

Genetics with dragons

Using an online learning environment to help students achieve a multilevel understanding of genetics

BY KILEY MCELROY-BROWN AND FRIEDA REICHSMAN

CONTENT AREA

Life science

GRADE LEVEL

6–8

BIG IDEA/UNIT

Genes are instructions for proteins, which give rise to traits.

ESSENTIAL PRE-EXISTING KNOWLEDGE

Prior knowledge of simple dominance and inheritance of traits is beneficial, but is not a prerequisite.

TIME REQUIRED

310 minutes (approximately seven class periods)

COST

Free

SAFETY

No special safety concerns

Genetics, a core topic of biology in both middle and high school, is difficult to teach and learn (Duncan et al. 2009; Tsui and Treagust 2010). This is in part because genetic phenomena span multiple organizational levels, many of which are invisible (e.g., cells, molecules) and arise from the behavior of entities unfamiliar to students (e.g., genes, proteins). In addition, the notion that genetic information merely specifies the structure (and consequently the function) of proteins is rather counterintuitive to children (Lewis and Kattmann 2004). However, knowing that genes provide instructions for making proteins and that proteins have many functions that ultimately give rise to physical traits is a powerful and generative understanding that can explain a plethora of genetic phenomena (Allchin 2002).

Current instructional practices tend to gloss over the causal mechanisms that link genes to traits (Duncan, Rogat, and Yarden 2009; Pavlova and Kreher 2013) in favor of an approach focused on patterns of correla-

tions between genes and traits, namely dominant and recessive inheritance. In contrast, *A Framework for K–12 Science Education* (NRC 2012) and the *Next Generation Science Standards* (NGSS Lead States 2013) place new emphasis—starting in middle school life science—on the central role of proteins in bringing about traits.

The Concord Consortium and our collaborators have developed a free digital genetics game, *Geniventure*, with an engaging narrative featuring dragons that need to be saved from extinction and highlighting the role of proteins in genetics. *Geniventure* runs on any modern web browser; it also runs on iPads, Chromebooks, and other tablets. *Geniventure* leverages our popular *Geniverse* software that has been used in classrooms by nearly 150,000 students over the last eight years, with approximately one-third of them being middle school students. We redesigned the original *Geniverse* to enhance learning by this younger audience and to include the multilevel components responsible for physical traits. Through scaffolded virtual

traits (a “target drake”), students simulate meiosis by selecting chromosomes from each parent to create their gametes (Figure 5). Geniventure then animates fertilization with the joining of sperm

and egg cells, producing a drake with a full set of alleles for each gene. Once students match the target, they observe gametes generated by animated random assortment of chromosomes and select from among them. Students ultimately create clutches of target drakes from crosses—by setting the alleles of the parents to favor the random generation of gametes that can come together by chance to create the target drake.

FIGURE 5: Level 4, Mission 1

By selecting chromosomes from each parent, students are expected to use their knowledge of inheritance patterns and to recognize and reason about predictable patterns in the offspring of two parent drakes.

Level 5: Test cross [approximately 15 minutes]

A classic tool in genetics is the *test cross*—uncovering a genotype by breeding against an organism with recessive traits—and level 5 scaffolds students toward understanding and using this process. Students are faced with a drake that has multiple dominant phenotypes, and therefore indeterminate genotypes. Students must set alleles to breed a recessive drake and determine the unknown genotype of the mystery drake (Figure 6). Students integrate their understanding of how alleles are inherited with their knowledge of relevant genotype–phenotype relationships.

FIGURE 6: Level 5, Mission 1

In performing a test cross, students must set alleles to breed a recessive drake and determine the unknown genotype of the mystery drake by examining the traits in the offspring.

Level 6: Polyallelic and X-linked traits [approximately 45 minutes]

Additional drake traits with more complex modes of inheritance are the focus of level 6. Students work with a trait that has three alleles, and with two genes found on the X chromosome. The familiar interfaces for changing alleles, sorting eggs, creating gametes, breeding, and performing test crosses enable students to explore and puzzle out mechanisms of non-Mendelian inheritance, bringing these more advanced topics within reach for many middle school students.

Evaluate: VentureMap

Students are evaluated throughout Geniventure. The VentureMap displays the number of crystals a student has earned for each level (Figure 7). The color of the crystal indicates a student's performance on each challenge. A red crystal suggests that a student did not perform well in that challenge, a yellow crystal indicates only one or two mistakes, a blue crystal shows that the student completed the challenge perfectly, and a black crystal reveals that the student made multiple mistakes and must retry that challenge before advancing to the next mission.

Intelligent tutoring system and teacher dashboard

Geniventure is designed to be used in classrooms, with guidance and reflection facilitated by a teacher. Geniventure includes

FIGURE 7: VentureMap

A comprehensive view of a student's progress and achievement is displayed on the VentureMap.



an Intelligent Tutoring System (ITS) that tracks students' actions as they play, with each action tied to one or more specific genetics concepts. The ITS provides students with real-time visual feedback and text-based hints targeting the specific concepts the student may be having trouble with. At the same time, the ITS relays the relevant information to a teacher dashboard. If a student makes a mistake on the same concept multiple times, the ITS will prompt the student to complete a focused, remedial "bonus" challenge for additional practice. Teachers can then facilitate strategic guidance of student learning by accessing the information provided by the ITS on the teacher dashboard. In addition, a comprehensive teacher's guide for Geniventure, including printable Geniventure worksheets and guided discussion questions, will

be available to the public in August 2019 (see Resource).

Using the data from the ITS and student crystals, the Geniventure teacher dashboard offers teachers real-time data on each student's progress and performance. Aggregated learning patterns across student models help teachers identify issues of concern for the entire class. Teachers can act on these data in a variety of ways, supporting individual students, grouping or regrouping students based on either strong or weak performance on certain challenges or concepts, or identifying opportunities for whole-class intervention, such as guided discussion or other off-computer sense-making activities.

Classroom management

In Geniventure, students are encouraged to work individually.

However, paired gameplay is also suitable if computers are limited or if a teacher prefers to group students for pedagogical reasons or classroom norms. Although Geniventure includes subtle sound effects, most students do not find them to be disruptive, and the volume on computers can be turned off to mitigate any noise control issues. Importantly, Geniventure offers flexibility for students who work at different speeds to complete the challenges. When the ITS detects that a student is struggling, the game presents hints that include both text and visual clues or “bonus” challenges. Because all student work is sent to the dashboard, teachers can monitor the number of student attempts per challenge and see which students were directed to bonus challenges. Students who complete challenges early are encouraged to repeat them to earn higher-level crystals. Because the game is online and accessible from any modern web browser on desktop computers and tablets, students who are absent from class may complete assignments as homework or during out-of-school time.

Conclusion

The NGSS encourage middle school students to dive deeper into understanding the role of

proteins in bringing about traits. We developed software that middle school students find engaging and that allows them to experiment with the multiple levels of genetics—from genes to proteins to traits—helping prepare them for high school biology. Geniventure offers an environment for young learners to interact with a multilevel model that illustrates scale, conceptualizes the structure-and-function relationship, and emphasizes coherence across concepts that are often challenging for teachers to convey with traditional instruction. ●

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RESOURCE

Geniventure—<https://learn.concord.org/geniventure>

Kiley McElroy-Brown [kmcelroy-brown@concord.org] is a project manager and **Frieda Reichsman** is a senior research scientist, both at The Concord Consortium in Concord, Massachusetts.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

- The chart below makes one set of connections between the instruction outlined in this article and the NGSS. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Standard

MS-LS1 From Molecules to Organisms: Structures and Processes

www.nextgenscience.org/dci-arrangement/ms-ls1-molecules-organisms-structures-and-processes

Performance Expectation

MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Developing and Using Models	Students use a model of a cell to investigate how skin color is produced. Students manipulate the genes and proteins inside the cell to view the overall effect on the organism.
Disciplinary Core Idea	
LS1.A: Structure and Function Within cells, special structures are responsible for particular functions and the cell membrane forms the boundary that controls what enters and leaves the cell.	Students use a model to interact with skin cells [melanocytes] and their protein components, responsible for producing melanosomes [melanin packets] and, therefore, the color of skin. Students also observe that the melanosomes are transported between cells via proteins in the cell membrane.
Crosscutting Concept	
Structure and Function	Students use a model to discover that physical characteristics and traits [phenotypes] observable at the organism level are a result of the proteins inside cells, made by the genes and DNA of the organism, by observing proteins in action.

Connections to the *Common Core State Standards* (NGAC and CCSSO 2010)

ELA/Literacy

CCSS.ELA-LITERACY.SL.8.5: Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

Mathematics

CCSS.Math.6.EE.C.9: Use variables to represent two quantities in a real-world problem that can change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.