

# Using Science Simulations to Promote and Assess Complex Science Learning

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# Formative Assessment Definition (CCSSO FAST SCASS)

“Formative assessment is a *process* used by teachers and students *during* instruction that provides feedback to *adjust* ongoing teaching and learning to improve students’ achievement of *intended* instructional outcomes.”

# Calipers II: Using Simulations to Assess Complex Science Learning Goals

- Develop formative and benchmark simulation-based assessments of science knowledge for key content in physical and life science and for science inquiry strategies.
- Enhance formative assessment simulation modules with immediate, individualized feedback, coaching, and reflection activities.
- Develop and document technology-based assessment designs and exemplars that take advantage of simulation environments to provide assessments of science standards for formative and summative purposes.

# Calipers II Goals (cont'd)

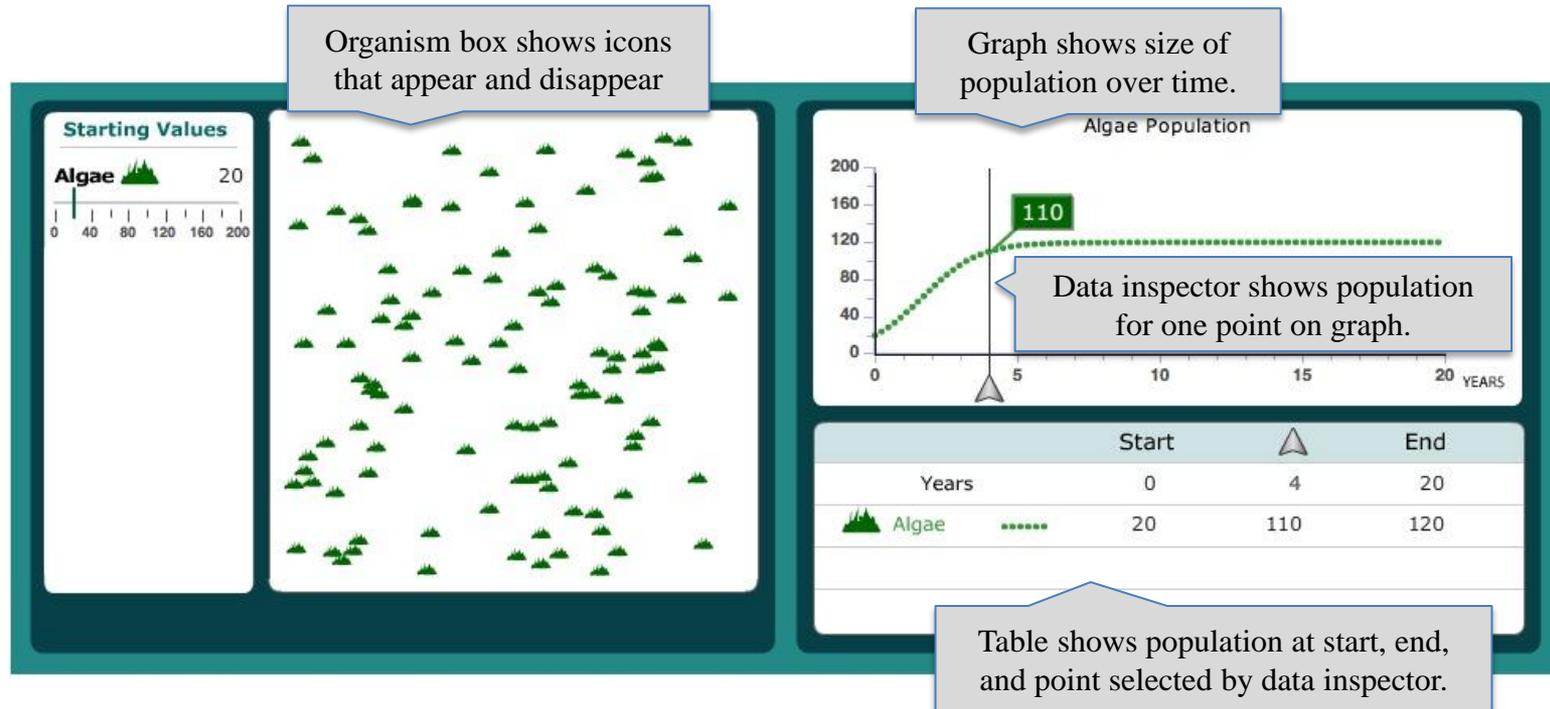
- Document the technical infrastructure and re-usable designs and processes employed.
- Provide evidence of the technical quality, feasibility, and usability of the new assessments.
- Study the influence of formative assessments on complex science and inquiry learning.
- Link the enlarged collection of Calipers II benchmark and formative, assessment to national science standards and the AAAS item clusters.

# Technology Affordances

- Animations of dynamic system phenomena
  - Can observe and review
- Simulation-based investigations
  - Iterative design
  - Virtual data collection
  - Conducting and saving multiple trials
  - Multimodal information and data displays
- Multiple, overlapping, simultaneous representations
- Scientific “tools of the trade”
  - Simulations, graphs, tables, zoom, drawing, highlighting
- Immediate, contingent feedback and hints, adaptive scaffolding
- Bayes Nets within simulations to assess proficiencies

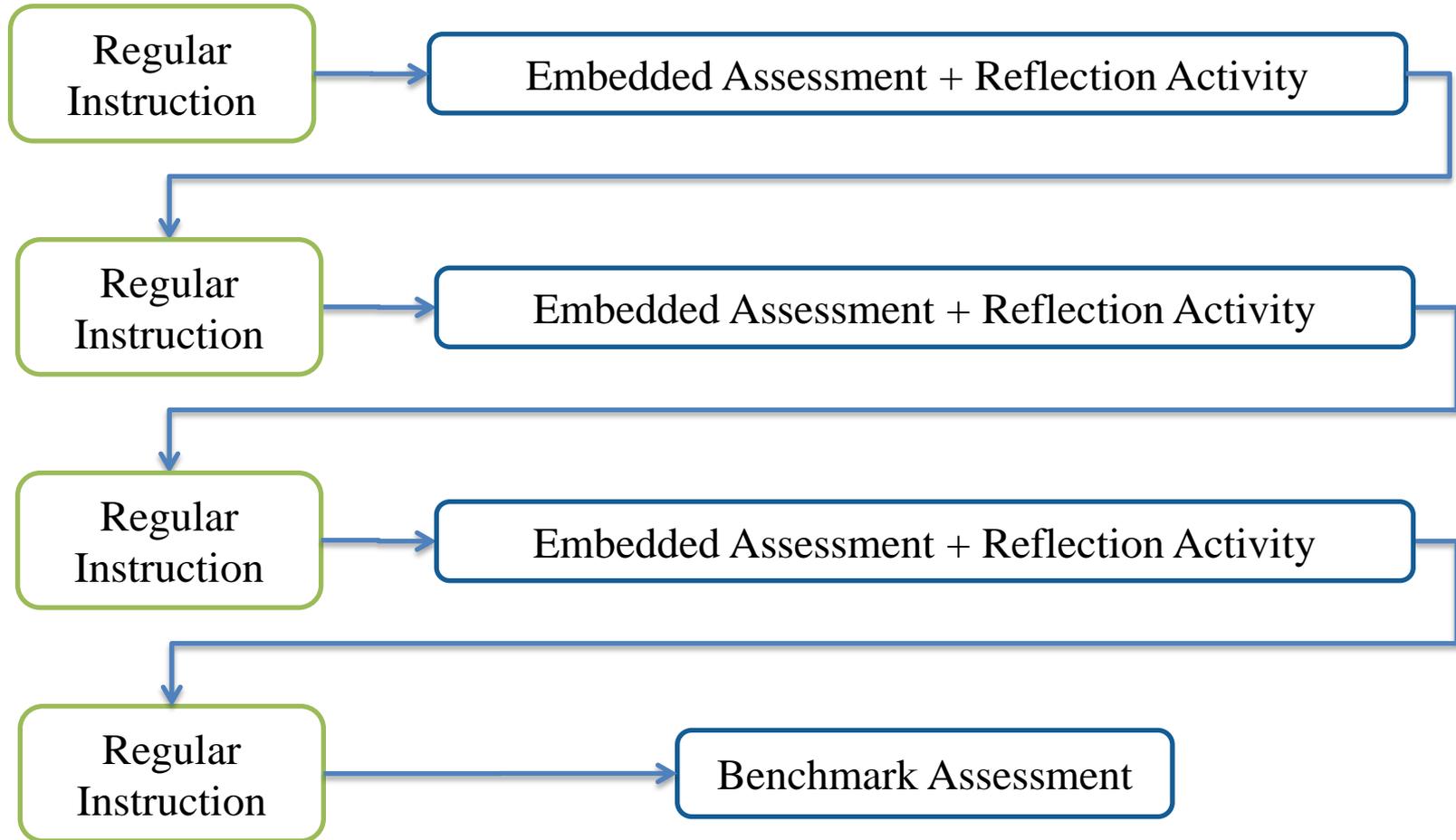
# Multiple Modes of Representation

## Active Inquiry



# SimScientists Assessments

## Embedded & Benchmark



# Embedded Assessment Components

Online assessment with feedback & coaching

### ASSESSMENT TASK

The screen shows a picture of the correct food web. Please complete the food web by drawing arrows where the highlighted arrows appear.

Grass  
Cricket  
Lizard  
Kookaburra  
Kangaroo

Make a food web diagram. Draw arrows to show the transfer of matter between organisms. Be sure to include each organism in the food web.

- To draw an arrow, click and drag from one dot to another dot.
- To delete an arrow, double click on it.

REVIEW ANIMATION

### STUDENT PROGRESS REPORT

Report for Mountain Lake - Predator Prey **life science** Completed on 03/23/2010/Bara

**Populations** ON TRACK  
Interactions between organisms and between organisms and the ecosystem's nonliving features cause the populations of the different organisms to change over time.

**Conduct** ON TRACK  
Conducting investigations involves carrying out scientific investigations using appropriate tools and techniques.

**Identify** NEEDS HELP  
Identifying Science Principles focuses on students' ability to recognize, recall, define, relate, and represent basic science principles. The practices assessed in this category draw on declarative knowledge or "knowing that."

**Design** NEEDS HELP  
Designing investigations involves asking questions, planning investigations and evaluating experimental design.

**Analyze** PROGRESSING  
Identifying patterns involves summarizing patterns in data, analyzing which data are relevant and drawing conclusions by relating patterns in data to theoretical models.

### TEACHER REPORT

Summary Report: Mountain Lake - Food Web **Try it | Detailed Report**

ASSESSMENT CLASS  
Mountain Lake - Food Web Period 7 Go!

Content	Needs Help	Making Progress	On Track
Roles	12 (46%)	4 (15%)	10 (38%)
Interactions	15 (58%)	4 (15%)	7 (27%)
Inquiry			
Identifying	15 (58%)	5 (19%)	6 (23%)
Using	10 (38%)	5 (19%)	11 (42%)

NH = needs help P = making progress OT = on track

Reflection Activities

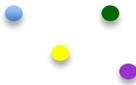
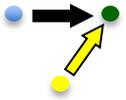
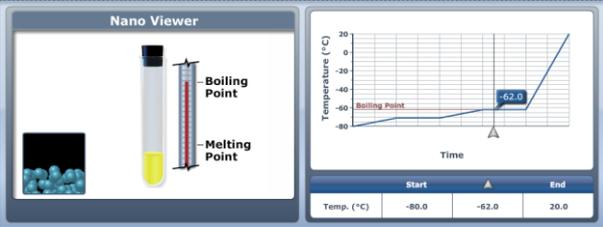
# NGSS Standards Assessed

- Cross-cutting concepts
  - Systems and System Models
  - Energy flow
- Science Practices
  - Using models
  - Investigations
- Ecosystem core ideas

# SimScientists Ecosystems System Model

Model Level	Descriptions	Content Targets	Science Practices
Component 	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. (NGSS: LS2.A—Interdependent Relationships in Ecosystems)	Analyzing and Interpreting Data
Interaction 	How do the the individual components interact?	Matter and energy flow through the ecosystem as individual organisms participate in feeding relationships within an ecosystem. (NGSS: LS2.B—Cycles of Matter and Energy Transfer in Ecosystems)	Developing & Using Models; Analyzing and Interpreting Data
Emergent 	What is the overall behavior or property of the system that results from many interactions following specific rules?	Interactions among organisms and among organisms and the ecosystem's nonliving features cause the populations of the different organisms to change over time. (NGSS: LS2.C—Ecosystems Dynamics, Functioning and Resilience)	Planning and Carrying Out Investigations; Analyzing and Interpreting Data

# Atoms & Molecules Target System Model

Component	Atoms and Molecules	Skill
		Observe
Interaction	Speed – Spacing – Collisions	Skill
		Analyze
Emergent	Boiling & Melting Point – States of Matter	Skill
		Measure & Investigate

# Demo: SimScientists

# Formative Assessment Features

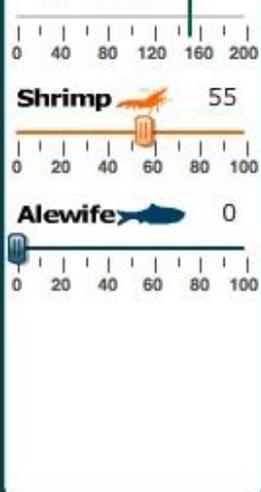
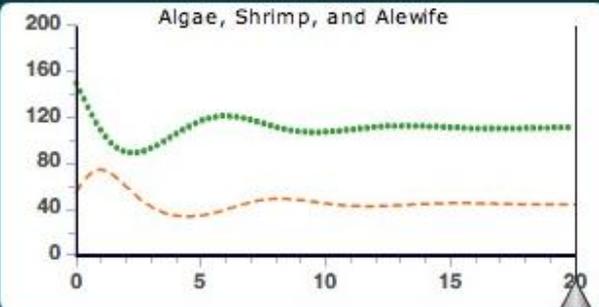
- Immediate, individualized feedback and coaching
- Reflection activities that address students' needs, promote transfer and scientific discourse
- Timely information that teachers can use

### Starting Values

Algae  150

Shrimp  55

Alewife  0

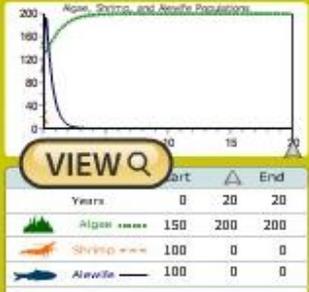



	Start	End	End
Years	0	20	20
 Algae	150	111	111
 Shrimp	55	44	44
 Alewife	0	0	0

Trial 1 CLOSE

### Trial 2



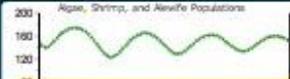


Trial 1

VIEW Q

Years	Start	End	End
Algae	150	200	200
Shrimp	100	0	0
Alewife	100	0	0





**!** In the highlighted trials, all three organisms did not survive for 20 years. Here are starting values that will allow all the organisms to survive 20 years:

- shrimp 15, alewife 15
- shrimp 40, alewife 15
- shrimp 50, alewife 20

Use one pair of starting values for each highlighted trial. Then click RUN.

CLOSE

Can you do better than Dr. A? Design three trials so that both the shrimp and alewife populations survive for 20 years.

- **Use the sliders to change the starting numbers of shrimp and alewife.**
- **Click RUN to see what happens.**
- **When you have saved 3 trials in which shrimp and alewife survive for 20 years, click NEXT.**

# Force and Motion



		Starting Values	
		Forward Force (kN)	Backward Force (kN)
Increase	—	15	10
Decrease	.....	5	15
Stays Same	----	15	15

The truck is moving at 10 km/h. Now the fire chief wants you to show how to make the truck's speed **stay the same**.

- Draw the forward and backward forces so that the truck's speed stays the same.
- Click RUN to observe how the truck's speed changes with the forces you selected.
- If the forces made the truck's speed stay the same, click SAVE TRIAL.
- If not, click CHANGE STARTING VALUES and try again.

# Progress Reports to Students

[Back to Home](#)

## Report for Mountain Lake - Predator Prey life science

Completed on 03/23/2010/Sara

### Populations

ON TRACK

Interactions between organisms and between organisms and the ecosystem's nonliving features cause the populations of the different organisms to change over time.

### Conduct

ON TRACK

Conducting investigations involves carrying out scientific investigations using appropriate tools and techniques.

### Identify

NEEDS HELP

Identifying Science Principles focuses on students' ability to recognize, recall, define, relate, and represent basic science principles. The practices assessed in this category draw on declarative knowledge or "knowing that."

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NEEDS HELP

Designing investigations involves asking questions, planning investigations and evaluating experimental design.

### Analyze

PROGRESSING

Identifying patterns involves summarizing patterns in data, analyzing which data are relevant and drawing conclusions by relating patterns in data to theoretical models.

# Progress Reports to Teachers

## Summary Report: Mountain Lake - Food Web [Try it](#) | [Detailed Report](#)

ASSESSMENT

CLASS

Mountain Lake - Food Web

Period 7

Go!

Content

**NH** Needs Help

**P** Making  
Progress

**OT** On Track

▶ Roles  12 (46%) 4 (15%) 10 (38%)

▶ Interactions  15 (58%) 4 (15%) 7 (27%)

Inquiry

▶ Identifying  15 (58%) 5 (19%) 6 (23%)

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**NH** = needs help

**P** = making progress

**OT** = on track

# Grouping Recommendations for Classroom Reflection Activity

ASSESSMENT

Mountain Lake - Food Web

CLASS

Period 7

Go!

**NH** Needs Help **P** Making Progress **OT** On Track

 [Reflection Activity PDF](#)

Group A students needed little help on either roles or interactions

Group B students needed help with interactions, but not with roles.

Group C students needed help with understanding the roles of organisms in an ecosystem.

Student ▼	Refl Gr. ▼	Roles ▼	Interactions ▼	Identifying ▼	Using ▼
Student 1	C	<b>P</b>	<b>NH</b>	<b>NH</b>	<b>OT</b>
Student 1	C	<b>NH</b>	<b>NH</b>	<b>NH</b>	<b>NH</b>
Student 3	A	<b>OT</b>	<b>OT</b>	<b>OT</b>	<b>OT</b>
Student 4	A	<b>OT</b>	<b>OT</b>	<b>OT</b>	<b>OT</b>
Student 5	C	<b>NH</b>	<b>NH</b>	<b>NH</b>	<b>NH</b>
Student 6	C	<b>NH</b>	<b>NH</b>	<b>NH</b>	<b>P</b>
Student 7	C	<b>P</b>	<b>NH</b>	<b>NH</b>	<b>P</b>
Student 8	C	<b>NH</b>	<b>NH</b>	<b>NH</b>	<b>NH</b>
Student 9	C	<b>NH</b>	<b>OT</b>	<b>NH</b>	<b>P</b>
Student 10	B	<b>OT</b>	<b>NH</b>	<b>OT</b>	<b>P</b>

# Classroom Reflection Activity

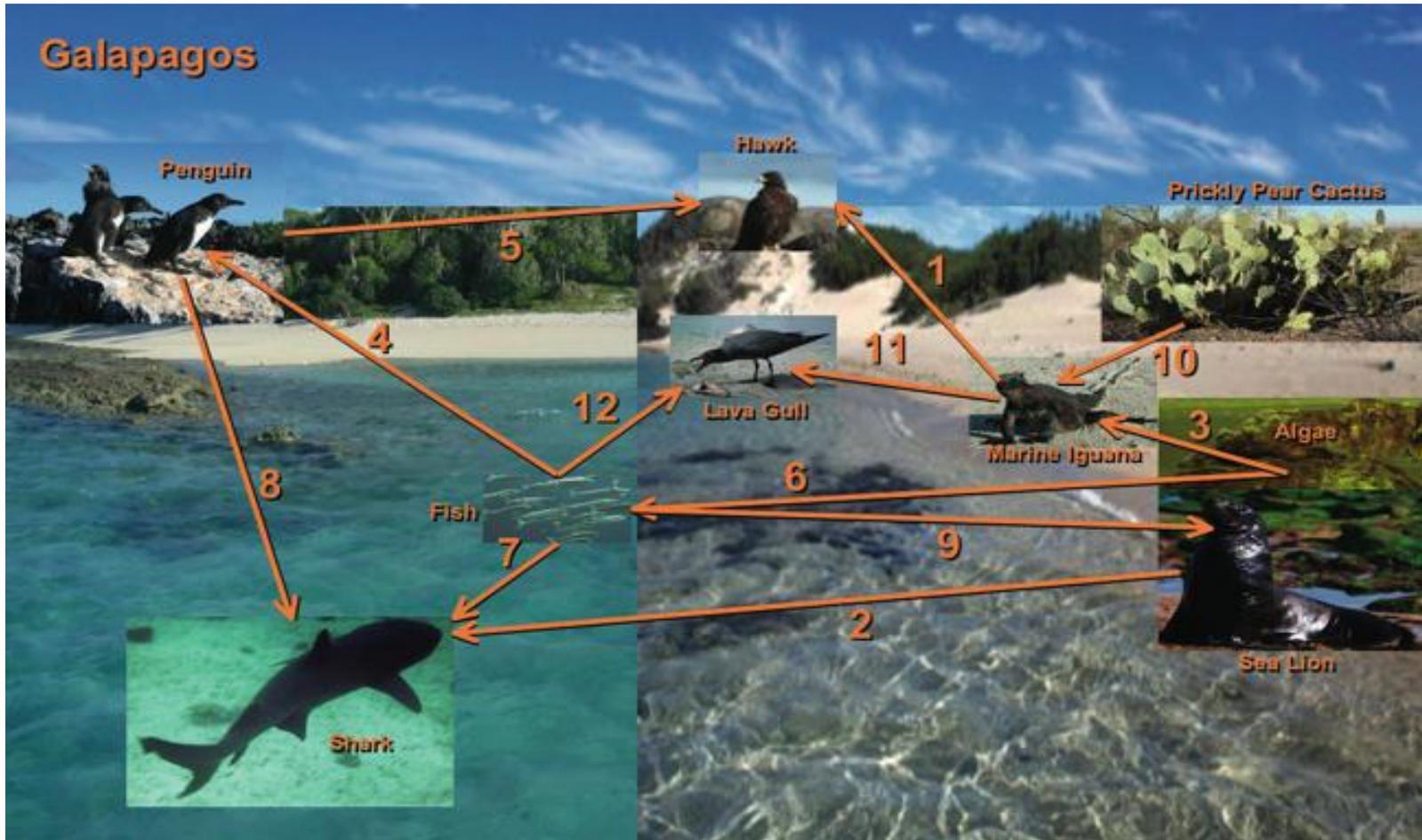
- Formative use of assessment results
  - Students assigned to teams based on embedded results
- Transfer to different, more complex system
- Jigsaw structure
  - Allows differentiated instruction via tasks of varying difficulty
  - Promotes small and large group discourse and collaboration
- Guidance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

# Workshop Reflection Activity

## For each ecosystem

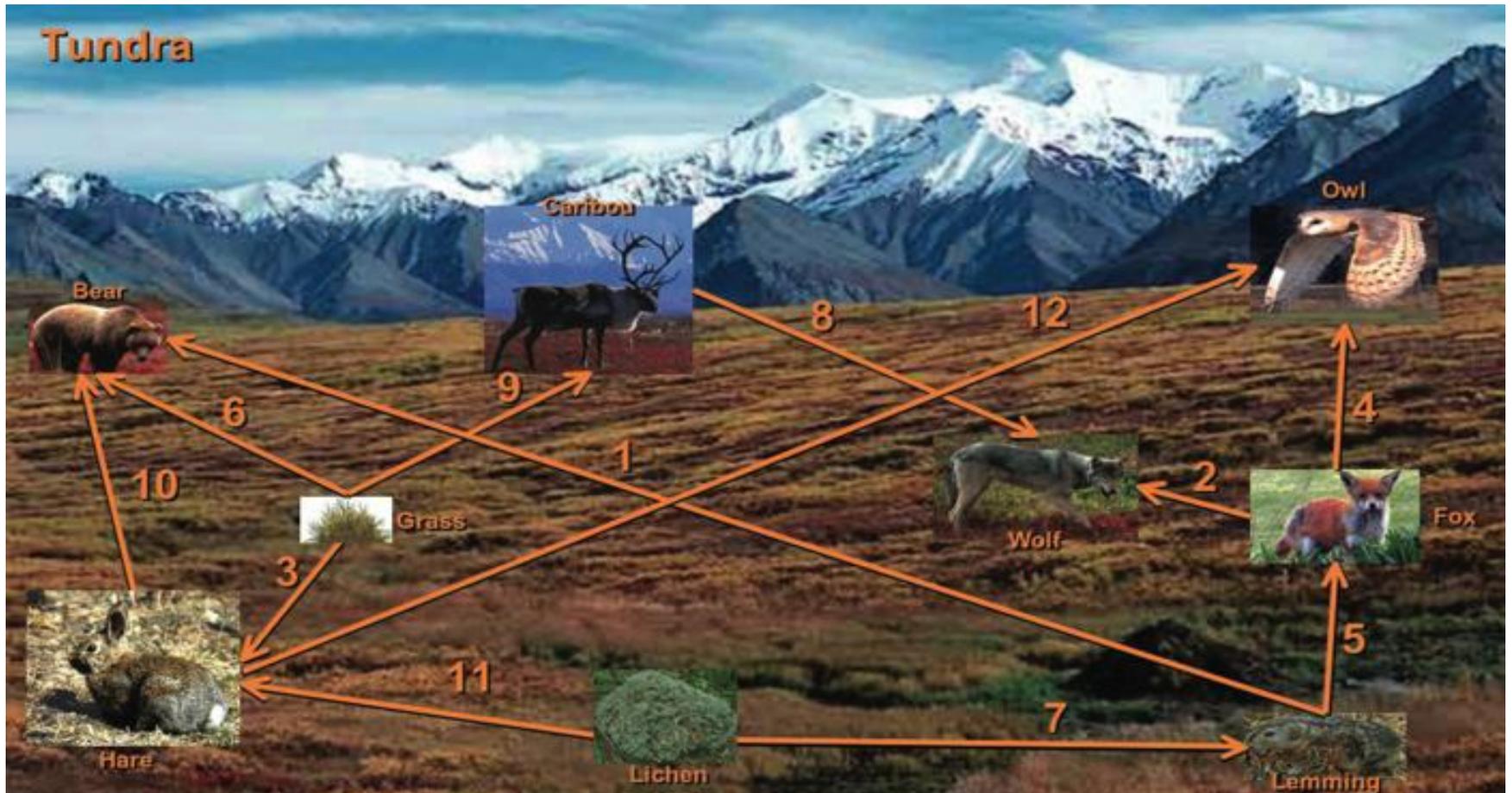
- Divide into 3 groups
  - Distribute Interaction Cards (3 groups)
    - Identify roles of organisms as consumers or producers
  - Draw arrows showing flow of matter and energy
  - Answer riddles
  - Make up a new riddle
- Present ecosystem
  - Identify two consumers, one producer
  - Show the energy and matter arrows for each
- Present riddle

# Transfer to new, more complex ecosystem



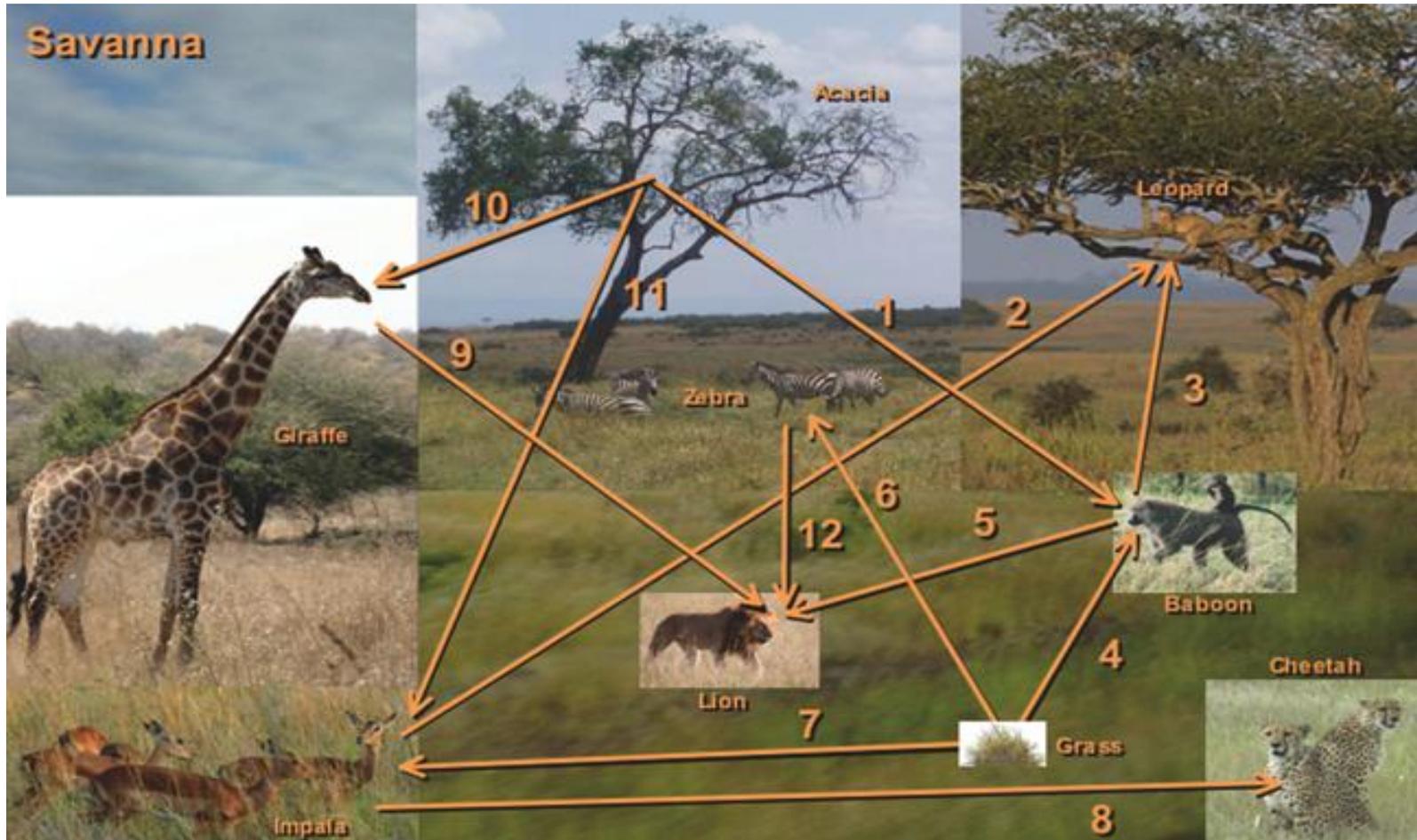
# Calipers II

## Reflection Activities: Ecosystems



# Calipers II

## Reflection Activities: Ecosystems



# Ecosystem Benchmark Assessment: Assess Transfer to New Ecosystem

http://simscientists.com/explorations/c9f2af641e84a9a52c03293a3a9ae53e4bab31149f7acb25c2f9da8fbb227b0cfa7e28b9b350bdd495c80148d3ae480341cf3bcb529214660edb2182a13eee

Grasslands - Assessment Jacob Loveland



The interface shows a grassland scene with a kangaroo, a koala, a lizard, a cricket, and a grass icon. A legend on the left lists: Grass (grass icon), Cricket (cricket icon), Lizard (lizard icon), Koekaburra (koala icon), and Kangaroo (kangaroo icon). A 'REVIEW ANIMATION' button is in the bottom right of the scene.

**Make a food web diagram. Draw arrows to show the transfer of matter between organisms.**

Be sure to include each organism in the food web.

- To draw an arrow, click and drag from one dot to another dot.
- To delete an arrow, double click on it.

You can review the animation and then return to this diagram.

8 of 26 NEXT ▶

# Summary Benchmark report

**Content** BB Below Basic B Basic P Proficient A Advanced

▶ **Roles** BB 3 (100%) 0 (0%) 0 (0%) 0 (0%)

▼ **Interactions** BB 3 (100%) 0 (0%) 0 (0%) 0 (0%)

Matter and energy flow through the ecosystem as individual organisms interact with each other. Food web diagrams indicate the feeding relationships among organisms in an ecosystem. All ecosystems have a flow of energy from a nonliving source, to producers, to consumers.

▶ **Populations** A 0 (0%) 0 (0%) 0 (0%) 3 (100%)

## Inquiry

▶ **Identify** BB A 1 (33%) 0 (0%) 0 (0%) 2 (67%)

▶ **Use** BB B 1 (33%) 2 (67%) 0 (0%) 0 (0%)

▶ **Design** BB B 1 (33%) 2 (67%) 0 (0%) 0 (0%)

**Detailed Report by Student and Target** 0 (0%) 3 (100%) 0 (0%) 0 (0%)

Student ▼	Roles ▼	Interactions ▼	Populations ▼	Identify ▼	Use ▼	Design ▼	Conduct ▼	Analyze ▼	Evaluate ▼	Communicate ▼
Simmons85, Sara85	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: blue;">A</span>	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: orange;">B</span>	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: blue;">A</span>
Simmons86, Sara86	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: blue;">A</span>	<span style="color: blue;">A</span>	<span style="color: orange;">B</span>	<span style="color: orange;">B</span>	<span style="color: orange;">B</span>	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: blue;">A</span>
Simmons87, Sara87	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: blue;">A</span>	<span style="color: blue;">A</span>	<span style="color: orange;">B</span>	<span style="color: orange;">B</span>	<span style="color: orange;">B</span>	<span style="color: red;">BB</span>	<span style="color: red;">BB</span>	<span style="color: orange;">B</span>

# SimScientists Research Findings

- AAAS review of alignment of content and inquiry targets with national and state standards
- Cognitive labs
- Classroom feasibility testing
- Pilot testing
- Field testing
  - EAG study involving 4 states, 28 districts, 58 teachers, 6,000 students
  - Calipers II and MASS, 3 states, 3 districts, 28 teachers, 2,500 students

# SimScientists Research Findings

- Technical quality
- Implementation evaluation
- Effects of embedded on summative simulation benchmark and conventional posttest

# CRESST Case Study Interviews

“I think that [students] are way more engaged. When I told them that we were going next door to work on the computers again, they all seemed pretty excited to go next door and work on it.”

# CRESST Case Study Interviews

- “...I like that kind of feedback when it doesn’t just go to the next page and they don’t know whether they did it right or not.”
- “...Yes, the science content is really being tested. Students are asked to conduct experiments, investigate, and draw conclusions and to use scientific skills. Students are not able to guess on the multiple choice questions because it probes them until they choose the right answer. Students are also taught about food webs in one biome and they are tested on another biome.”

# CRESST Evaluation Conclusions

- Observations showed that students were actively engaged most of the time during assessments.
- Both teachers and students generally believed that the SimScientists program was beneficial to learning.
- Teachers found the automatically scored, immediate feedback—especially the reports generated by the questions—helpful to students. The instant reports allowed teachers to easily see which questions students had the most difficulty with so that they could tailor their lessons accordingly.

# CRESST Evaluation Conclusions

- Teachers collectively agreed that the simulation assessments had greater benefits than traditional paper-and-pencil tests because of the simulation's instant feedback, interaction, and visuals.
- Teachers agreed that the assessments would be useful in measuring their individual state standards.

# Current Findings

## The SimScientists simulation-based assessments

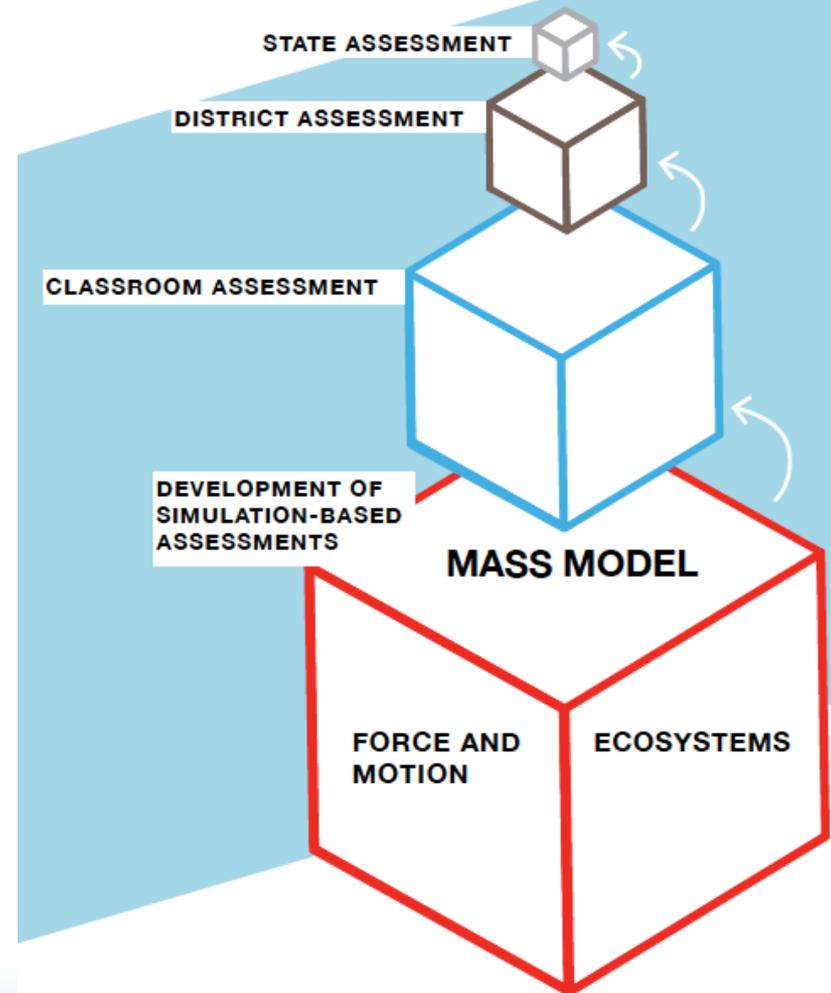
- Measure constructs not tested well by static modalities
- Can discriminate measures of inquiry and content
- The curriculum-embedded assessments seem to have positive effects on student learning
- The summative benchmark assessments have sufficient technical quality to be components of a state science assessment reporting system

# Summary of Technical Quality Analyses

- Correlations
  - Moderate correlations between benchmark and post test (0.57–0.64)
  - Correlations between content and inquiry are higher on the post test than the benchmark
- Gap analysis for ELLs and SWDs
  - Both groups perform better than expected on the benchmark assessment (based on their post test ability estimates)
- Reliability
  - High for all measures (coefficient alpha: 0.83–0.89)
- Effect of the treatment
  - Small, significant effect on the post test (0.07–0.08)
  - Moderate, significant effect on the benchmark (0.3–0.4)
  - Larger effect on benchmark inquiry than content (up to 0.58)

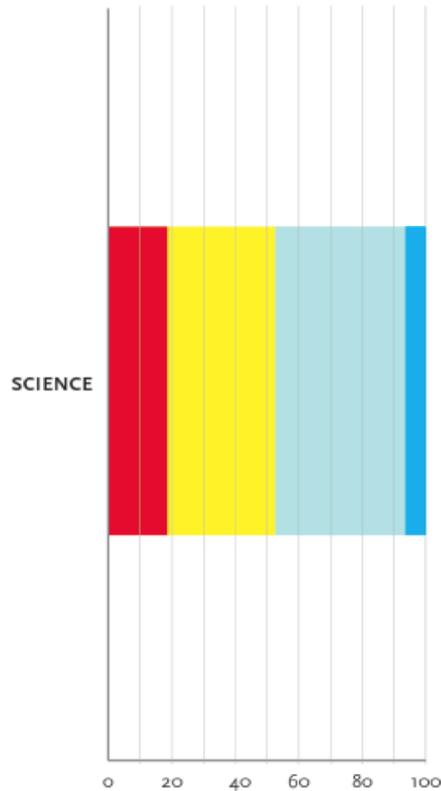
# Balanced, Multilevel Assessment System Models

- Reporting benchmark results alongside district and state data
- Matrix sampling of short “signature” tasks from different topics

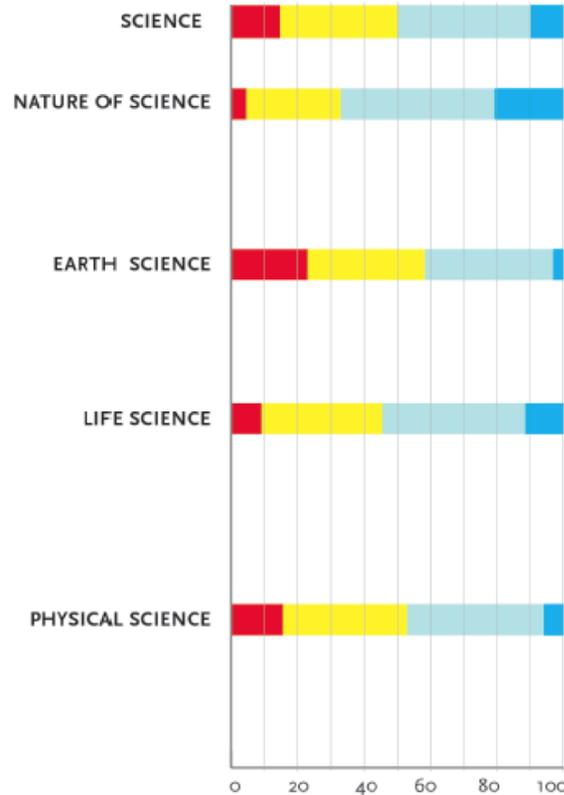


# Side-by-Side Model

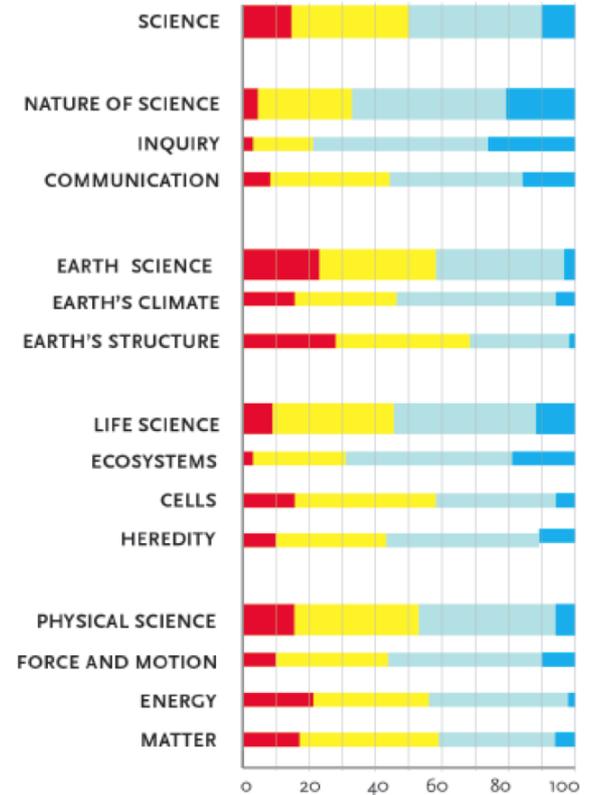
STATE ASSESSMENT



DISTRICT ASSESSMENT



CLASSROOM ASSESSMENT

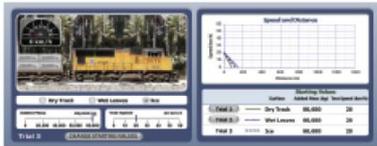


BELOW BASIC BASIC PROFICIENT ADVANCED

# Signature Task Model

## State Test Forms

### Matrix Sampling



The engineer has been dismissed! There are not trains on the track! But what are the tracks? And the test says to "vary the speed of the train".

Design an experiment to test how wind affects the distance needed to stop the train compared to a dry or wet track.

- Use the video feature to watch a 100% speed.
- Use the sliders to choose the values of **Wet Track** and **Wet Wind**.
- Click **STOP** to see what happens.
- Save these trials that show how different variables affect the stopping distance of the train.



Observe the trout in the simulation. Where does the trout get the energy it needs to swim and hunt?

Use the sliders to adjust the amount of algae, plankton, seal, shrimp, and tuna in the simulation.



The scientist wants to study the grasshopper population. They want to have populations of grass, grasshopper, and predator for 10 years.

- Design these trials to have both the smallest and the largest populations possible for 10 years.
- Use the sliders to change the starting numbers of grass, grasshopper, and predator.
- Click **STOP** to see what happens.

When all trials are complete, click NEXT.



Your training supervisor makes you to research for an unknown planet. The planet needs to be a planet at 30°C (86°F).

- Use the video feature to observe the **Atmosphere** feature. Watch the planet and the **Atmosphere** feature.
- Use the sliders to change the planet.
- If you want to change the planet, adjust a different slider.

Provide the **Atmosphere** feature and space between the planets of the unknown planet. The planet is already set for you.

## Simulation-based task item bank

### Specifications and Simulation environments



When driving, it is important to know how soon you can stop. These variables that affect the car's stopping are the car's mass, the car's speed, and the road's friction. The car's mass is 1000 kg. The car's speed is 100 km/h. The road's friction is 0.5.

Design an experiment to test how the magnitude of a backward force affects the car's stopping time.

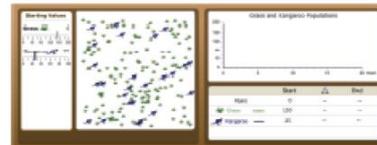
- In your experiment, the mass will stay at 1000 kg.
- The force you choose will change the speed of the car.
- Use the sliders to choose the values of **Wet Road** and **Wet Wind**.
- Click **STOP** to see what happens.
- Save these trials that show how different backward forces affect the car's stopping time.



Make a field with a grasshopper. Check the number of grasshoppers in the field. Use the sliders to change the number of grass, grasshopper, and predator in the field.

- To adjust the sliders, click and drag from the slider to another dot.
- To double the sliders, double-click on it.

The car shows the simulation and then return to the diagram.



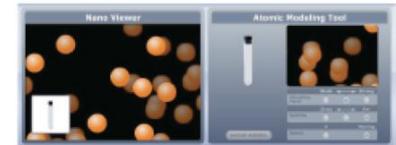
There is a lot of grass for the grasshopper to eat. If the grasshopper eats 20 grasshoppers, what will happen to the grasshopper and grass populations during the first three years?

predict that the grasshopper population will

- INCREASE, • DECREASE, • stay the same.

predict that the grass population will

- INCREASE, • DECREASE, • stay the same.



You will be using two tools to study particles that the robot detects.

The first tool is based on the world's most powerful microscope. You will use the video feature to see subatomic particles at the atomic level.

The second tool is a computer simulation called the "Atomic Modeling Tool".

This tool allows you to see the attraction force between the particles. The amount of space between the particles and the speed of the particles.

## Simulation-Based Classroom Assessments

# Continuing Research

- Study vertically aligned simulation based assessment suites for life and physical science of
  - Classroom assessments
    - curriculum embedded assessments (for formative purposes)
    - benchmark assessments (for summative purposes)
  - Large scale assessments
    - signature tasks (for summative purposes)
- Create simulation-based curriculum supplements

# Contact information

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