SimScientists: Effective Instruction and Assessment

Background
A series of national reports urge science education to go beyond emphasis on basic science facts to support science learning that results in deep understanding of scientific ideas and an ability to engage meaningfully in the practices of science (Bransford et al., 2000; Duschl et al., 2007). Inquiry practices—asking questions, finding ways to explore them empirically, investigating and evaluating competing alternative models, arguing from evidence—are judged to be severely lacking in the enacted U.S. curriculum. The report, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics,* emphasizes the need for instruction that is inquiry-based and problem-centered and that engages students in the practices of science. Strong instruction should be accompanied by a supportive system of assessment that links classroom, district, and state reports of science learning progress.

The National Science Foundation (NSF) has funded projects that have produced suites of simulation-based assessment and instructional resources along with research evidence of their feasibility for classroom use, utility for instructional decision-making, and technical quality as evidence of complex science learning. These research and development projects form the SimScientists program in WestEd's Science Technology, Engineering, and Math program. (See http://simscientists.org.) The projects have conducted field tests in five states (including Nevada) to document their feasibility, utility, quality, and impacts on learning.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas and the draft *Next Generation Science Standards* seek to focus on fewer, deeper learning goals. Systems thinking and model-based learning are identified as key resources for reformulating science education (NRC, 2011, 2012). The cross-cutting concepts of Systems and Models are recommended for application to life, physical, and Earth science so that students develop the kinds of organized knowledge structures held by experts. Also highlighted is the scientific practice of developing and using models to visualize, study, understand, and communicate about systems.

The NSF-funded Calipers I and II projects have developed simulations to assess complex science learning. The Foundations of 21st Century Science Assessment project has conducted research on the value of static, animated, and interactive environments for providing evidence of students' skills in using inquiry strategies. Related SimScientists projects have extended the use of science simulations to support instruction and to build coherent sets of science assessments that could be used at classroom, district, and state levels.

All of the SimScientists modules incorporate research-based learning principles: meaningful problems, application of science knowledge in active investigations, formative assessment, and articulation and reflection. The science simulations present students with rich authentic environments that present simplified models of complex systems in the natural world such as ecosystems or watersheds. The simulations are dynamic and can show processes that may be otherwise unobservable and cannot be directly manipulated because they are too large (earthquakes) or too small (chemical reactions), too fast (hurricanes) or too slow (plant growth or erosion). The simulations are designed to represent the cross-cutting structures of all systems—components, interactions, and emergent system behavior. For example, consumers and producers are components in all ecosystems. They interact to transmit energy and matter throughout an ecosystem. Interactions among the component organisms result in emergent population levels that can vary under changing conditions. Because simulations can be manipulated to test predictions such as the effects of changes in numbers of organisms or environmental conditions on population levels, students can demonstrate their abilities to engage in the inquiry practices of science by actively conducting investigations. In addition, as students conduct inquiry by using simulations, data can be collected automatically to trigger individualized feedback, provide links to further instruction, and generate reports on learning progress.

Figure 1 shows screenshots from embedded modules of a terrestrial ecosystem for middle school. In the left screenshot, students are asked to draw a food web showing the transfer of matter and energy between organisms based on observations of feeding behaviors in the ecosystem. When a student draws an incorrect arrow, a feedback box coaches students to observe again by reviewing the animation and then to draw the arrow from food source to consumer. Feedback addresses common misconceptions. The right screenshot shows coaching for investigations of population changes due to variations of nonliving and living factors.

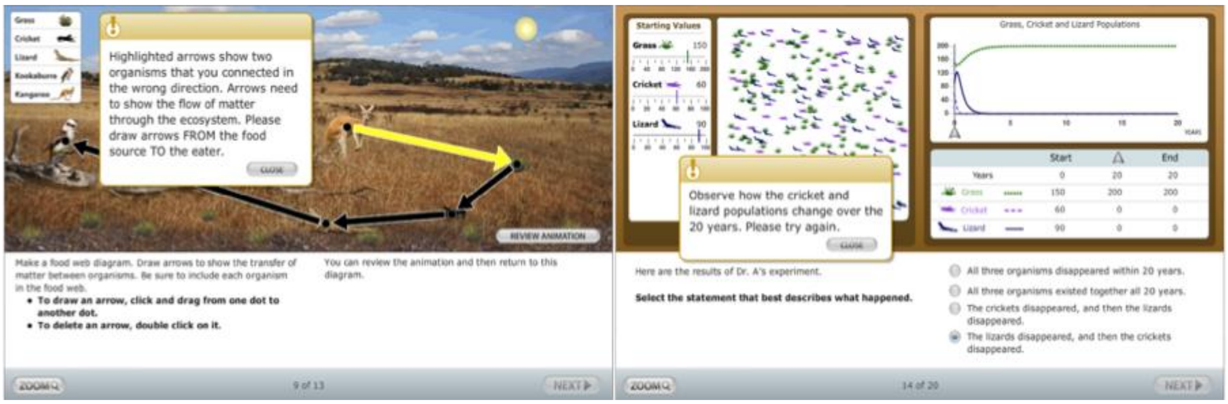

Figure 1. Screenshots from two *SimScientists* Ecosystem curriculum modules.

Simulations can also expand the ways students show what they know by offering a range of response formats "beyond the bubble," such as hot spots, drag and drop, drawing, operating sliders, and generating graphics, tables, and visualizations. This greater range of ways to show science phenomena in action and the allowance of multiple ways to respond offer great promise for reducing language demands and increasing access for students with disabilities and English learners (Quellmalz, Timms, & Silberglitt, 2012).

In the Calipers II project, assessments were developed that shared common specifications and simulation environments to provide sets of assessments for classroom, district, and state levels that were vertically linked. At the classroom level, simulations form the bases of curriculum-embedded assessments to monitor progress. The curriculum-embedded, simulation-based assessments are intended to be formative—to provide feedback and additional instruction (in the form of graduated coaching) as needed. The same simulation environments host end-of-unit benchmark assessments intended for summative information about student proficiency on science content and practices. Suites of simulation-based modules were developed for middle school life and physical science systems. A new project is developing sets of simulation-based signature tasks, derived from the same designs. These shorter simulations could function as components of district or state science tests. Another NSF-funded project, Human Body Systems, is extending the use of simulations to high school biology.

For More Information

Simulation-based curriculum and assessment modules are available for use by districts and states. More information can be found at http://simscientists.org and by contacting Edys Quellmalz (equellm@wested.org) at (650) 381-6427.