Simulations Signal a New Era in Science Assessment

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Students taking a standardized science test might read a passage describing an underwater ecosystem and then answer a series of related multiple choice questions. One day soon, students could be asked, instead, to demonstrate how well they understand the way an underwater ecosystem works. They would respond using computer-based simulation activities — making observations, inferring relationships, predicting outcomes, and analyzing data about the ecosystem. In short, they would use scientific inquiry.

This type of test question might require students to design an experiment to determine what would happen if too many of a particular species of fish were introduced into the ecosystem, or to predict how pollution or global warming would affect the system over time. As part of their investigation, students would be able to observe various organisms and their interactions, create food webs, and explore and graph population models.

"It's not likely that multiple choice questions are going to disappear. But we will see new approaches to testing certain knowledge and skills," says Edys Quellmalz, Director of Technology Enhanced Assessments and Learning Systems at WestEd, "and science will lead the way."

Assessing Students' Knowledge of Complex, Dynamic Processes

SimScientists, a five-year WestEd effort begun in 2007, is developing such science test formats — prototypes that will usher in a new era of computer-based assessment. The program encompasses five separate research projects, all on the role science simulations can play in improving middle school science instruction and assessment, and the optimum design of such simulations.

One project is investigating how to modify simulation-based activities for students with disabilities. Another focuses on cognitive research into how well various types of computer-based assessment tasks measure science learning, and the relative merits of simulation-based versus traditional assessment tools. The projects address three major science areas: life science (ecosystems, the human body), physical science (forces and motion, atoms and molecules), and earth science (plate tectonics, climate and weather).

Quellmalz, SimScientists' principal investigator, says schools are increasingly using computerized animations — and, in a few cases, interactive simulations — to teach science.

"Some assessment tools don't adequately measure students' understanding of complex science systems or their ability to conduct scientific inquiry," Quellmalz says, because assessing that level of knowledge is very hard to accomplish with a set of "static" written questions. "We will be using an interactive modality to get at neglected or poorly measured areas."

Science is the perfect context for such an approach, according to Quellmalz. "Science involves dynamic systems, such as ecosystems or plate tectonics, which have multiple components, a lot of causal interactions, and are challenging to observe because they take place over very long or very short periods of time, occur on a very large or very small scale, or are not easily visible," she says. "When students run a computer-based simulation, they get to see what happens to populations if, for example, something disrupts an underwater system and all the fish die. Such activity prompts questions about why the fish died: Did the number of predators change? Was the culprit a chemical introduced into the system?"

A physical science simulation might model the components, interactions, and system behaviors of forces acting on an object and the results of that action. For example, students might be asked to design an experiment to determine the effects of friction on a vehicle's speed and acceleration or predict how a change in mass influences an object in motion. In earth science, students might take part in a simulation on plate tectonics, using observations of earth's surface features and data sampling and analysis to understand geologic events such as earthquakes or volcanic eruptions.

Such simulations, says Quellmalz, allow students to "analyze what happens to a system, in terms of a set of cause-and-effect relationships, over time." That's something, she says, they may or may not be able to learn about from reading a textbook. It represents a level of model-based reasoning that cannot be adequately measured by conventional assessments. But with computer simulations, "The process is much more authentic," says Quellmalz. "You can present a model of a rich environment and its various components and then allow students to observe and investigate how those components interact."

Aiming For Prototypes and Wider Replication

SimScientists projects are built on research from a three-year demonstration project that provided evidence of the technical quality, utility, and feasibility of simulation-based science benchmark assessments. The five new projects are still in the design phase, but several early outcomes have already undergone small-scale testing in classrooms. These include a number of computer-based simulations, some in the form of assessment tools and others in the form of curriculum modules with built-in coaching. Sixth graders in San Carlos, California, participated in the first demonstration project, testing the usability of several simulations. Two additional small-scale feasibility studies have begun in the San Francisco Bay Area, and additional pilot testing is planned in Utah, North Carolina, and Nevada.

Quellmalz says the project team decided to design curriculum modules after teachers who saw early simulation activities designed for assessment asked, "Can we use these for instruction?" She said the question made researchers realize that "many of the science concepts we were trying to assess probably weren't being taught very well in the first place." The curriculum modules, compared to those used for assessment, include more explanation, demonstration, modeling, and coaching. Students also receive feedback as they work through the simulations.

Each of the program's five projects will produce prototypes that demonstrate effective design and can be replicated on a wider scale. Quellmalz says that she'd like to interest local school officials in pilot testing the prototypes, hoping they'll be motivated by realizing that traditional assessment tools don't adequately measure how well their students have mastered many state science standards, particularly the dynamic interactions within science systems. "It's an opportunity for a superintendent to get additional information about what students in the district know and can do in science," she says.

Meanwhile, Quellmalz notes, interest in and use of interactive formats — including computer simulations — is growing. "We're already seeing greater use of technology to deliver and score conventional kinds of test items," she says. "We will next move toward more innovative formats." In fact, this year's National Assessment of Educational Progress for science included a number of interactive computer tasks to test students' ability to engage in science inquiry. At the state level, Minnesota has begun using an interactive online science assessment.

SimScientists projects are being funded through 2012 by the National Science Foundation and the U.S. Department of Education. Collaborators include the American Association for the Advancement of Science and the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) at the University of California at Los Angeles. Acting as co-principal investigators and project managers on SimScientists projects are Michael J. Timms, former Associate Director of WestEd's Science, Technology, Engineering & Mathematics program, Barbara Buckley, Matt David Silberglitt, and Jodi Davenport. Other project leadership is provided by Art Sussman and Mark Loveland.

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