# SimScientists: Using Science Simulations to Promote Model-based Learning and Assessment

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**Abstract:** How can we teach and assess the core knowledge and skills that students need to succeed in the 21st century? The proposed session will engage participants in the computer-based supplementary curriculum-embedded and assessment modules developed in a set of research and development projects in WestEd's SimScientists program, funded by the U.S. National Science Foundation (NSF) and Department of Education (www.simscientists.org). The projects are led by Edys Quellmalz, Director of Technology Enhanced Assessment and Learning Systems in the Science Technology Engineering and Mathematics program at WestEd. Collaborators include the American Association for the Advancement of Science (AAAS) and the Center for Research and Evaluation of Students and Standards (CRESST) at UCLA.

## Theory and Research Base

Throughout a series of international and national reports and standards-setting efforts runs the theme that science education must go beyond basic science facts to support science learning that results in deep, connected understanding of science systems and an ability to engage in the inquiry practices of science (Bransford et al., 2000; Duschl et al., 2007). This recognition of the need to explicitly integrate fragmented science concepts into understanding science as systems and model-based reasoning about them requires a significant restructuring of science education. Taking advantage of the power of technology to represent dynamic models of science systems in curriculum and assessment could well transform 21st century science education.

Our approach is grounded in the profound changes simulations have made in the nature of inquiry in mathematics and science—for scientists, as well as for students (Quellmalz & Pellegrino, 2009). Simulations can represent dynamic science systems "in action," making invisible phenomena visible. Simulations allow representation and manipulation of the causal, temporal, and spatial relationships of science systems that are too big, too small, too fast, too slow, or too dangerous for classrooms. Simulations can make these dynamic models available for extended and active investigations of authentic problems (Gobert & Clement, 1999). This allows students to develop their abilities to engage in the active inquiry practices of science. When coupled with a technical infrastructure that captures and analyzes students' actions and answers, simulations can provide rich, immediate, customized feedback for students and diagnostic reports for teachers with guidance for further instruction.

The SimScientists modules are intended to activate and reorganize the typically inert body of science knowledge transmitted by textbooks into principled models of the particular science system that students can transfer and apply to the range of examples of the system in the natural world. The simulation environment, instructional activities, and assessment tasks are organized into three cross-cutting model levels of a science system—components and functions, interactions among components, and emergent system behaviors (2000; Chi, et al., 1991; Buckley, et al. 2010). The simulation-based curriculum supplements and assessments promote and monitor students' progress in the use of the inquiry practices of science as the students create and use models to describe and investigate the science systems.

The session will engage participants in the simulation-based assessments and instructional modules developed for ecosystems units taught in middle school. Below we describe the projects within the SimScientists program from which the simulation-based assessments and instructional modules for ecosystems will be drawn and the collaborative features within them.

The ***Calipers II: Using Simulations to Assess Complex Science Learning*** project, funded by the U.S. National Science Foundation, is currently in the fourth year of using evidence-centered design to develop suites of formative assessments to embed in extant curriculum units, as well as unit benchmark assessments to document student proficiency levels. The assessments are aligned with national middle school science standards for six science systems, two each for life, physical and earth science. The assessment suites are composed of two or three embedded formative assessments that the teacher inserts into a unit at key points and a summative benchmark assessment at the end of the unit. The SimScientists Learning Management System (LMS) was developed to deliver the Calipers II assessments and collect data. The LMS enables teachers to assign assessments, view progress reports, assign differentiated follow-up classroom reflection activities, score constructed responses from the benchmark assessment, and view summative proficiency reports. Figure 1 presents screenshots of Calipers II embedded assessments that provide immediate feedback and coaching as students working in teams of two interact with the simulations.

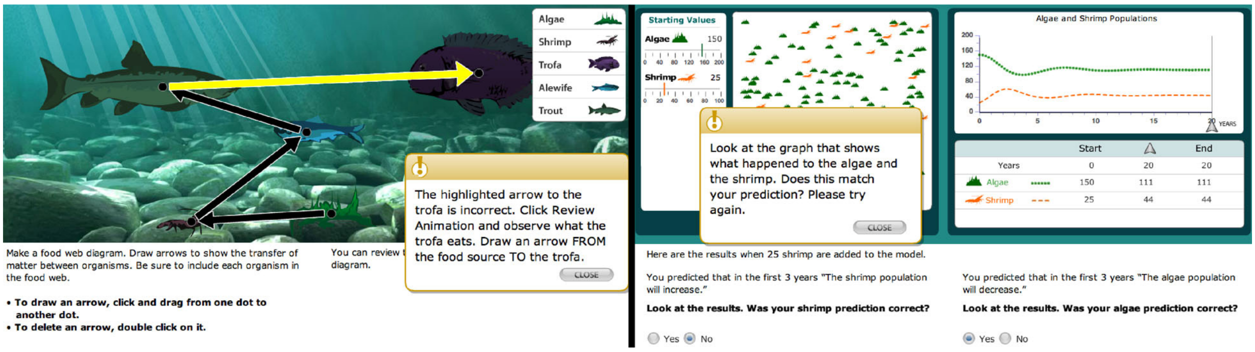


Figure 1. Calipers II Embedded Assessments Provide Feedback and Coaching.

In the left screenshot, students are asked to draw a food web showing the transfer of matter and energy between organisms based on prior observations made of feeding behaviors in the novel ecosystem. When a student draws an incorrect arrow, a feedback box coaches students to observe again by reviewing the animation and to draw the arrow from the food source to the consumer. Feedback also addresses common misconceptions. In addition, students working in teams engage in scientific discourse by discussing the tasks and questions and agreeing upon strategies for conducting the investigations and interpreting the results. The right screen shot shows feedback and coaching for investigations of population changes. The embedded assessments produce progress reports for students and teachers (Figure 2). The progress reports help the teacher adjust instruction during subsequent reflection activities that stress the big idea that all ecosystems share the same organizational structure and that similar behavior emerges from this structure. An important component of the dynamic embedded assessment is an offline reflection activity designed to provide differentiated tasks and to engage students in scientific discourse and collaboration as they apply their science content knowledge and inquiry skills to new, more complex ecosystems (Tundra, Galapagos, and Savanna). Students are assigned to teams which are given tasks that address the content and inquiry targets with which the teams needed the most help. For example, one Tundra team might examine pictures of organisms eating behaviors to agree on their roles as consumers. Another Tundra team might be responsible for identifying the producers. A third Tundra team might be responsible for beginning to draw some of the arrows depicting the flow of energy and matter in the system. Using a "jigsaw" structure, small groups merge into a larger Tundra group to combine their classifications of organisms and roles and complete drawing the food web on a poster representing the flow of matter and energy throughout their particular ecosystem. Student peer assessment is promoted as the students as well as teachers evaluate the posters and presentations of them using criteria for judging the clarity, accuracy, and evidence cited for identifying the roles of the organisms and the arrows representing the flow of matter and energy.

At the end of the unit, the teacher administers the summative unit benchmark assessment with tasks and items parallel to those in the embedded assessments, but that require transfer to a different ecosystem and do not provide coaching. Students must take the benchmark assessment individually since it is a summative assessment to gauge their proficiency at the end of the unit, whereas the teacher may assign students to work in teams during the embedded assessments. After teachers score the constructed text responses, benchmark assessment results are reported by the LMS for four proficiency levels for each target. Figure 2 shows the embedded assessment progress report and the benchmark assessment proficiency reports.

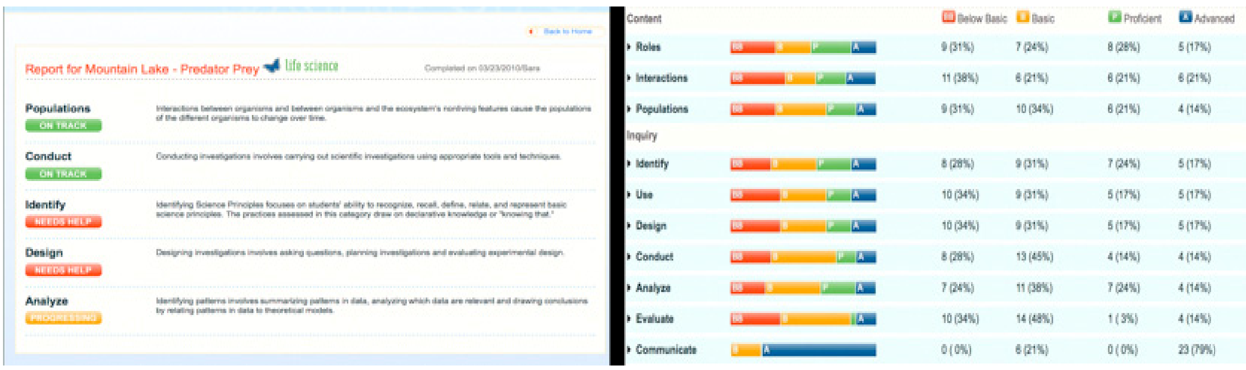


Figure 2. SimScientists Reports for Embedded and Benchmark Assessments.

The Calipers II embedded and benchmark assessments were studied in a large pilot test in three U.S. states (Nevada, Utah, North Carolina), involving 28 districts, 40 schools, and 55 middle school teachers. The resulting rich data set of 5,800 students provided strong evidence to support the feasibility, instructional utility, and technical quality of the assessments. Teacher and student responses to the simulation-based assessments were strongly positive. The study showed that the simulation-based embedded and benchmark assessments can be used on a large scale with diverse student populations and in school systems with varying technical infrastructures. The embedded assessment coaching strategies and reflection activities provided a basis for extending these strategies into simulation-based instruction.

The project, ***SimScientists: Interactive Simulation-based Learning Environments***, funded by the U.S. Department of Education is reframing the embedded assessment simulations to add enriched instruction. The project uses the Calipers II model-based learning framework and evidence-centered design principles to organize content and inquiry targets into three model levels for the instructional modules. Both instruction and assessments target content and inquiry skills at the three model levels (components, interactions, and emergent behavior). The curriculum suites feature meaningful problems, active investigations, scaffolding, reflection activities, and transparently embedded formative assessment tasks, followed by administration of Calipers II-developed summative benchmark assessments of documented technical quality. With dynamic presentations of the science system "in action" at different levels, each of the three curriculum suites overviews the levels of the system to be investigated in the upcoming simulation activities and provides explanations and examples prior to the simulation-based inquiry tasks, which use feedback and coaching like that in the Calipers II embedded assessments. Affordances of the technology, such as highlighting, zooming, and drawing arrows focus students on relevant components and processes. Culminating reflection activities engage students in scientific discourse as they collaborate to transfer their understanding of the ecosystem model levels to new environments such as the Tundra, Galapagos, or Savanna.

Each SimScientists curriculum suite consists of a dynamic introduction to the system and three simulation-based instructional modules that include instructional inquiry activities for student teams, seamlessly embedded formative assessments that capture student responses, graduated feedback and coaching, and a follow-up collaborative reflection activity to promote scientific discourse and transfer. The linked unit benchmark assessment includes similar simulation-based tasks, but without feedback and coaching. Each instructional module is designed to be inserted by the teacher into an ongoing unit on the topic. For example, after students had studied descriptions of producers, consumers, and decomposers in a middle school unit on ecosystems, a teacher could insert a simulation-based instructional module in which students make observations in a novel ecosystem to identify the roles of organisms and their place in food webs (components, roles, and interactions). Later in the unit, simulation-based curriculum modules can be inserted to investigate population dynamics (emergent system behavior).

## Theme of the Session and Expected Outcome(s)

The theme of the session is how science simulations can fundamentally transform science teaching and testing. Participants will learn how a science systems model can be used to promote learning, transfer, and principled, deep assessment. Participants will learn about the forms of student collaboration incorporated in the designs of the instructional and assessment tasks.

## Session Activities

Edys Quellmalz, Facilitator
Barbara Buckley, Facilitator

- Demonstration of the instructional and assessment modules
- Small group participation in responses to simulation-based tasks that demonstrate feedback and coaching
- Play recording of student thinking aloud during cognitive lab
- Small group participation in Reflection Activities to experience transfer of model levels to new ecosystems and forms of student collaboration in the jigsaw tasks.
- Summary of research findings
- Discussion questions
- Potential future collaboration

## References

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