered Moth linking activity was designed to reinforce these ideas. During this activity, students simulate how moth predators locate prey in different environments. They compare the survivability of light and dark colored moths before and after the Industrial Revolution, based on the ease with which predators could find them. Some teachers referenced RoboRiot to help students understand how environmental conditions, rather than gene dominance, affect an organism's ability to survive. For example, one teacher asked during the activity debrief, "Who remembers the game? Could we say the Sand robot was better when it battled the Fire robot, the same way the peppered moth was desirable, fittest pre-industrial? But the Ice robot could beat the Sand robot; there were conditions where the traits weren't desirable…Thinking back with the robots, there were a lot of genetic variations that could be preferable or not."

Another teacher made similar references to the robots to connect the game and activity with the idea that dominant traits are not always better. She asked students, "When have we seen when the dominant trait isn't the desirable one?" Students responded that hair and eye color were traits that do not affect one's ability to survive. The teacher then reviewed the peppered moth activity and explained that the recessive trait was advantageous at one time, but the dominant trait was advantageous later. Then she asked, "Are some robots better than others? What similarities or differences did you see between the robot chart and the peppered moths?" Using examples from the game, she demonstrated that the strength of the robots depended on the circumstances; based on who a robot was "versing," either the recessive or dominant trait would help them survive.

RQ2: Do students who use the module learn key concepts relating to genetics?

Findings from the study suggest that students who used the module in conjunction with regular genetics instruction learned some concepts relating to genetics. For example, their Quick Write responses suggest that playing RoboRiot prepared students to recognize that alleles determine an individual's traits. Additionally, their Quick Writes reflected an understanding that both parents contribute alleles to determine a trait. As one student explained, "A particular robot comes from the mother and father traits." Another student echoed, "They mix the traits and you get half and half. One from each parent."

Findings also suggest that the robot recycler in RoboRiot allowed students to experience randomness more directly, and understand its implications more thoroughly, than does working with Punnett Squares alone. According to one student, "The recycler is like a Punnett Square because like a Punnett Square the alleles are randomly chosen for the offspring but they are different because a Punnett Square has four absolute choices and aren't randomly mixed like the alleles in the recycler." In this statement, the student expresses misconceptions with regard to the Punnett Square, but communicates an accurate description of what happens in the recycler. In a similar vein, another student writes that the mixing of alleles is "random in the game and predictable in the Punnett Square." Through students' repeated interactions with the recycler, relative to their work with Punnett Squares, it seems that students established a more accurate sense of the roles of randomness and probability in determining an offspring's traits.

Some evidence suggests students were able to apply their experience with the recycler to their understanding of the real-world genetics concepts of randomness and dominance, our target concepts for the module. One student articulated, "When the recycler chooses its alleles, it makes a robot with a certain type like how traits are inherited by a combination of alleles that choose what the outcome is." Another student explained that, in the recycler and real life, "[alleles from different parents] combine into one and whichever is dominant will be the trait." A few students, however, expressed misconceptions that we hoped to dispel. For example, one student wrote, "when you put two robots in the recycler whichever trait/type of bot is stronger, that's the type of bot it'll be and when two people have a baby whichever trait is stronger is what trait the baby will have." Thus, while the recycler visualization and associated instruction led many students to express accurate ideas about the target genetics concepts, they were not sufficient in displacing misconceptions for all students.

Results from the multiple-choice post-assessment are mixed. The "Baby Mice" prompt, designed to tap students' ideas about the appearance of traits in offspring, had seven options from which students selected to explain why five baby mice that came from different colored parents were different colors. More than half of students who completed the assessment (47 out of 83, or 56.6%) selected the correct response, which is "The baby mice got half their traits from their father and half from their mother." While this correct response rate may seem encouraging, we cannot ignore the fact that the other 36 students chose responses that reflect misconceptions about how traits are inherited. In the class section that performed the best, 77.3% of students responded correctly, while only 30% of students responded correctly in the lowest performing section. The most common incorrect response, chosen by ten students across two of the four focal classes (12% of students who completed the assessment), claimed "The baby mice inherit more traits from their fathers than their mothers." The second more common incorrect response, selected by nine students across all four sections, claimed "Parent's traits like fur color don't matter – nature decides what something will look like." These incorrect choices reveal that, despite their use of the module, many students came away from their genetics unit with the misconceptions about how traits are inherited.

Results from the "Is it 'Fitter'" assessment probe, designed to identify how students interpret the phrase "survival of the fittest," are only slightly more encouraging. There are four possible responses. Forty seven students out of the 58 students who completed the assessment (or 81%) chose the correct response, which is "I think 'fit' means more apt to reproduce." Incorrect responses propose that "fit" means "bigger and stronger," "able to run faster," and "more intelligent." In the class section in which the teacher used the term "fit" repeatedly during instruction, 100% of her 22 students chose the correct response, while only 43.1% of students responded correctly in the other three sections, in which this concept was emphasized less often or not at all.

Looking at results from these assessments, the variance in student performance across sections suggests that teachers' efforts to support sense-making during instruction, in addition to students' prior experiences such as gameplay, play a critical role in dispelling scientific misconceptions. The game experience alone did not compensate for details that teachers did not emphasize.

Discussion

Results of the study suggest that the Preparation for Future Learning model had limited success in this instructional context. Teachers regularly referenced RoboRiot in the context of instruction, but most often these references were in the service of promoting surface knowledge of genetics terms and procedures. Less frequently, teachers referenced the game to help instill deep-level understandings of randomness and dominance, common sources of persistent misconceptions among students. The assessment results, in which many students selected responses that reflect these misconceptions, reveal the consequence of this.

Thus, except on rare occasions, the module fell short of its instructional potential. The explanation for the limited success, we believe, resides in a mismatch between the goals of the module and the modest yet pressing instructional goals of the teachers in the study. While our goal was to promote deeper learning of genetics concepts than is typically learned in middle school, we conducted the research in a school in which teachers confront the time-sensitive challenge of preparing students for standardized tests that mandate only a surface understanding of genetics. As a result, we found that teachers referenced our analogy and used our materials in the service their goals, leaving the farther-reaching potential of the module largely untapped.

From the perspective of the Preparation for Future Learning framework, this mismatch between the instructional goals of the module and those of the teachers should not negatively impact student learning. The PFL model posits that a prior experience such as gameplay supports transfer, regardless of what happens during instruction. The PFL model does not account for the quality or focus of instruction at all and, by extension, Schwartz and Bransford imply that it does not matter what the teacher does within the black box of instruction; students merely need the prior experience for subsequent sense-making to take place. In this study we found that, in fact, it matters quite a bit when and how teachers tap into that prior experience for the purpose of sense-making. In this way, the results of the study call into question a central assertion of the PFL model.

It is possible that the nature and quality of instruction matter less or not at all in the long term. Given the complexity of the concepts of randomness and dominance, our goal was for students to come away from their genetics unit with a productive but incomplete conceptual model rather than a comprehensive understanding of those concepts. Students' use of the module may have provided them with a solid foundation from which they will develop accurate conceptual knowledge when they encounter the content again in future years. This is a question that we intend to explore.

References

Bransford, J., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. In A. Iran-Nejad & P. D. Pearson (Eds.), Review of research in education, 24 (pp. 61–101). Washington, DC: American Educational Research Association.

Driver, R., Squires, A., Rushworth, P., and Wood-Robinson, V. (1994). Making sense of secondary science. New York: Routledge.

Keeley, P., Eberle, F., & Tugel, J. (2007). Uncovering student ideas in science: 25 more formative assessment probes (Vol. 2). Arlington, VA: NSTA Press.