Supporting Model-based Teaching and Learning with Simulation-based Instruction

Barbara C. Buckley
Edys Quellmalz
WestEd

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The SimScientists Team

designs, develops, & tests simulation-based instruction & assessments.

- ***WestEd***

  Edy Quellmalz, PI

  Daniel Brenner

  Barbara Buckley

  Jodi Davenport

  Darlene Jenkins

  Kevin Jordan

  Weiling Li

  Mark Loveland

  Kim Luttgen

  Anita Moorjani

  Matt Silberglitt

  Art Sussman

- **Diverse Expertise**

  Science

  Cognitive science

  Instructional design

  Assessment

  Measurement

  Technology

- **Funding**

  National Science Foundation

  US Department of Education

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Goal

- To foster and assess students' integrated understanding of **important, complex science systems** and the **science practices** used to investigate them.

Research

- **Role of simulations** in enriching science learning and assessment
- **Design principles** for creating effective simulation-based learning and assessment tools
- **Use** of science simulations at different levels of the educational system — classroom, district, and state

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Overview

- What we are building and why
- What we mean by Model-Based Learning
- How we support Model-Based Learning

Poster on Friday describes design process.

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Rationale

- The No Child Left Behind Act (2001) has resulted in no child left untested.
- Few tests assess the knowledge and reasoning valued by science educators.
  - Richly interconnected & useful knowledge
  - Science practices for extending knowledge through investigations
  - Reasoning for connoisseurship

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We build – simulation-based...

- Instruction in model-building
- Formative assessments *for* Learning
- Summative assessments *of* Learning

Ecosystems, Cells, Human Body Systems

Force & Motion, Atoms & Molecules for grades 6-8, ages 11-13

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Instruction in Model-Building

Introduces

- Qualitative, mechanistic systems thinking
- Emergent causality
- Representations
- Science practices

Focus on integrating concepts through inquiry

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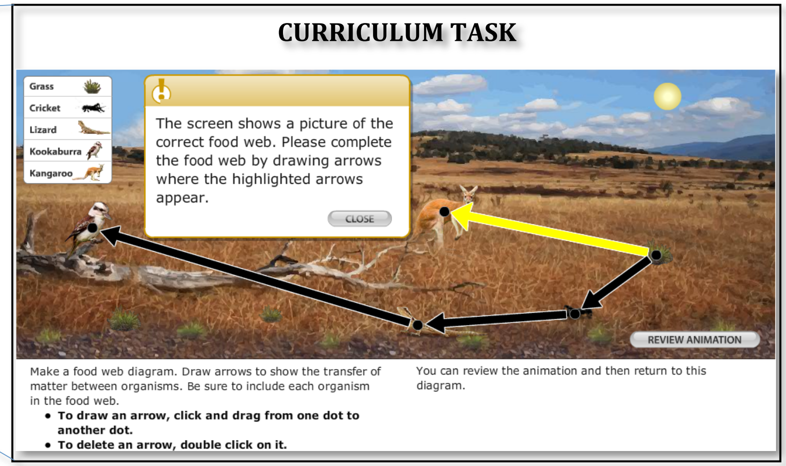
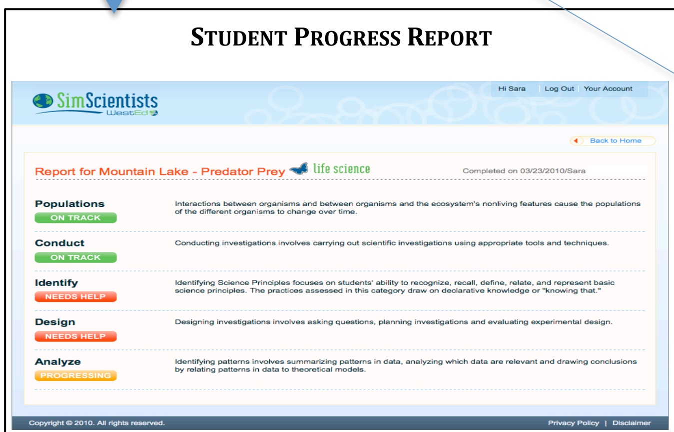
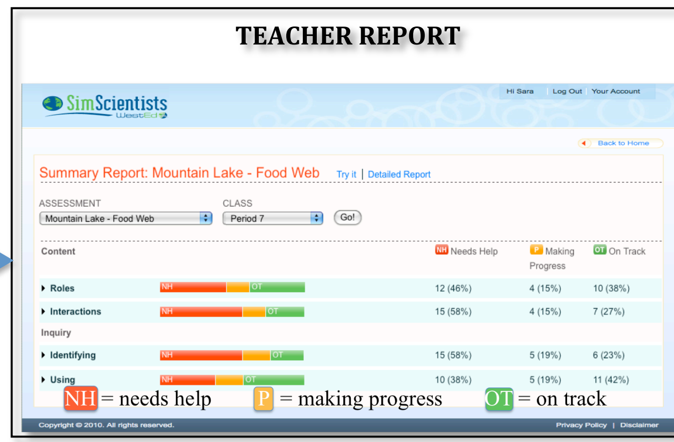
Formative Assessment

Online assessment with feedback & coaching







Reflection Activities

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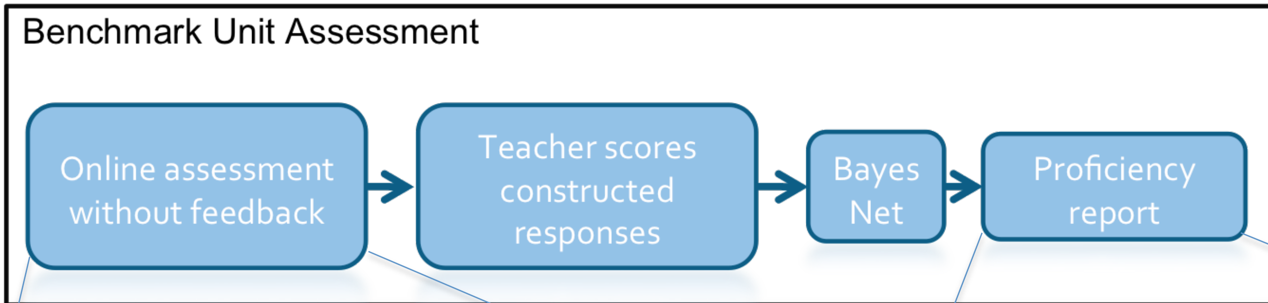
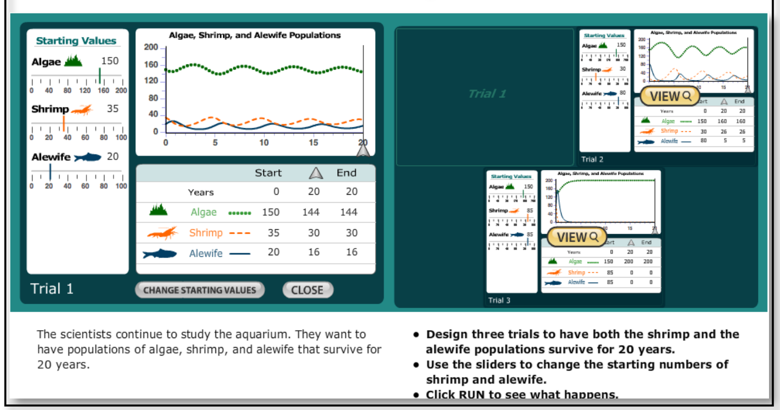
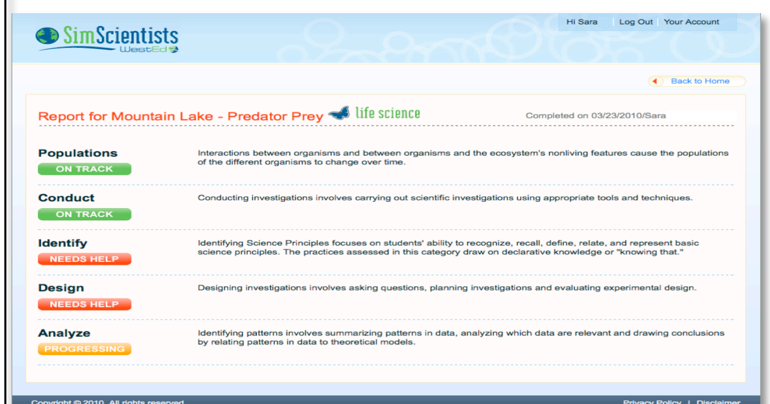
Summative Assessment



BENCHMARK INQUIRY TASK



BENCHMARK REPORT



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Theoretical Foundations

Understanding dynamic phenomena requires mental models (Johnson-Laird, 1983)**.**

Model-Based Learning (MBL)
(Gobert & Buckley, 2000; Buckley, 2011)

Evidence-Centered Design (ECD)
(Mislevy, et al, 2003)

Emergent Causality/Systems Thinking

Cognitive Science Research

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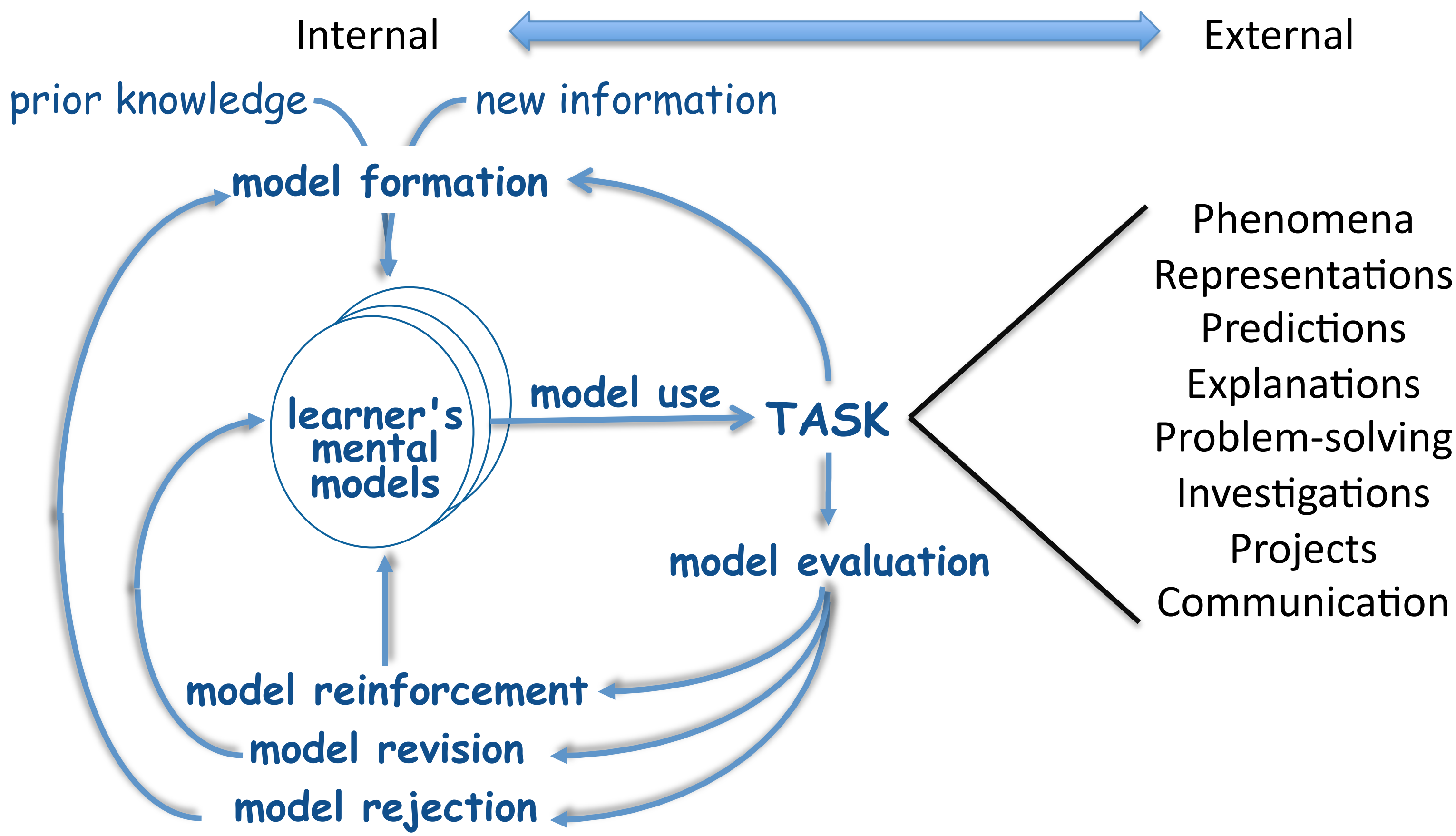
Model-Based Learning

(Gobert & Buckley, 2000; Buckley, 2011)



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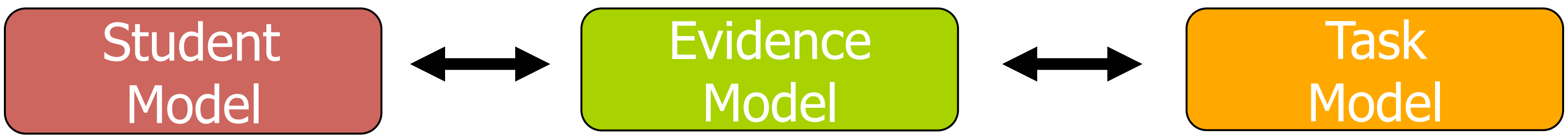
Evidence-Centered Design
(Mislevy et al., 2003)



What complex of knowledge, skills, or other attributes should be assessed?

What behaviors or performances should reveal the relevant knowledge and skills described in the student model?

What tasks or situations should elicit the behaviors or performances described in the evidence model?

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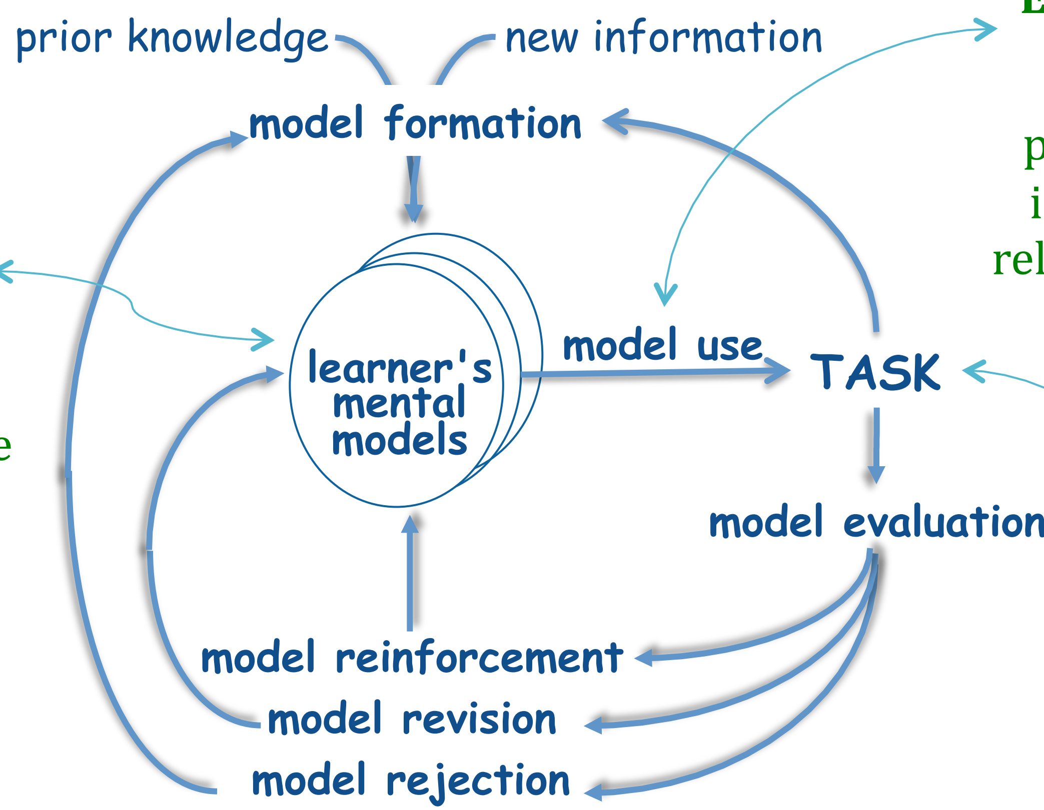
Theoretical Framework:
Model-Based Learning + Evidence-Centered Design

Student/Target Model

What knowledge and skills are to be taught or tested?



Evidence Model

What levels of performance are indicative of the relevant knowledge and skills?

Task Model

What tasks or situations elicit those performances?

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Target Model based on Emergent Causality

- Components
  - System components have structure and rules of behavior.
- Interactions
  - Components interact with each other and their environment as permitted by their structures and behaviors.
- Emergent
  - Complex system behaviors or properties emerge from these interactions.

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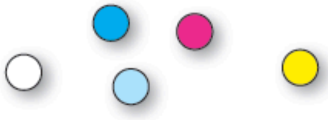
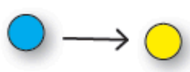
Ecosystem System Model

MODEL LEVELS	MODEL LEVEL DESCRIPTIONS	CONTENT TARGETS (CORE IDEAS)	INQUIRY TARGETS (SCIENCE PRACTICES)
COMPONENTS 	What are the components of the system and their rules of behavior?	Every ecosystem has a similar pattern of organization with respect to the roles (producers, consumers, and decomposers) that organisms play in the movement of energy and matter through the system.	Design Investigations Conduct Investigations Identify Patterns in data Draw Conclusions Evaluate Conclusions
INTERACTIONS 	How do the individual components interact?	Matter and energy flow through the ecosystem as individual organisms participate in feeding relationships within an ecosystem.	
EMERGENT BEHAVIORS 	What is the overall behavior or property of the system that results from many interactions following specific rules?	Interactions among organisms and the ecosystem's nonliving features cause the populations of the different organisms to change over time.	

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How do we support MBL and MBT?

- Simulations & representations that link
  - Components, interactions & emergent phenomena
  - Abstract representations & models
- Tasks based on science practices
- Immediate, graduated and tailored feedback
- Progress reports to students and teachers
- Reflection activities

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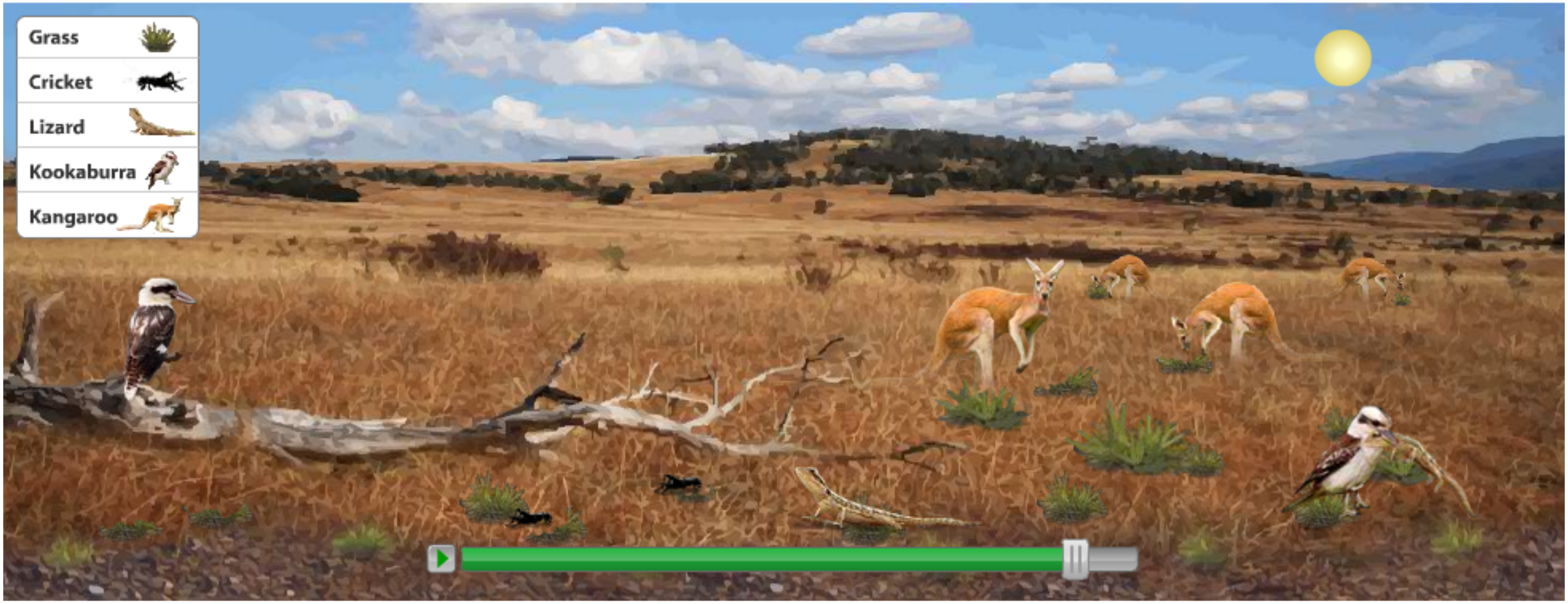
Dynamic Interactive Representations



Embedded Assessments - Customized, graduated coaching

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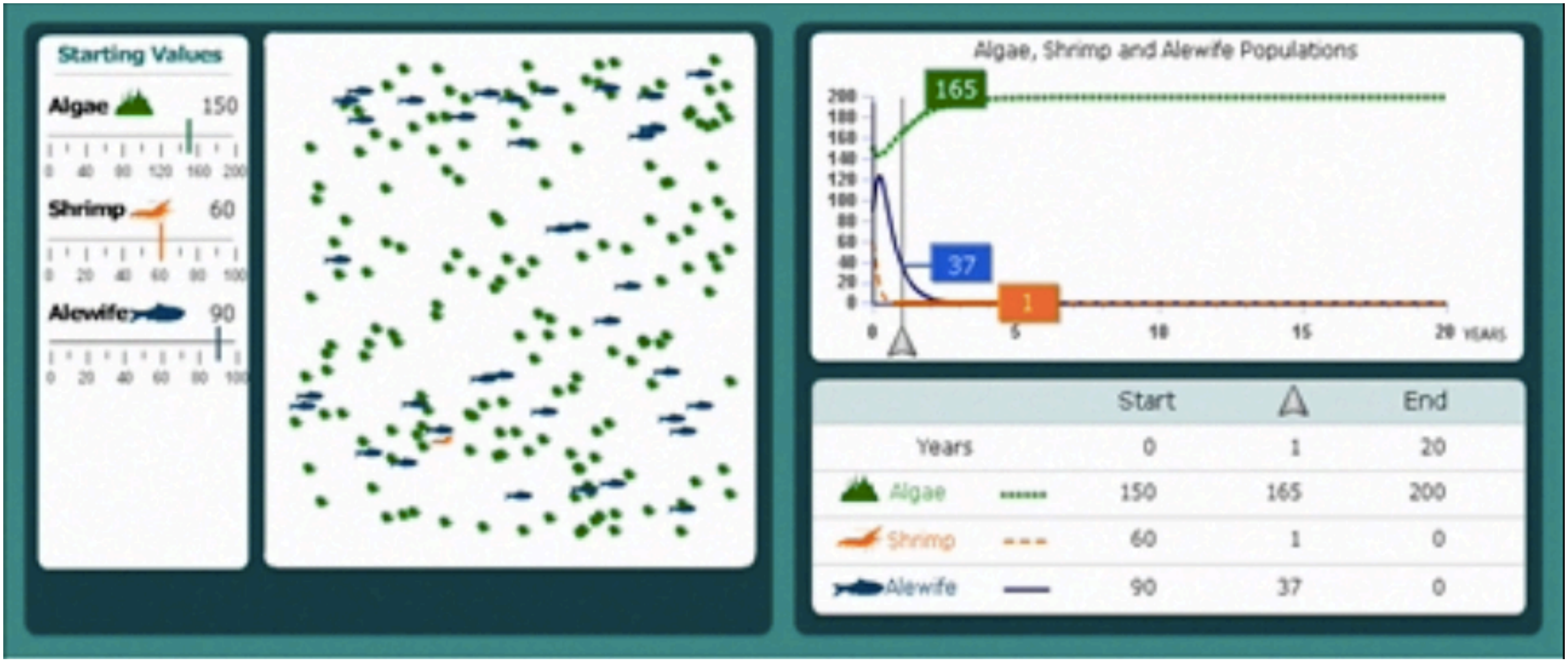
Ecosystem Population Model



Input variables Organism view Population graphs

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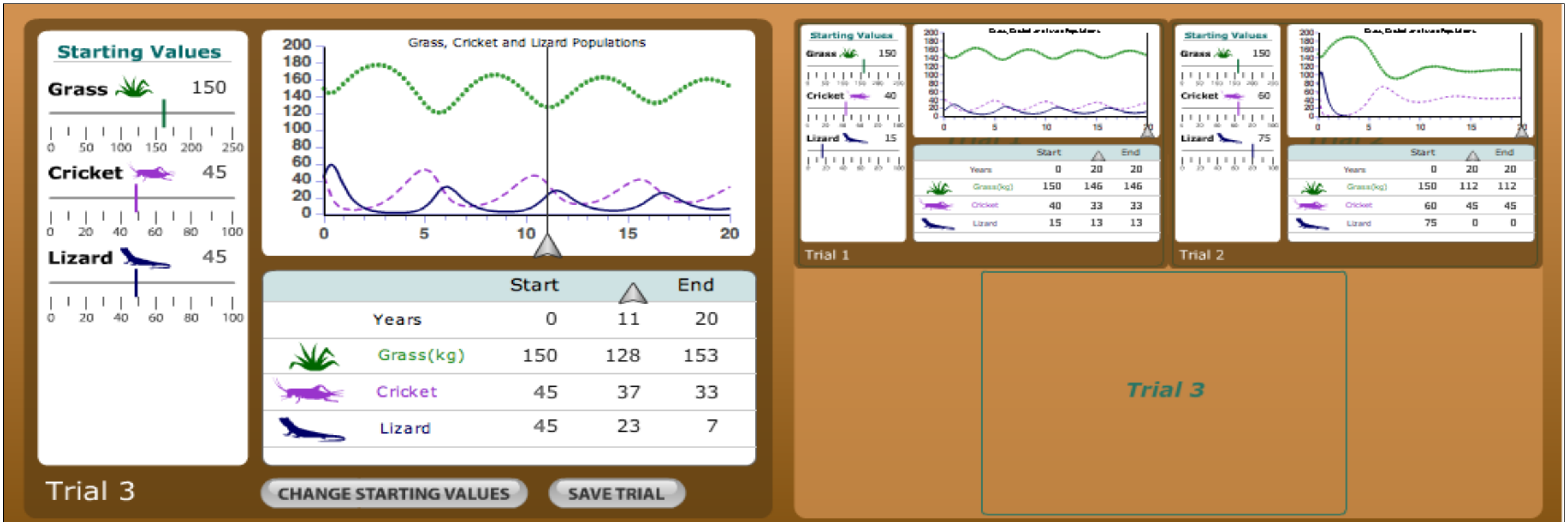
Ecosystem Populations



The scientists continue to study the burned grassland. They want to have populations of grass, crickets and lizards that survive for 20 years.

- **Design three trials to have both the cricket and the lizard populations survive for 20 years.**
- **Use the sliders to change the starting amounts of crickets and lizards.**
- **Click RUN to see what happens.**

When all trials are complete, click NEXT.

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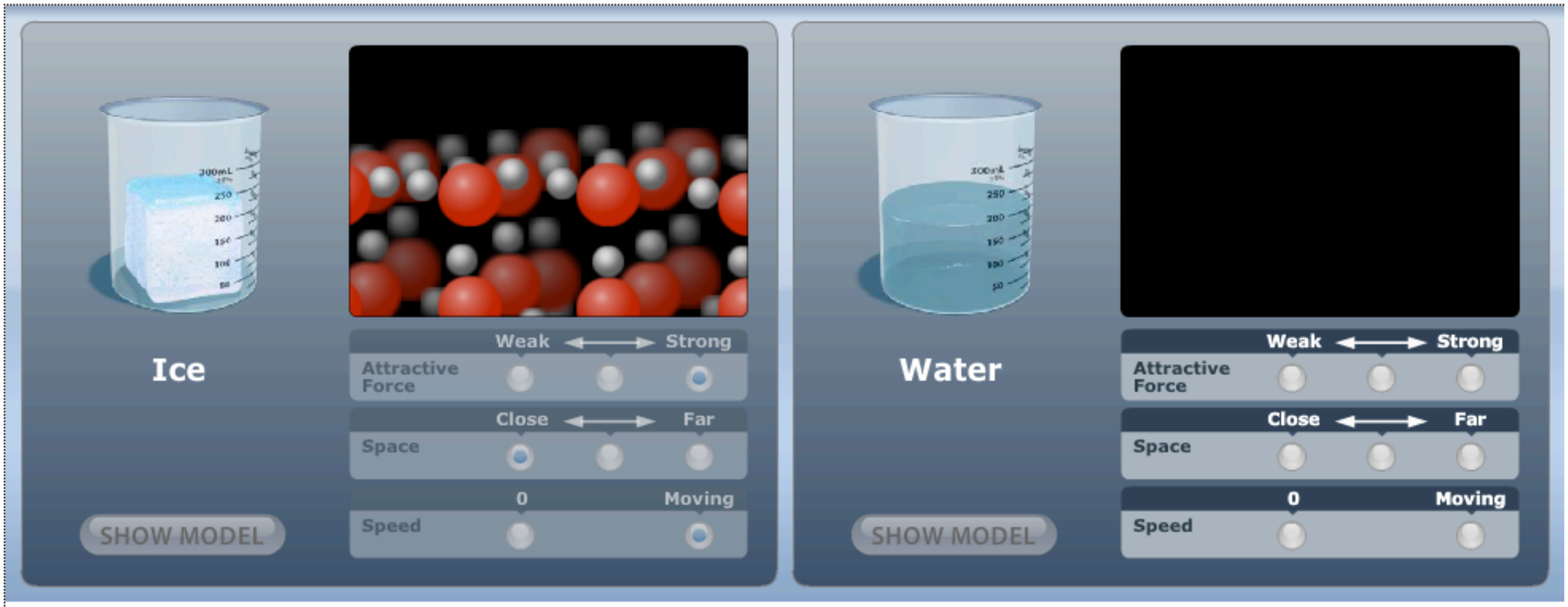
Modeling Tools



Your robot brings the ice sample inside the research station. The ice melts, leaving a beaker full of water.

The atomic model for ice is shown on the left.

Now use the Atomic Modeling Tool to create a model of what you think water looks like at the atomic level.

- Use the radio buttons to choose the **Attractive Force** between the molecules, the **Space** between the molecules, and the **Speed** of the molecules.
- Then click SHOW MODEL to see the model.
- If you want to change your model, select a different radio button.
- When you are finished, click NEXT.

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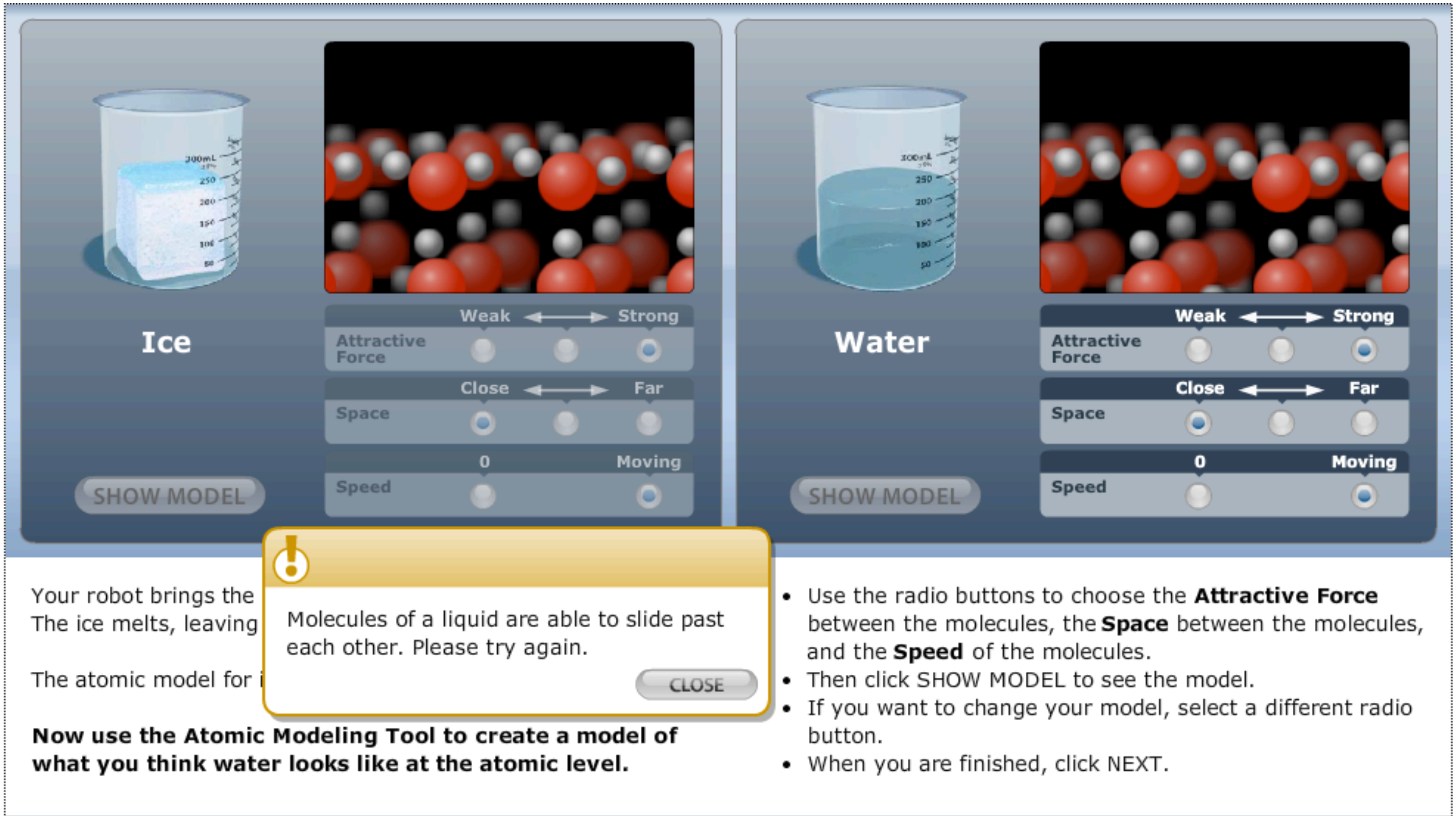
Feedback & Coaching



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Make predictions

Your robot found liquid bromine! Your training supervisor needs to know what happens when the bromine evaporates.

Predict what happens when bromine evaporates. Click Yes or No to show all the ways you think the bromine molecules will change.

Some new molecules will form.	Yes	No
Some molecules will vanish.	Yes	No
Some molecules will get smaller.	Yes	No
Some molecules will move faster.	Yes	No
Some molecules will get farther apart.	Yes	No

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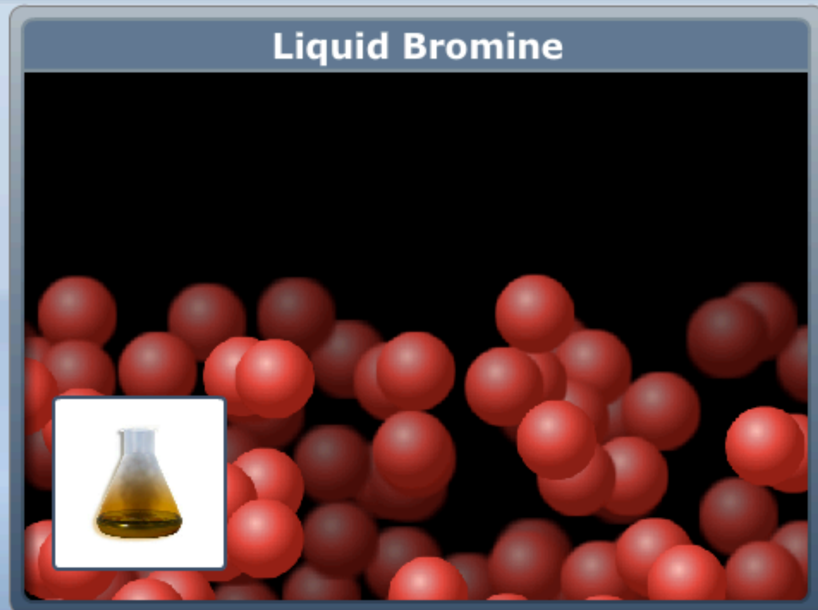
Evaluate predictions



The Nano Viewer shows a sample of bromine molecules. The bromine is evaporating!

You predicted that molecules would not move faster.
Was this prediction correct?
○ Yes ○ No

You predicted that molecules would not get smaller.
Was this prediction correct?
○ Yes ○ No

You predicted that molecules would not get farther apart.
Was this prediction correct?
○ Yes ○ No

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Classroom Reflection Activity

- Transfer to different, more complex systems
- Formative use of assessment results
  – Students assigned to teams based on embedded results
- Jigsaw structure
  – Allows differentiated instruction via tasks of varying difficulty
  – Promotes small and large group discourse and collaboration
- Guidance to teacher
  – Teacher review of key points in simulation
  – What to look for during group work and questions to pose in response
  – Presentations
  – Evaluation of presentations

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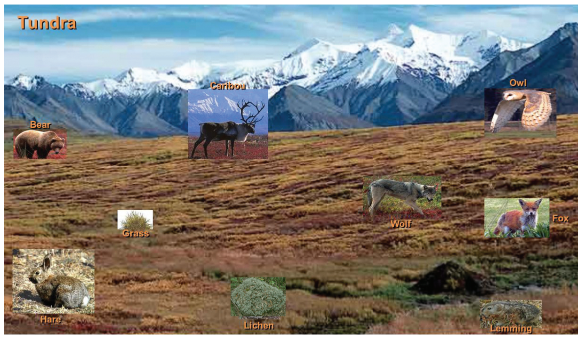
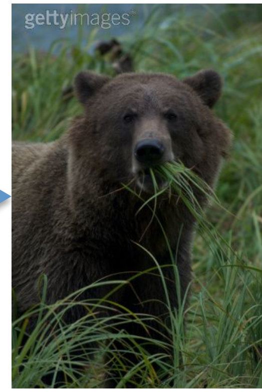
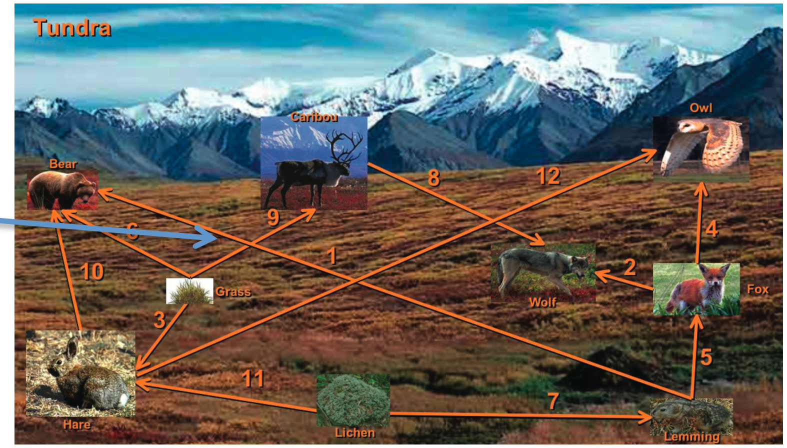
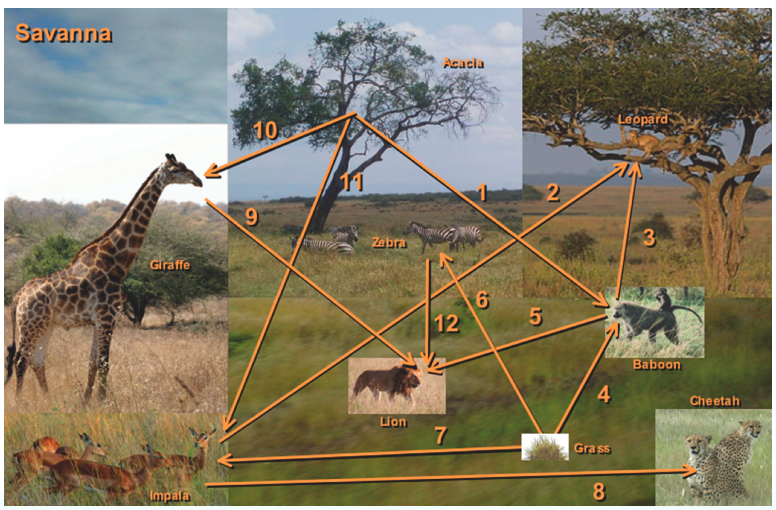
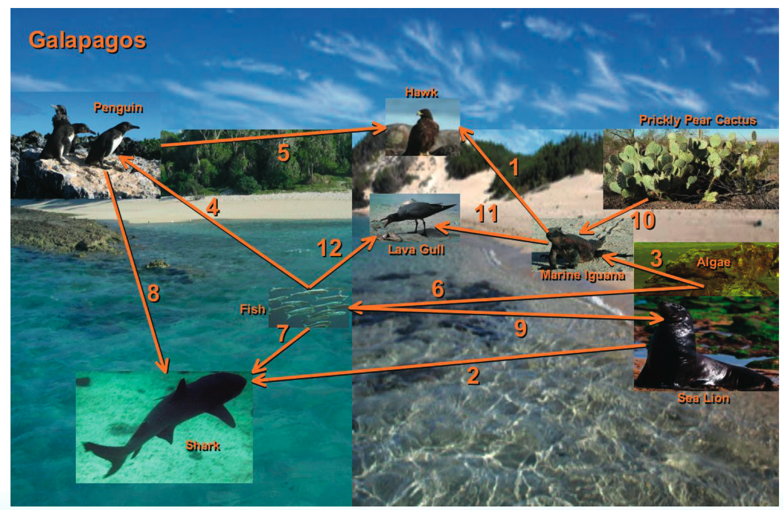
More Complex Ecosystems











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Testing Ecosystems Suite

Phase	N	Data collected	Use of Data	Results
Think-Alouds	28 students	Audio of think-aloud Screen capture of actions LMS data: actions & answers Researcher notes	Usability of interface Accessibility of content Construct validity	Revisions Tasks elicit targeted performances for 84% students
Classroom Feasibility	125 students 1 teacher	LMS data: actions & answers Cognitive labs Classroom observations Teacher surveys Teacher Interviews	Usability in classrooms Participation patterns Engagement Instructional Utility	Technical improvements (bandwidth, loading times) Revision of reflection activities Revision of teacher materials
Pilot Testing	3,529 students 36 teachers	+ External post test	+ Technical Quality	Infit between 0.8 and 1.2 for all item bundles Reliability = 0.85 Benchmark measures inquiry better than post test. 77% of students were 'highly engaged'.
Field Testing (in progress) Randomized Control Trial	763 students 5 teachers	+ External pre & post tests	+Technical Quality + Learning Gains	Treatment groups outperformed control groups on • learning gains (effect size 0.19) • benchmark assessment (effect size 0.43) (holding pre test constant) Mid-level students (pre test) outperformed low and high students on benchmark (effect size 0.52).

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Conclusions to date

- Simulation-based assessments
  - are usable in schools with diverse technical infrastructures,
  - have instructional utility for the teacher, and
  - sufficient psychometric technical quality to support inclusion in high stakes testing.
- Preliminary results suggest that the embedded formative assessments can increase learning gains.

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Thank You!

For more information…

Poster session: Friday 0900, Room RH3B

Website: www.simscientists.org

Email: bbuckle@wested.org

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References

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