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by Mary Anne Clark

Science is the next best thing to recess.
(Norval Kneten, President, Barton College)

An increasing market for online courses (Allen and Seaman 2007) has created a need for online laboratory experience, and Second Life, a multiuser virtual environment (MUVE) developed by Linden Lab, offers a new dimension for science education. Virtual environments can be visited as “field sites” for face-to-face or online courses, developed for stand-alone courses given entirely within the virtual world, or used as resources for informal learning. Virtual experiments performed in Second Life laboratories offer students activities that are both hands-on and minds-on, making it possible for students to replicate classic experiments or perform laboratory activities that might be too dangerous, too expensive, or too time-consuming in the real world. As an added benefit, the social environment invites conversation outside of formal class hours, and the game-like environment of Second Life encourages exploration. This article describes the development and preliminary testing of Genome Island, a virtual laboratory environment for teaching undergraduate genetics in Second Life.

Second Life, Science, and Recess

Through the interest and inventiveness of its educational community, Second Life is rapidly developing into a course management venue (Kemp and Livingstone 2006). This is due to the innate characteristics of the Second Life environment, including the possibilities for creating interactive objects, the potential for multimedia presentation, the flexibility of the environment, and the immersiveness of the experience. The gamelike nature of Second Life's virtual environment has particular implications for science education as it fosters a sense of play in the virtual laboratory. Norval Kneten, chemist and former dean of science and humanities at Texas Wesleyan University where I teach, used to say that "Science is the next best thing to recess!" As Laszlo (2004) points out, "Playing with ideas is, after all, what science is about" (400). Laszlo identifies aspects of play in both the intellectual and procedural components of doing science: Scientists play "guessing games" with the natural world and employ a number of "toys," such as instruments and other laboratory tools, in evaluating their guesses.

Second Life also facilitates social learning. Robbins (2007) has noted that when social interactions in Second Life are mediated by avatars rather than via message boards or chat rooms, students have a more vivid sense of being part of a community. The avatar puts a face, a body, and a physical location on each community member, all of which contribute to a sense of "thereness." As Annetta, Klesath, and Holmes (2008) have pointed out, the feeling of social presence conferred by an avatar contributes to the perception of the virtual environment as a real place. As an additional advantage, in contrast to other kinds of simulated experiments, the immersive graphic environment of Second Life supports learning with visual memory. For example, a student inferring the parent plant's genetic makeup by counting red and white flowers among the progeny has seen the flowers in the garden as well as recorded their numbers in a table. The visual image may make it easier for the student to recall the relationships between parent and progeny later.

Science educators have begun to see the value of the virtual world as a laboratory environment; a number of simulations are now available online, in Second Life and elsewhere (Exhibit 1). The quantitative aspects of genetics are particularly suitable for simulated laboratory experiments; Second Life's scripting tools allow variable and realistic data sets to be generated by programming each object in a data population to select its features according to established probabilities.

Genome Island

Genome Island began, almost literally, with a light bulb. One of the most common Second Life building and scripting tutorials is for making a light that switches on and off. A modification of this basic script now animates many of the experiments on Genome Island. Late in 2004, I began to experiment with building and scripting in Second Life using tutorials available both in-world and elsewhere online; I constructed some of the genetics objects that are now found on the island as part of this exploration. Initially, I worked entirely "after hours," but early in 2007, with funding from a fellowship and the encouragement and generosity of Texas Wesleyan's biology department, I moved the project from its small plot on the Second Life mainland to a private island and began to develop Genome Island as a teaching venue. A critical event was the installation of laboratory computers capable of running the Second Life program at Texas Wesleyan, which meant students could access Genome Island from campus. By the end of the spring semester in 2007, Genome Island was ready for student trials.

Since Second Life's main grid is restricted to people over the age of 18, the conceptual material at Genome Island is pitched at a level appropriate for a university undergraduate. Selected areas of the island are suitable for more advanced students. The materials on the island are not intended to correspond to any particular textbook or curriculum but constitute a series of encounters with genetic objects. These interactive objects behave according to established genetic principles.

Activities are organized into four main areas (Figure 1). The Abbey and Gardens contain experiments illustrating the principles of Mendelian inheritance. More complex inheritance patterns and genetic interactions are represented in the Terrace. The Tower houses demonstrations of molecular genetics, bacterial genetics, and Drosophila genetics. The Gene Pool demonstrates principles of population genetics and includes the Atelier where students or other guest builders who want to contribute activities to the island can work. Visitors can follow walkways or stepping stones, fly from place to place, or use the teleport panels found at the entry points to the island and in each of the main areas. Teleports also connect related experiments.

There are now about 50 different activities available at Genome Island. For each one, a note card or slide show provides background information, suggests a hypothesis to be tested or a principle to be applied, and gives instructions for using one or more interactive objects to generate a data set. Some data is recorded in the chat record from which it can be copied and pasted into spreadsheets for further analysis (Exhibit 2). Other data is not automatically recorded but has to be processed as it is collected. For example, bacterial colonies have to be counted, rabbit coat colors identified, pedigree patterns figured out, or DNA sequences matched. Methods of analysis are suggested for each activity.

Representative Activities

Genome Island experiments occupy a niche somewhere between a written problem set in which all data are immediately accessible and identical for all students and a real-life laboratory experiment in which data collection might take hours or even weeks to complete and might vary from student to student. At Genome Island, students can perform an experiment quickly, usually within a few minutes, but each data set, within the probabilities governing the experiment, can be different. The four activities described below illustrate some of the data that can be collected on Genome Island and the learning objectives addressed by each experiment. The Bacterial Transformation and Message in a Bottle experiments are found in the Tower, the Monohybrid Cross comes from the Abbey Greenhouse, and the X-linked Inheritance experiment is part of the Cattery on the Terrace.

Bacterial Transformation

The Bacterial Transformation experiment (Exhibit 3) is a reproduction of the 1928 experiment by Frederick Griffith that yielded the first indication that there was a chemical basis for inheritance. The learning objective of the activity is for students to be able to explain the results of injecting each of four mice with a different bacterial culture. This experiment could not be reproduced in most university laboratory settings, both because of the danger of handling pathogenic bacteria and because of serious ethical objections with regard to animal rights. To explain the data that the activity generates, students must understand how each of the four bacterial cultures is different from the others and why two of the four cultures can result in the death of the mice. Students must also understand that while the test organism is the mouse, the genetic change occurs only in the bacteria injected into the mouse.

Monohybrid Pea Cross

The Monohybrid Cross experiment (Exhibit 4) is a reproduction of one of Gregor Mendel's experiments with garden peas. The traits represented in this activity are two seed colors governed by a single pair of genes: yellow vs. green. The cross represents three generations of progeny from two pure-breeding parents with different traits. The appearance of each pea in the second and third generations is determined independently, based on the probabilities of inheriting each possible trait. The learning objective for this experiment is for students to be able to apply Mendelian principles to explain the types and ratios of progeny that appear. In just a few minutes, students can generate representative data like that Mendel collected over several growing seasons.

X-Linked Inheritance in Cats

The Cattery is my Second Life homage to Judith Kinnear's CatLab; the activity here studies sex linkage, the inheritance of traits carried on the sex-determining chromosomes (Exhibit 5). The learning objective is for students to recognize the features of X-linked inheritance and to be able to identify the presence or absence of the dominant orange gene in each parent and kitten. Clicking on one of four cat houses in the exhibit produces a set of parents. Clicking on the parents then results in kittens. Although this experiment could be performed with real cats, the two-month wait for progeny, as well as an inconvenient number of kittens, would render it impractical.

Message in a Bottle

The Message in a Bottle experiment (Exhibit 6) is part of a Tower unit on genetic coding. Many genes encode the structure of proteins with specific groups of nucleotides in DNA corresponding to specific amino acids in proteins. Students often confuse DNA and proteins; this exercise is designed to help clarify the relationship between the two. After examining the introductory information on this relationship, the student clicks on the bottle to get a note card containing the DNA coding sequence for a specific human protein. In-world links to an external DNA translation utility (EBI) and a protein sequence comparison program (NCBI) allow the student to identify the protein encoded by the DNA sequence. The learning objective here is for the student to understand the differences between DNA and protein sequences, to understand the informational relationship between the two, and to acquire experience using genetics databases. This activity illustrates how external data resources accessed from within Second Life can be applied to specific tasks.

Teaching on Genome Island

The best use of the materials on Genome Island will vary with class size, class level, students' level of access to and experience with computers, students' science background, and the instructor's teaching style. The same activity can be used for multiple purposes and can be revisited as students develop more sophisticated understanding of a given topic. Instructors might wish to assign specific activities as independent investigations or run a given experiment as an in-class demonstration with a large group of observers. Students might be given a list of experiments to complete or allowed to blaze their own trail around the island. Experiments might be followed with a synchronous group discussion in one of the conference areas on the island, by asynchronous online reflections, or by written reports. Self-assessment games are also offered in several areas.

I brought students from two of my classes into Genome Island in 2007 and early 2008 for initial testing of the site. A group of 5 advanced genetics students in Fall 2007 was followed by a larger group of 23 freshmen in Spring 2008. None of the students in either group had previous experience with Second Life. The students were assisted with setting up Second Life accounts and given a brief, supervised orientation session. After they completed a self-paced scavenger hunt designed to provide navigational practice and to familiarize them with the island, the students were assigned a small set of Genome Island's available activities. Since students were familiar with Wesleyan's WebCT course management system, I used the WebCT assignment page, accessible from within Second Life, to provide information about tasks for the week and to collect students' task reports (Figure 2).

I observed and informally debriefed the advanced students as we explored the new learning environment together. Observing this group of first users helped me to understand more clearly the special character of the Second Life environment, which is different both from a classroom setting and from a typical Web-based course (Exhibit 7). In a live, synchronous class, the instructor is available to establish context, demonstrate procedures, clarify instructions, and answer questions. Web sites can use a navigation menu to lead students through sequential activities. In Second Life, on the other hand, the instructor may be off-world, students frequently work asynchronously, and the virtual territory to be navigated is the size of a small campus. The Genome Island activities are accompanied by general operational instructions and basic background information; in addition, related activities are grouped together. However, most activities can be used in different conceptual frameworks, and the intended conceptual focus, the specific navigational pathway, informational resources, and data collection procedures must all be included in each assignment (Exhibit 8).

The freshmen students in the second class were asked to complete a questionnaire about their experience in Second Life (Exhibit 9). The survey asked about access to and ease of operation of the Second Life software, assignment routines, specific Second Life features and Genome Island activities, and the student's general evaluation of Second Life as a learning venue. Student responses to Second Life were about evenly distributed between positive and negative (Table 1); a significant factor in determining students' overall satisfaction was the ability to run Second Life from their personal computers. Being confined to campus labs understandably vitiates the benefits of the online environment. In addition, the pilot group may not have been in-world long enough to overcome the stresses of working in an unfamiliar environment. Favored activities were those that presented puzzles to be solved by the application of principles learned in preparatory experiments performed in Second Life.

Student performance on Second Life learning objectives was assessed as part of the final laboratory exam, which included material covered in Second Life activities (Table 2). The mean student score on items drawn from Second Life activities was higher than mean performance on items related to other lab activities although the wide variation in individual student performance makes the difference between means barely significant.

Since time on task is an important factor in learning, general visitor data was collected from proximity sensors distributed at various locations around the island (Table 3). The sensors count unique visitors and total time spent in range of the sensors. A student who leaves an area and then returns during a specified time period is not counted as a new visitor, but the time spent during repeat visits does contribute to total time. The sensors do not distinguish between my students and other visitors to the island and cannot distinguish visitors actively engaged with experiments from passive observers who may just be passing through. Of the 111 visitors to the Greenhouse in May 2008, no more than 23 could have been students from my freshman class. Sensors located in low-activity sections of the Tower give average monthly visit durations of about 3 minutes, so the average visit duration of 14 minutes for the Greenhouse indicates active engagement from at least some visitors.

Conclusion

These initial trials indicate that virtual worlds offer a learning environment that combines active engagement with the convenience of online access. Encouraged by the results of my preliminary trials, I taught a fully in-world course for nonmajors in the fall of 2008, and I am now trying Second Life "light" (virtual laboratory experiences offered as in-class instructor demonstrations) with the current group of freshmen. When the current class is completed, I will be able to compare student responses to these two instructional modes with those from the “field trip” approach used with the pilot classes.

Genome Island is available for public access, and I welcome testing of the activities by students from other institutions. A guide to Genome Island for instructors is in preparation.

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