The Future of Strategic Modeling and Simulations to Support Investigative Learning in Undergraduate Biology

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SUMMARY

In "The Liberal Art of Science: Agenda For Action" (1990), the AAAS urged "science should be taught as it is practiced." To understand science as it is practiced, students must first engage in problem posing, experience open-ended problem solving, and convince others of the reasonableness and usefulness of their solutions. Given the increasing enrollment in biology and the decreasing space, funds, and time for laboratory and field opportunities found in most institutions, how can we provide for these experiences? Where are these experiences for students in the "virtual" university?

One answer may lie in designing instructional environments that make better use of our technological resources. The availability of computer models and simulations for undergraduate education has increased dramatically over the past decade. Minimally these programs provide simple predictive data, but they also serve as powerful tools for explanation and argumentation in biology. For many biology students, model-building and strategic simulations offer real opportunities to explore a problem, to make decisions about what is meaningful, and to support their ideas using scientific reasoning.

KEY WORDS: modeling, simulation, investigative learning, curricular reform, student-centered learning, instructional technology, problem solving

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Biological knowledge is the result of personal interactions throughout our life. Students have always brought their own experience, interests, and “informed” views about the nature of the biological world to the classroom. However, the increasing availability of technological resources and global access to information will significantly change what they bring to both real and virtual learning environments in the 21st century. In these classrooms, instructors are more likely to function as co-learners than as sources of information. Designing a learning environment that acknowledges that facts are not proprietary is essential.

In order to promote an understanding of how scientific knowledge is created, modified, and used, it is necessary to “deal explicitly with problem solving and not just with solutions”.[1] To these ends, we feel that strategic modeling and simulation effectively contribute to student experience in problem posing, problem solving and peer persuasion. Students are encouraged to model and to test their own ideas and those of others in the classroom. Using strategic modeling and simulations, students can work together within robust microworlds and try out scientific strategies before going into the lab or out to the field.

"Models are very powerful and interesting tools in science, which can not only generate predictions, but also (and more importantly) can guide explanation, interpretation, understanding, and discovery in science. When models are used in combination with computers, we can use our most powerful strategy for analyzing the behavior of models - visualization."[2] Models are much simpler than the biological systems they represent, but are still helpful in engaging students in testing both their own ideas and those of others. Models that are easily changed encourage experimentation and interactive exploration.

Students should have an opportunity to develop several models or explanations to account for observed phenomena and then test them. Unlike software games that reward users for finding the right solution, strategic simulations ask students to recognize the complexity of scientific problems. Open-ended simulations challenge students to address the question of closure. Furthermore, research is not complete, no matter how many experiments have been conducted or how many puzzles have been solved, until peers outside of a research team are persuaded of the utility of the answers.

For this presentation, an interactive model on wine fermentation will be used as an example. (See next page for details of the Wine Minimodel system.) Grapes, Yeast, Ethanol, and Stress icons are connected to form a fermentation system. The student can easily change the initial value for an icon, add or remove icons, and then run a simulation. For example, eliminating Stress from the model could simulate an open system for fermentation.

By introducing wine fermentation as a model rather than as a process description, the instructor is providing an environment to facilitate exploration of what the students know and don’t know about this process. Experimentation provides opportunities for students to examine

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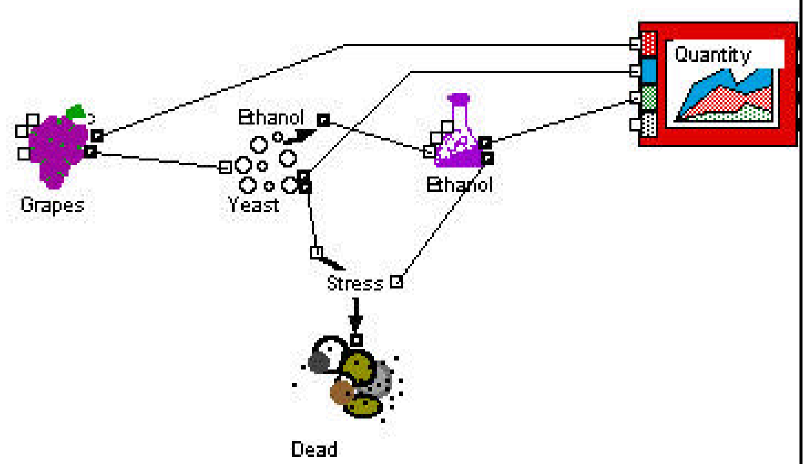
[1] Moore, J.. Science as a Way of Knowing. "Understanding Nature Form and Function". *American Zoologist* 28: 1988, p.449.

[2] Wimsatt, W. and Schank, J. *The BioQUESTLibrary V*, eds. Jungck, J. & Vaughan, V. San Diego: Academic Press. 1998.

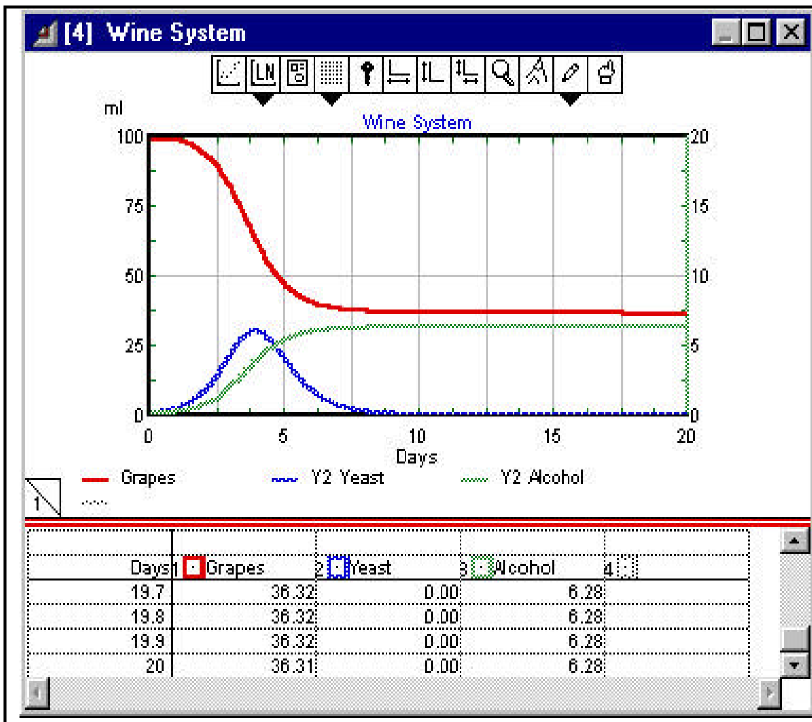
their own conceptual understanding and those of others in the classroom. These simulations examine fermentation from multiple perspectives. The instructor functions as a co-learner.

Another potential advantage from the modeling and simulation experience is the ease of extension into new applications. Although students are using a model that has grapes, yeast and alcohol, there are other situations in which by-products accumulate and inhibit the



Fermentation is the principal process in manufacture of wine. In this model, there are icons for grapes, yeast ethanol, stress, and a plotter.

A closed batch process is modeled by linking the icons so that sugars from the grapes are used as the yeast grows. Ethanol, a toxic waste product, is produced. The accumulation of ethanol eventually inhibits further microbial action.



Running this simulation, students can see the changes in the wine system over time. Sugar decreases, yeast grows quickly, and ethanol accumulates. The yeast declines as the available sugar decreases. The ethanol eliminates active cells. In this run, fermentation stops even though there is considerable sugar remaining.

Running the simulation again with revised starting values of the model components allows students to explore the process.

Simulating with the Wine Minimodel[1]

conversion processes. This model might apply on a larger scale to human society. If our waste products accumulate enough, should we not expect to inhibit the production of humanity?

The BioQUEST Curriculum Consortium promotes simulation design criteria that are also useful for evaluating simulations. Identification of these features is based on earlier work[2] supplemented by observations made during extensive field testing of modeling and simulation use across the United States.

Figure 1. Desirable Features of Strategic Simulations
1. Novelty of problems each time 2. Realistic outcomes for each experiment 3. Infinite opportunities to do experiments 4. Computational power 5. Speed in obtaining results 6. Large data size 7. Facilitation of successive hypothesizing (logical and numerical testing) 8. Sequentially developed problem difficulty 9. Hypothesis as solution 10. Opportunity for peer review

The use of computer models and simulations has increased dramatically over the past decade. For many biology students, model-building and strategic simulations offer real opportunities to explore a problem, to make decisions about what is meaningful, and to support their ideas using scientific reasoning. As powerful tools for explanation and argumentation in undergraduate biology, strategic modeling and simulations show continued promise for 21st century education.

Odum, H.T and Odum, E.C. "Wine Minimodel." *The BioQUESTLibrary VI*. In Press. SanDiego: Academic Press. 2000.

[2] Jungck, J. and Calley, J. "Strategic simulations and post-socratic pedagogy: Constructing computer software to develop long-term inference through experimental inquiry." *American Biology Teacher* 47: 1985, 11-15.