



# Using Web-Based Simulations to Promote Inquiry

by Mel Limson, Crystal Witzlib,  
and Robert A. Desharnais

It is widely accepted that inquiry-based curriculum programs have positive effects on cognitive achievement, process skills, and attitudes toward science (NRC 2000). Science teachers seek engaging, effective, and inquiry-based activities that are standards-aligned and convenient to implement in their classrooms. For many years, the web has provided teachers and students with a vast resource of factual information (some of it multimedia). More recently, websites have been developed where teachers can obtain effective inquiry-based tools for teaching science. We report on how one of these sites, the Virtual Courseware Project ([www.sciencecourseware.org](http://www.sciencecourseware.org)), was used to engage students in an inquiry-based study of the principles of genetic inheritance.

## About the project

The Virtual Courseware website has a free suite of activities for both the life science laboratory and Earth science field studies

that can be used by students ranging from middle school to high school, or in the college classroom. Virtual Courseware activities are innovative, experimental simulations that emphasize the inquiry process. Students learn by doing: making observations, proposing hypotheses, designing experiments, collecting and analyzing data generated by the software, and synthesizing and communicating results through an online notebook and report. The activities also include an online assessment quiz that consists of randomized, interactive questions. Students' answers are graded automatically and stored in a database server hosted by the Virtual Courseware Project, and a printable certificate of completion is issued for each

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**Mel Limson** ([mlimson@the-aps.org](mailto:mlimson@the-aps.org)) is the K–12 education programs coordinator at the American Physiological Society in Bethesda, Maryland. **Crystal Witzlib** is a former seventh-grade science teacher at the John Muir Middle School in Burbank, California. **Robert A. Desharnais** is a professor of biology at California State University, Los Angeles.

student. The certificate of completion is generated automatically after a student has taken the quiz and is presented to the student together with the quiz results.

Teachers can access student and class results, allowing them to quickly gauge how well the key concepts were understood. Additionally, teachers have the option of modifying the grading rubric and guiding questions for the laboratory report, a feature that makes Virtual Courseware adaptable for different populations of learners. Examples of Virtual Courseware appropriate for middle school science students include *Drosophila*, for studying the principles of genetic inheritance; Natural Selection, for studying evolution; Relative Dating, for studying geological time; and Faults, for studying geological patterns.

We used the *Drosophila* simulation for two main purposes. First, we wanted students to grasp how phenotype alone can be used to determine what traits are passed from parents to offspring. By observing patterns of inheritance, recessiveness or dominance can be hypothesized. Secondly, we wanted to expose students to the inquiry process. *Drosophila* was used in both Gifted and Talented Education (GATE) and nonGATE seventh-grade classes at the culmination of the genetics unit. Prior to using the activity, students knew only how to determine offspring by using genotypes and Punnett squares.

### Virtual experiments

The *Drosophila* activity transforms the traditional fruit-fly laboratory experience into a virtual experiment. Students first register and create an account with a class code that is generated when the teacher sets up the class. The class account stores students' notebooks, reports, and quizzes, which remain accessible for student review during subsequent sessions. The use of a class code also permits the teacher to view the notebook, grade and comment on the report, and analyze the quiz results. After logging on, students see a lab bench with the equipment necessary to perform the fruit-fly experiments (Figure 1). Throughout the activity, students can add im-



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ages, data, and additional notes to the online notebook accessible through the Notebook tab. Once the report is activated by the teacher, the Report tab guides students in writing their online lab reports. After the teacher has activated the quiz, students can use the Quiz tab to answer a series of interactive and randomized questions related to the tasks they perform with the activity. Using the Options tab, students can turn on or off the sounds, transitions, and on-screen directions.

In a typical experiment, students (1) select a male and female fly with specific traits, (2) mate these two parent flies, (3) observe and record the characteristics that are passed on to their offspring, and (4) analyze the results and provide a

**FIGURE 1** The virtual lab bench



#### The Lab Bench

**YOUR TASK:** (1) Select a male and female fly with specific traits, (2) mate these two parent flies and observe the characteristics that are passed onto their offspring, (3) record the data, and (4) analyze the results. Use the computer to custom order flies or to analyze the data you will collect. Use the incubator to grow and keep the flies. Use the microscope to closely look at the flies. Use the trash can to clean up all the flies. **TO START:** Click on the computer to order new flies for mating.

**FIGURE 2** Selecting traits to study

hypothesis ratio based on the outcome of the experiments. Offspring from one cross can also be mated to produce a second generation. The computer in the Lab Bench tab allows students to order flies with different combinations of mutations or to analyze the data that are collected.

Designing an experiment begins with the Fly's Supplies screen (Figure 2). The fly being customized is in the view on the left half of the screen, along with a list of its characteristics. Visible mutations are chosen from a tabbed catalog on the right. Up to three traits may be selected for any single experiment. Possible choices include gender and 30 traits in nine different categories: bristles, body color, antennae, eye color, eye shape, wing size, wing shape, wing vein, and wing angle. Thousands of experimental combinations are possible. In the simplest case, students choose one mutation and cross it with a normal wild-type fly. For example, a female with vestigial

**FIGURE 3** Viewing flies in the microscope

wings and a wild-type male can be ordered and added to the shopping cart. At checkout, images of these flies can be recorded directly into the online notebook.

The next steps occur at the Lab Bench. The customized flies are shipped, unpacked, added to a mating jar, and placed in the incubator to initiate mating. A 10-second animation shows the development of flies through a normal life cycle. Another animation shows the offspring flies being anesthetized with ether in preparation for viewing under the microscope.

Data collection occurs in the Microscope View (Figure 3), where students can automatically sort flies based on their phenotype. A table in the upper right of the screen lists the gender, count, and phenotype of each group of flies. By clicking on a button, students can send their data to the Lab Bench computer for later analysis. Clicking on a fly pile zooms the view to a single fly. Students can save the fly image in their online notebooks and add them later to their reports.

*Drosophila* allows multiple generations. Students can choose two flies in the microscope view for a new mating. Multiple generations allow students to see examples of classic Mendelian genetic ratios. For example, the second generation of offspring from a mating between a vestigial-winged female and wild-type male is shown in the Microscope View in Figure 3. The second generation is now sorted into four piles and the data (gender, count, and phenotype) are listed in the upper-right section. Because vestigial wings are a recessive trait, these data show a 3:1 ratio between the normal and mutant flies.

*Drosophila* also allows test crosses. In this case, an offspring fly in the microscope view is added to the mating jar and then a new fly from the store can be used for a mating with the offspring fly. Test crosses with a recessive fly allow students to distinguish between flies with the same phenotype, but different genotypes.

Data analysis occurs in the Computer View. Data transferred from the microscope appear in tabular form. Students can propose a numerical hypothesis for the expected ratio of the different fly phenotypes and see how well their hypothesis matches the data. A chi-square statistical analysis is also an option. All data tables and analyses can be saved in the online notebook.

### Teacher preparation

Teacher preparation for the activity is fairly simple. A *Teacher Registration and Workspace Guide* and a *Teacher Manual* are both available on the website. In the online Teacher Workspace, the teacher can register multiple classes, and class codes are automatically generated (Figure 4). These codes are given to students to use

when they register so that their notebooks, reports, and quiz results are accessible by the teacher.

The teacher can modify the online default report guide and grading rubric to make it appropriate for middle school students (Figure 5a). Each section, header, and line of text can be customized using the Report and Rubric Editor tabs in the Teacher Workspace. Furthermore, the teacher can save versions under different names and associate each version with a particular class in the My Classes tab. Once students submit a final report, the teacher can easily grade and comment on it through the report link on the Assessment tab (Figure 5b).

In our classroom implementation, we compiled a student-preparation worksheet that included four predetermined fruit-fly crosses as guiding examples (Figure 6) and other websites (see Resources) on fruit flies and their use in genetics. The *Drosophila* activity was introduced to students by guiding them through an animated tour and other components of the website.

### Using *Drosophila* in the classroom

*Drosophila* was used as a week-long activity at the culmination of a month-long unit on genetics. A summary of how we used the *Drosophila* simulation with students in five middle school classes is shown in Figure 7. Although the activities were designed to accommodate one student per computer in a classroom or computer lab, working in pairs or in small groups was also effective. If there is limited access to computers in the classroom, the teacher can demonstrate the activity using the self-animated tour or by setting up and using an example student account. Students can then complete the activities on their own time as a homework assignment if they have access to computers connected to the internet. We provided students a list of local, public libraries with computers and internet access they could use during after-school hours. The website is database-driven and has dynamic features (student and teacher accounts), and thus can be used on any computer connected to the internet. No student or class information is stored on the local machine.

On the day we started the Virtual Courseware lab, students were required to do two of the four crosses that we assigned. Advanced students in the GATE classes were to pick one of four crosses to complete and were required to do one cross of their own. Again, the flexibility for customization of Virtual Courseware permits differentiated instruction among all learners. Although the GATE students finished the activity much faster, the non-GATE students performed and understood just as much as the advanced students.



Students were quickly engaged and amused at the entertaining, yet accurate simulation, while instinctively using the activity. Partners worked together, and surprisingly, different groups began checking on the various outcomes that other groups were obtaining and providing hypotheses for one another. At the end of the class period, we followed up with a short group discussion on using the activity. As instructors, we enjoyed observing the camaraderie of students that led to a true learning environment while we circulated through the computer lab room and only occasionally guided some partner groups in an inquiry-directed manner.

The assessment components of the activity are the report and quiz. All student groups were required to compose their reports by following the teacher-designed report guide and by importing images and tables saved into their notebook. Virtual Courseware provides teachers the flexibility to modify and customize the default report guide template and the grading rubric for the student reports. Furthermore, teachers have the discretion to assign the work as group or individual work. In our case, we assigned students to work in pairs or groups

**FIGURE 4** The teacher workspace



**FIGURE 5**

**(a) Report Template and Rubric Editors (b) Grading Rubric for assessment of student reports**

(a)

**Drosophila Report Template Editor**

Choose the report template you would like to use or edit below. To create a new report template, duplicate an existing report template and edit the duplicate. The current status is all the default report templates.

Report Template Name	Last Edited	Author
Default Template	1 year, 10 months ago	John
For General Biology	1 year, 10 months ago	John
For Microbiology	1 year, 10 months ago	John

  

**Drosophila Rubric Editor**

Choose the rubric you would like to use or edit below. To create a new rubric, duplicate an existing rubric and edit the duplicate. The current status is all the default rubrics.

Rubric Name	Last Edited	Author
Default	1 year, 10 months ago	John
Student Form	1 year, 10 months ago	John

**Edit Objective**

Objective Statement:  
The design of this experiment demonstrates Mendel's law of segregation.

Buttons:

(b)

**Experimental Design**

Plan: We started a Drosophila system and a male with white eyes (w<sup>+</sup>) and a female with red eyes (w<sup>-</sup>). They mated and we got wild type flies (w<sup>+</sup>w<sup>+</sup>). Then we started a wild type offspring with a new Drosophila system.

**Materials and Methods**

Start your science team.

**Results and Discussion**

Start your science team.

Rated by Class 41  
Start your science team.  
Number of this phenotype: 4

Rated by Class 41  
Start your science team.  
Number of this phenotype: 4

Buttons:

of three. The report guided students to state their hypotheses, explain their results, and defend their conclusions. All students successfully completed reports and were given full credit for the assignment. Because it was designed for high school students and its interactive nature could not be edited by the teacher, the quiz was an extra-credit, optional assignment. The quiz addresses the learning objectives of the activity, but the details of the questions are randomized each time it is rendered. Students were challenged by the quiz in the *Drosophila* activity, but many of them retook the quiz several times, improving their performance and, in the process, their learning. Students had an incentive to complete the quiz—a printable, personalized certificate of completion that has been programmed into the activity. Both assessment components, the report and quiz, have a date and time stamp associated with every save and can be monitored from the Teacher Workspace. Thus, the teacher

can set a deadline for students to complete the experiments and submit their report or take the quiz.

**Observations of inquiry**

We were pleased by the amount of inquiry learning resulting from this activity. Students were able to justify the explanations of their scientific experiments, and independently formulated and tested alternative hypotheses to see how genetic patterns would be inherited. For example, a pair of students was surprised to find that after two generations their flies turned out to have yellow-colored bodies, despite having red-colored parents. They tracked the gene by writing down the chain of events and discovered that the recessive trait in the yellow flies came from the grandfather.

Both low- and high-achieving students were constantly engaged. It was unusual for students to be disciplined or

## FIGURE 6

## Supplemental student-preparation worksheets

***Drosophila melanogaster* (fruit fly) preparation**

Directions: You will need the internet for this assignment. Use the websites listed to answer the questions.

Mutant fruit flies

[www.exploratorium.edu/exhibits/mutant\\_flies/mutant\\_flies.html](http://www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html)

Read this entire site and answer the questions below. This site gives examples of fruit-fly mutations.

1. A mutation is any change in the genetic message carried by that gene that makes some trait of an organism different from normal, for example, having six fingers rather than five. Are all mutations bad?
2. What does it mean for a fruit fly to be “wild type”?
3. What color will an ebony fruit fly be?
4. Can a fly be “eyeless”?

A quick and simple introduction to *Drosophila melanogaster*

[www.ceolas.org/fly/intro.html](http://www.ceolas.org/fly/intro.html)

5. What will fruit flies accumulate around?
6. How long is the life cycle of a fruit fly?
7. How many pairs of chromosomes do fruit flies have?
8. Besides the fruit fly, name two other insects that have had their entire genome sequenced.

***Drosophila***

[www.sciencecourseware.org/vcise/drosophila](http://www.sciencecourseware.org/vcise/drosophila)

This is the website we will be using in class for our lab next week. Please spend some time investigating the site and answering the questions below.

Click on the blue tab on the left that reads Tour. Use the red arrows on the upper right to go from page to page. This will take you through the entire experiment we will be doing. Wait until the timer gets to the end before you move on to the next page, or you will miss information.

9. Who will give you your class code?
10. For what is the incubator used?
11. To start an experiment, what must you click on?
12. What must you click on to have the flies delivered to the Lab Bench?
13. Can your report be printed?
14. Are the questions the same each time you take the quiz?

After you finish the tour, click on the red tab on the left labeled User Homepage. On the lower right you can click on a button labeled Enter as a Guest. Click this button and enter. Important: DO NOT CLICK on the BACK button of your web browser or it will bring you back to the homepage!

15. Click on the computer.
16. Click on Order Flies.
17. Order a female with purple eyes (found under Eye Color) and a male with curly wings (found under Wing Shape). After ordering the flies you will have to check out.
18. Click on the box to unpack your flies and follow the directions given to you in the yellow boxes.
19. Sort your flies when you get to this step.
  - a. How many piles will be formed?
  - b. Will any of the flies have purple eyes? If yes, how many? If no, what does this tell us about the trait for purple eyes?
20. Go to Analyze Results.
  - a. What was the total number of flies that were the offspring of this mating?
21. Go back to order more flies. Try mating at least two more fly types. Experiment and have fun trying to learn the program.

***Drosophila***

Directions: Use any two of the following matings to write a detailed lab report for the *Drosophila* activity. Make sure to save your experimental findings in the online notebook so that you can use that information for your report. You will find the online report on the [sciencecourseware.org](http://sciencecourseware.org) website.

1. Female Eyeless (Eye Shape) and Male Miniature (Wing Size)  
Observe the results and save to notebook.  
Mate the male offspring with a new order of Female Eyeless.  
Observe the results and save to notebook.
2. Female Wild Type and Male Dichaete (Wing Angle)  
Observe the results and save to notebook.  
Mate the Male Dichaete offspring with a new order of Female Dichaete (Wing Angle).  
Observe the results and save to notebook.
3. Female Purple Eyes (Eye Color) and Male Yellow Body (Body Color)  
Observe the results and save to notebook.  
Mate the Female Wild-Type offspring with Male Purple Eyes.  
Observe the results and save to notebook.
4. Female Lobe (Eye Shape) and Male Shaven (Bristles)  
Observe the results and save to notebook.  
Mate the Lobe Male with a Wild-Type Female.  
Observe the results and save to notebook.

FIGURE 7

## Summary of implementation in the middle school classroom

Day	Activity focus	Comments
Day 1	Students introduced to website and animated tour. Students picked partners. Partners registered for student accounts.	Partnering allowed students to exchange ideas and decreased the amount of grading. Students' first initials and last names were combined to register a single account.
Days 2–3	Report activated for partners. Partners followed worksheet with predetermined fruit-fly crosses. Gifted and Talented Education (GATE) students picked one of four crosses to complete and performed a cross on their own; non-GATE students picked two of the four crosses to complete. Partners began composing report using data saved into notebook.	Software allows teacher to <ul style="list-style-type: none"> <li>• modify the Report Guide,</li> <li>• modify the Scoring Rubric,</li> <li>• decide when to activate the report, and</li> <li>• decide when to activate the quiz.</li> </ul> Students can access the web-based program, notebooks, and reports at home or at the public library. Student results and teacher assessment saved to server, not on local machine.
Day 4	Quiz activated for extra credit. Students worked in pairs, some took quiz multiple times. Certificates of completion printed. Partners continued composing reports.	Quiz is advanced for seventh graders. Quiz can not be edited by the teacher because of its interactive nature. Several students repeated the quiz until they got correct answers. This contributed to their learning. Students excited by the printable and personalized certificate of completion.
Day 5	Reports due by time-stamp deadline.	Reports, notebooks, quiz answers, and scores can be viewed through the Teacher Workspace. Reports were graded online using the previously customized rubric. Students were able to view their grades and teacher comments on their reports by logging in to their accounts.

asked to stay on task because they wanted to use the program. Though it was rarely necessary during the activity in our computer lab, we enforced a policy that grading points would be deducted if we found students going to other websites not directly related to *Drosophila*. One of the most rewarding moments occurred when a student said, “I went home and almost finished the report last night on my computer.” At the time this student had 13 missing assignments, but was now putting in time outside of class!

The response to the *Drosophila* activity was better than we expected. Students were excited and motivated to think and discover, and several told us that they hadn't understood genotype and phenotype before mating the flies. Students grasped the basic concepts more fully by applying and discovering the principles they had learned earlier in our genetics unit. ■

### Acknowledgments

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### Reference

National Research Council (NRC). 2000. *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

### Resources

Mutant fruit flies—[www.exploratorium.edu/exhibits/mutant\\_flies/mutant\\_flies.html](http://www.exploratorium.edu/exhibits/mutant_flies/mutant_flies.html)

The Virtual Courseware Activity: *Drosophila*—[www.sciencecourseware.org/vcise/drosophila](http://www.sciencecourseware.org/vcise/drosophila)

The Virtual Courseware Project—[www.sciencecourseware.org](http://www.sciencecourseware.org)

The WWW Virtual Library: A Quick and Simple Introduction to *Drosophila melanogaster*—[www.ceolas.org/fly/intro.html](http://www.ceolas.org/fly/intro.html)