

Developing Simulation-Based Assessments for Learning Next Generation Science

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SimScientists Current and Recent R&D Projects

SimScientists Assessments: Physical Science Links (NSF DR K-12)

SimScientists Human Body Systems (NSF DR K-12)

SimScientists Assessment System (IES Measurement)

SimScientists Model Progressions (IES Development)

Calipers II: Using Science Simulations to Assess Complex Science Learning (NSF DR K-12)

Foundations of 21st Century Science Assessments (NSF REESE)

Multilevel Assessments of Science Standards (IES Measurement)

SimScientists: Interactive Simulation-based Science Learning Environments (IES Development)

Integrating Science Simulations into Balanced State Science Assessment Systems (OESE EAG)

Theoretical Foundations

Evidence-Centered Assessment Design

Student Model → **Task Model** → **Evidence Model**

What claims do you want to make about **students'** knowledge and skills?

What **tasks** prompt **students** to demonstrate the knowledge and skills?

How can **student** performance on the **tasks** be interpreted as **evidence** to support the claims?

Theoretical Foundations

Model-Based Learning

Model Formation → Model Use → Model Evaluation

Complex tasks prompt students to integrate knowledge with new information

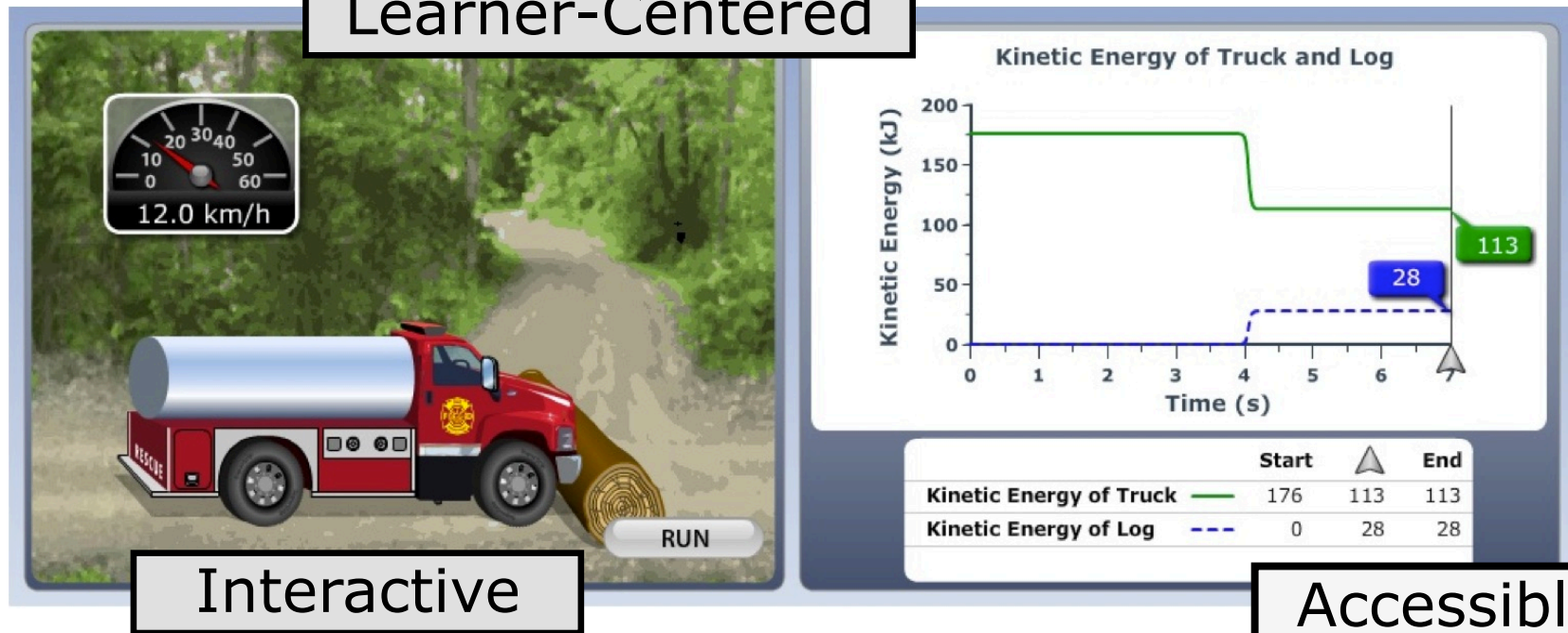
Students try to make sense of phenomena as they complete the tasks

Models may be rejected, revised, reinforced or enhanced based on the interaction with the task

Theoretical Foundations

Universal Design for Learning (UDL) and Computer-Based Testing (UD-CBT)

Learner-Centered



Interactive

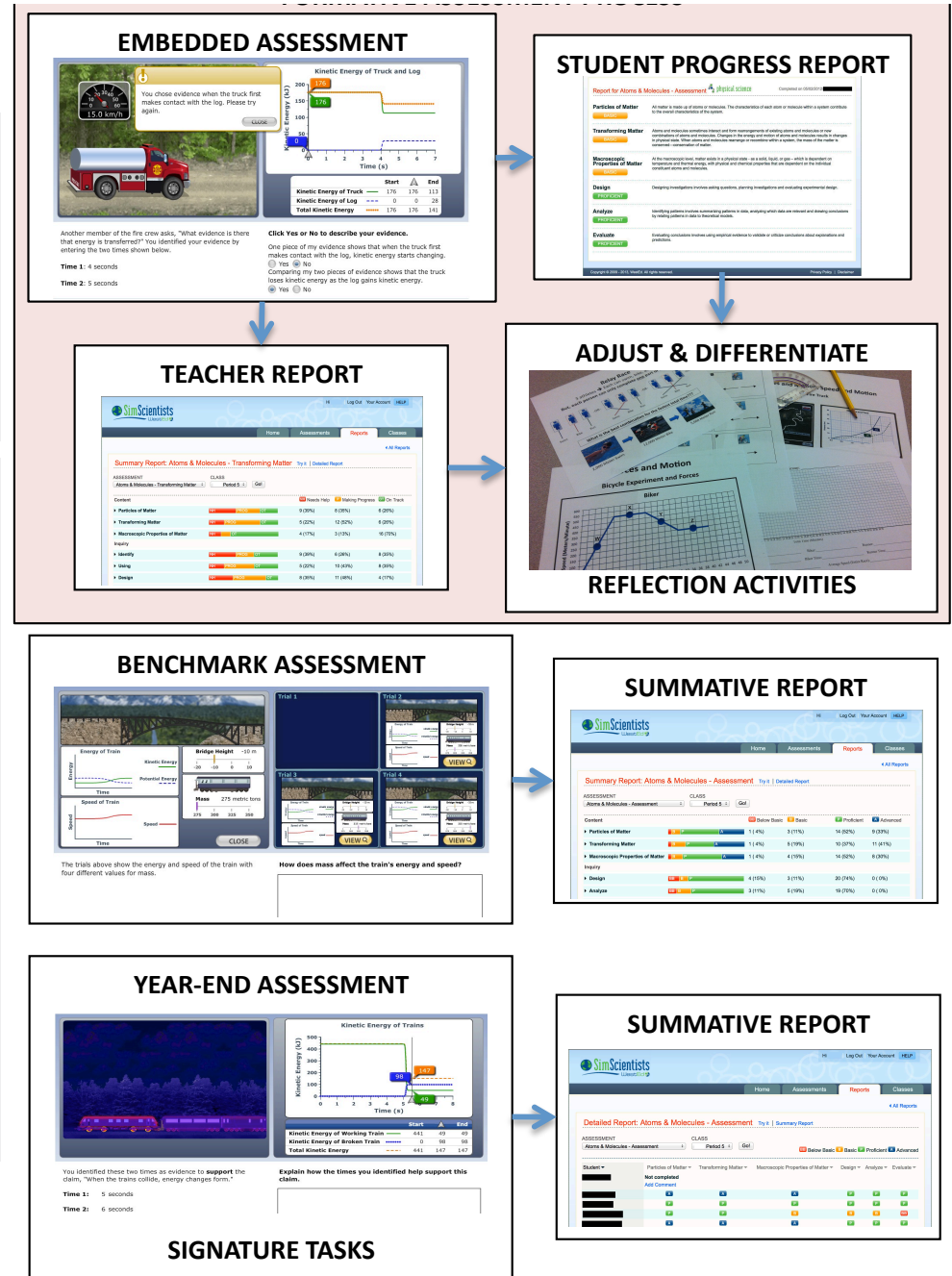
Accessible

Theoretical Foundations

Multilevel Assessment Systems

Integrated assessment design—using common specifications to develop parallel tasks for different levels of the system

Integrated report design—gathering data from all levels of the system





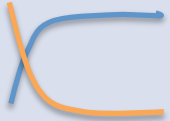
Applying Evidence-Centered Design to NGSS

Claim Construct, use, and present arguments to support the claim that when the motion energy of an object changes, energy is transferred to or from the object.

Evidence Statement *Construct arguments by ...*



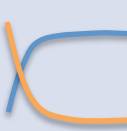
- Using data as evidence to support a claim

Integrating Evidence-Centered Design & Model-Based Learning

Model Level	Descriptions
<p data-bbox="212 500 575 565">Component</p> 	<p data-bbox="695 500 1969 639">What are the components of the system and their properties?</p>
<p data-bbox="218 763 569 821">Interaction</p> 	<p data-bbox="695 763 1787 896">How do the individual components interact?</p>
<p data-bbox="239 1026 548 1091">Emergent</p> 	<p data-bbox="695 1026 1745 1243">How are system behaviors and properties caused by interactions among components?</p>

Applying Evidence-Centered Design & Model-Based Learning to the *Next Generation Science Standards*

MS-PS3-1 ... relationships of kinetic energy to mass and speed

Model Level	Descriptions
Component 	Kinetic energy
Interaction 	Energy transfer
Emergent 	Changes in motion

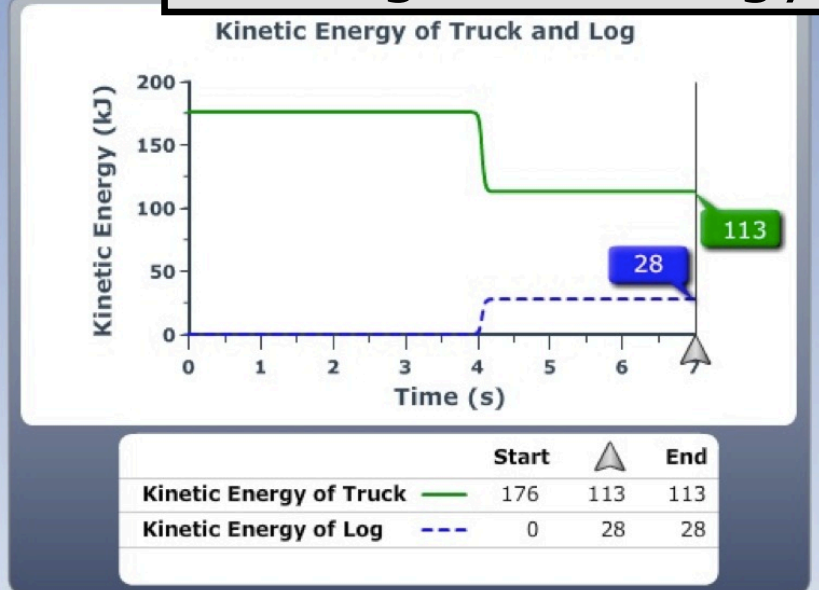
MS-PS3-5 ... when the motion energy of an object changes, energy is transferred to or from the object

Task Model

Changes in Motion



Changes in Energy



Energy Transfer?

Demo



Think

*What did you observe?
How can you explain your
observation?*

*What evidence supports
your explanation?*

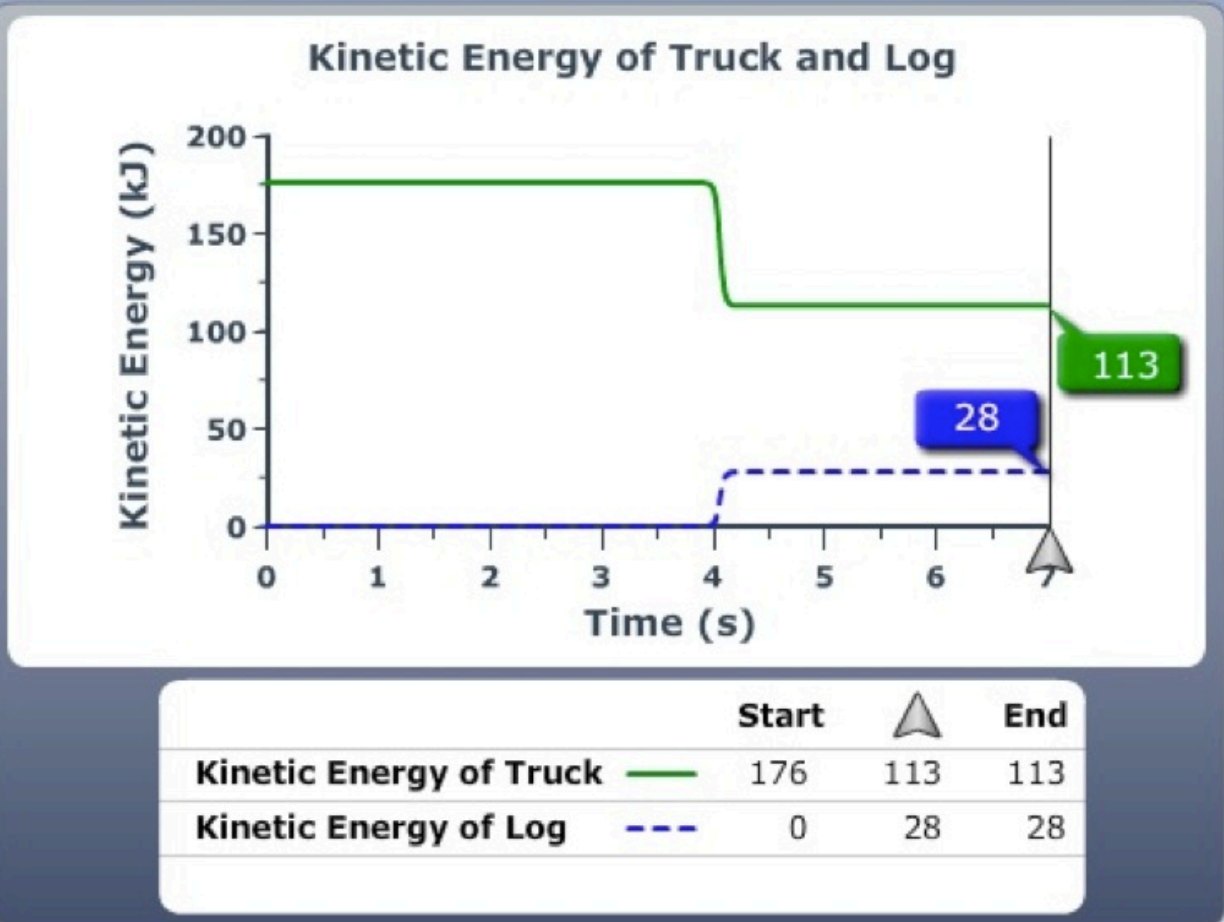
Discuss in a pair

Share with the group

Hands-On

Small groups

Discuss observations, explanations and evidence



Feedback

*What does three-dimensional
assessment look like?*

Are we there yet?

Assessment Development

Data Collection

Alignment and quality reviews of energy and waves units

Classroom feasibility testing of two embedded and one benchmark assessment

Observations, formative evaluation

Sample

One teacher, 5 classrooms, ~100 Students

Analyses

Descriptive statistics

Data mining

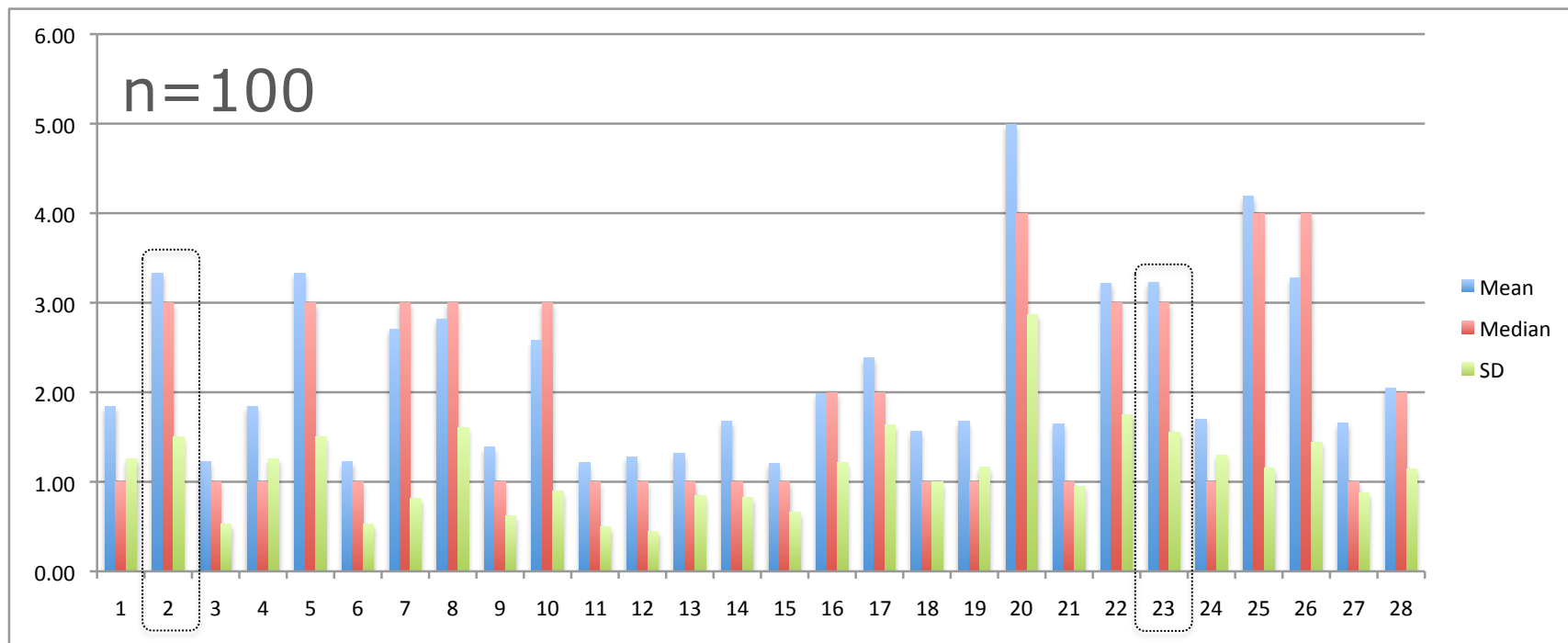
Classical psychometrics

IRT

Bayes' Nets

Embedded Assessment 1

Number of Tries to Correct



Embedded Assessment 1

Data Dive



The force transfers energy from the engine to the rest of the truck. The Fire Chief wants your help investigating the energy of the truck.

Click Yes or No to describe the energy of the truck.

- Energy is a type of force. Yes No
- The truck's engine creates energy for the truck. Yes No
- The truck's engine uses energy to create the force. Yes No
- An increase in energy causes the mass of the truck to increase. Yes No

Show Data

Prev Next

Energy [3]
PSLEnergyEM1 v8.01.06

3 of 37

NEXT ▶

Embedded Assessment 1

Data Dive

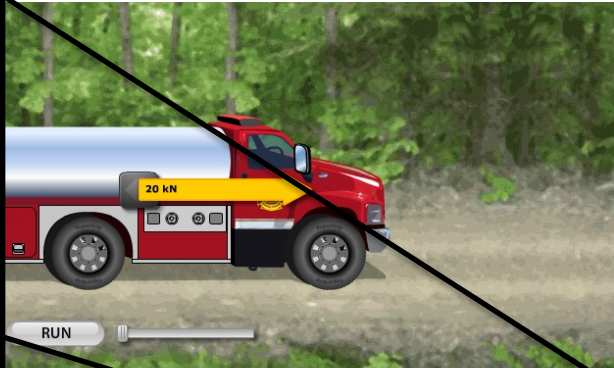
Click Yes or No to describe the energy of the truck.

Energy is a type of force. Yes No

The truck's engine creates energy for the truck. Yes No

The truck's engine uses energy to create the force. Yes No

An increase in energy causes the mass of the truck to increase. Yes No



The force transfers energy from the engine to the rest of the truck. The Fire Chief wants your help investigating the energy of the truck.

Click Yes or No to describe the energy of the truck.

Energy is a type of force. Yes No

The truck's engine creates energy for the truck. Yes No

The truck's engine uses energy to create the force. Yes No

An increase in energy causes the mass of the truck to increase. Yes No

Show Data Energy [3] 3 of 37
 Prev Next PSLEnergyEM1 v8.01.06 **NEXT**

Tries = 1	Tries = 2	Tries = 3	Tries = 4	Tries = >4
14	13	27	22	22

Embedded Assessment 1

Data Dive

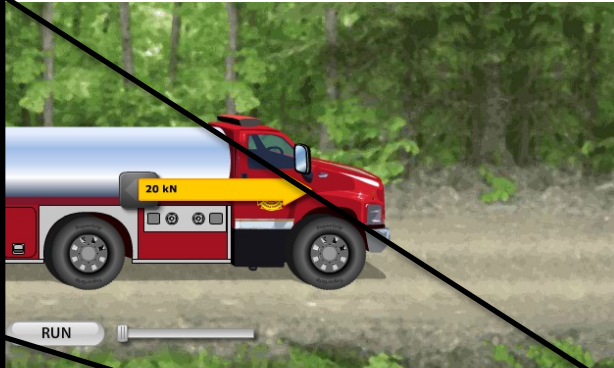
Click Yes or No to describe the energy of the truck.

Energy is a type of force. Yes No

The truck's engine creates energy for the truck. Yes No

The truck's engine uses energy to create the force. Yes No

An increase in energy causes the mass of the truck to increase. Yes No



The force transfers energy from the engine to the rest of the truck. The Fire Chief wants your help investigating the energy of the truck.

Click Yes or No to describe the energy of the truck.

Energy is a type of force. Yes No

The truck's engine creates energy for the truck. Yes No

The truck's engine uses energy to create the force. Yes No

An increase in energy causes the mass of the truck to increase. Yes No

NEXT ▶

FirstAnswer=Yes	FirstAnswer=No	Changed Right to Wrong
72%	28%	15%
76%	24%	15%
87%	13%	35%
17%	82%	8%

Embedded Assessment 1

Data Dive


Click Yes or No to describe the energy of the truck.

Energy is a type of force. Yes No

The truck's engine creates energy for

The truck's engine uses energy to create force.

An increase in energy causes the mass of the truck to increase.



A force transfers energy, but they are not the same thing. Please try again.

CLOSE

No
No
No
No

NEXT ▶

FirstAnswer=Yes	FirstAnswer=No	Changed Right to Wrong
72%	28%	15%
76%	24%	15%
87%	13%	35%
17%	82%	8%

Embedded Assessment 1

Data Dive

Click Yes or No to describe the energy

Energy is a type of force.

The truck's engine creates energy for the

The truck's engine uses energy to create force.

An increase in energy causes the mass of truck to increase.



When the truck is moving it has kinetic energy. Forces are the pushes and pulls that cause the truck to move. Energy and forces are not the same thing. Please try again.

CLOSE

No
No
No
No

truck to increase.

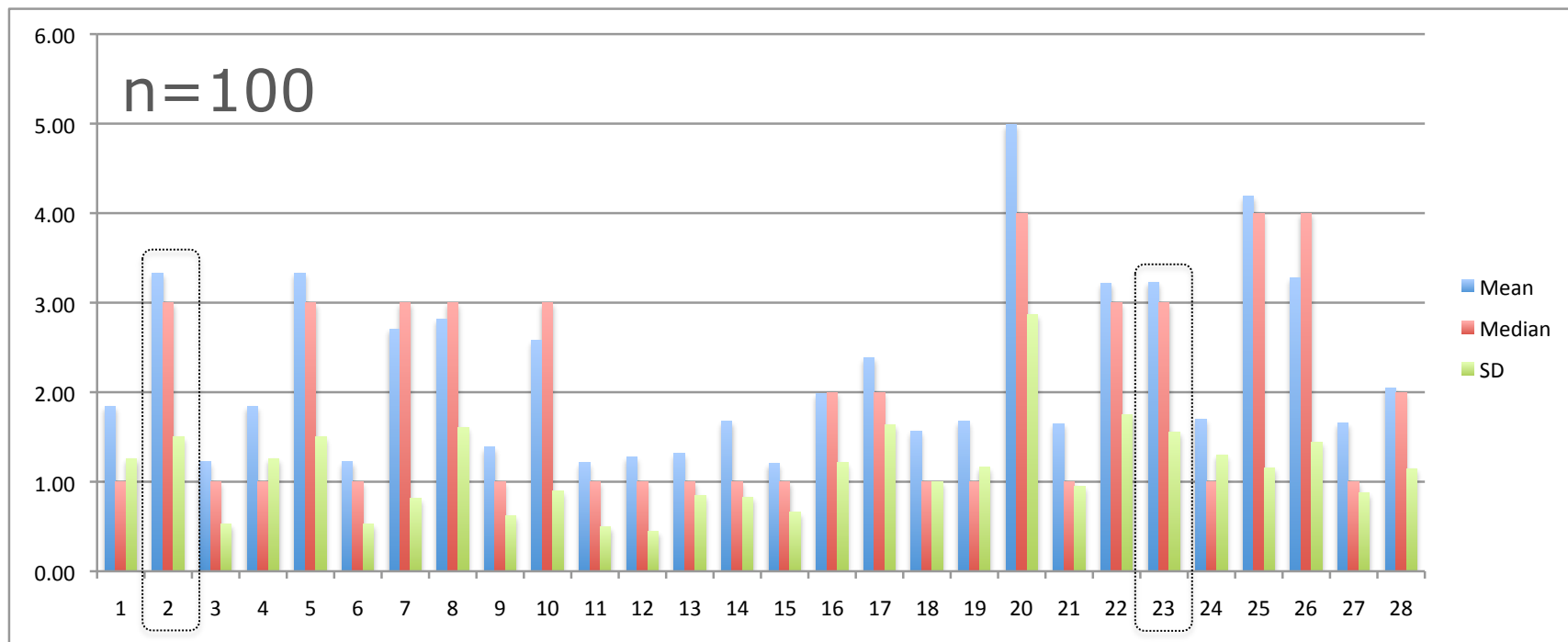
Show Data

NEXT ▶

FirstAnswer=Yes	FirstAnswer=No	Changed Right to Wrong
72%	28%	15%
76%	24%	15%
87%	13%	35%
17%	82%	8%

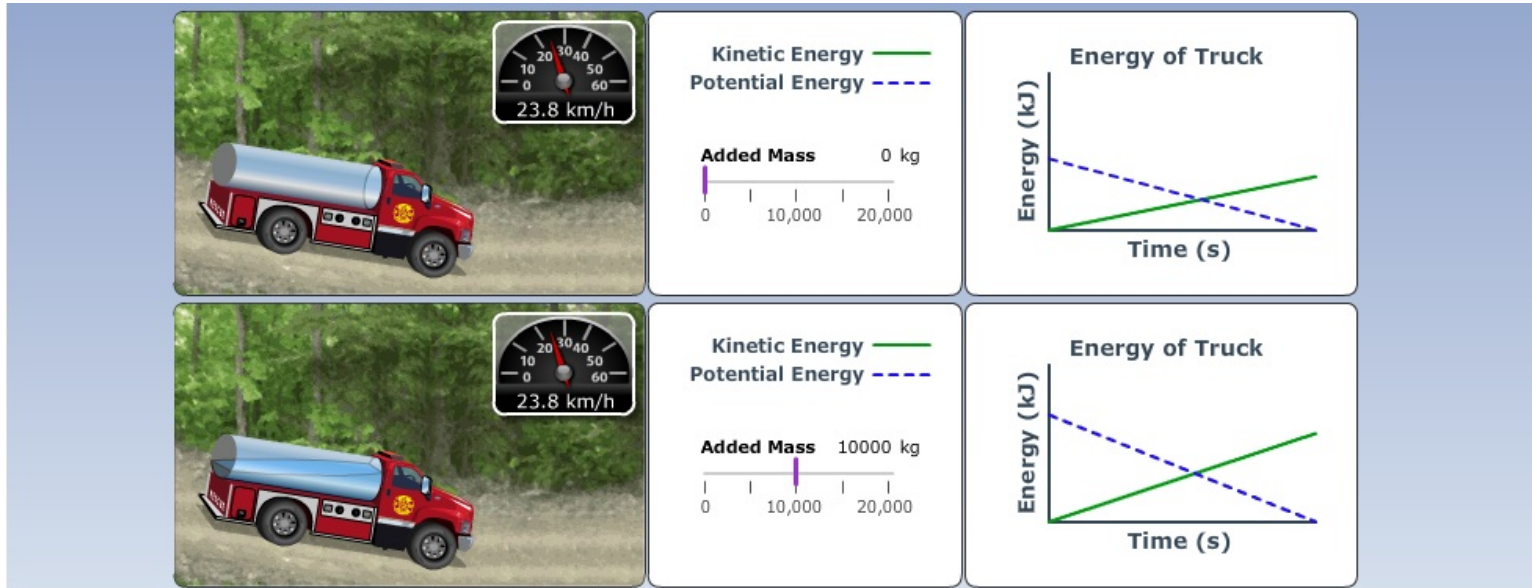
Embedded Assessment 1

Number of Tries to Correct



Embedded Assessment 1

Data Dive



Click Yes or No to explain how the truck's energy changes as it coasts downhill.

Potential energy is changed into kinetic energy.

Yes No

Mass is changed into potential energy.

Yes No

Potential energy disappears as kinetic energy is created.

Yes No

Mass is changed into kinetic energy.

Yes No

Show Data

DownhillConclude2 [27]
PSLEnergyEM1 v8.01.06

27 of 37

NEXT ▶

Embedded Assessment 1

Data Dive

The screenshot shows a simulation of a truck on a hill. On the left, a red truck is shown. To its right is a speedometer showing 23.8 km/h. Further right are two graphs: 'Kinetic Energy' (green line) and 'Potential Energy' (blue dashed line) with an 'Added Mass' scale below them. On the far right is a graph titled 'Energy of Truck' showing Energy (kJ) vs Time (s). Below these graphs are several assessment questions with radio button options for 'Yes' and 'No'. A large black box highlights the first two questions.

Click Yes or No to explain how the truck's energy changes as it coasts downhill.

Potential energy is changed into kinetic energy. Yes No

Potential energy disappears as kinetic energy is created. Yes No

Mass is changed into potential energy. Yes No

Mass is changed into kinetic energy. Yes No

kinetic energy is created. Yes No

kinetic energy. Yes No

Show Data DownhillConclude2 [27] 27 of 37
 Prev Next PSLEnergyEM1 v8.01.06 NEXT ▶

Tries = 1	Tries = 2	Tries = 3	Tries = 4	Tries = >4
26	21	7	20	23

Embedded Assessment 1

Data Dive

The screenshot shows a simulation of a truck on a hill. On the left, a red truck is shown. To its right is a speedometer showing 23.8 km/h. Further right are two graphs: 'Kinetic Energy' (green line) and 'Potential Energy' (blue dashed line) with an 'Added Mass' scale from 0 to 20,000 kg. On the far right is a graph titled 'Energy of Truck' showing Energy (kJ) vs Time (s). Below these is a question box with four radio button options.

Click Yes or No to explain how the truck's energy changes as it coasts downhill.

Potential energy is changed into kinetic energy. Yes No

Potential energy disappears as kinetic energy is created. Yes No

Mass is changed into potential energy. Yes No

Mass is changed into kinetic energy. Yes No

kinetic energy is created. Yes No

kinetic energy. Yes No

Show Data Downhill/Conclude2 [27] 27 of 37 NEXT ▶

FirstAnswer=Yes	FirstAnswer=No	Changed Right to Wrong
88%	12%	19%
34%	66%	20%
36%	64%	30%
37%	63%	19%

Embedded Assessment 1

Data Dive

Variable Values [0,0,0,0,0,0,1]
 Variable Values [0,0,0,0,1,1,1]
 Variable Values [0,0,0,0,1]
 Variable Values [0,0,0,1,1,1,1,0,1]
 Variable Values [0,0,0,1,1,1,1]
 Variable Values [0,0,0,1,1]
 Variable Values [0,0,0,1]
 Variable Values [0,0,1,1,1]
 Variable Values [0,0,1,1]
 Variable Values [0,1,0,1]
 Variable Values [0,1,1,1,0,1]
 Variable Values [0,1,1,1,1,1]
 Variable Values [0,1,1,1]
 Variable Values [0,1,1]
 Variable Values [0,1]
 Variable Values [1,0,0,0,0,1]
 Variable Values [1,0,0,1,1]
 Variable Values [1,0,0,1]

VariableValuesTotals 1
 VariableValuesTotals 2
 VariableValuesTotals 1
 VariableValuesTotals 1
 VariableValuesTotals 1
 VariableValuesTotals 2
 VariableValuesTotals 4
 VariableValuesTotals 1
 VariableValuesTotals 4
 VariableValuesTotals 1
 VariableValuesTotals 1
 VariableValuesTotals 1
 VariableValuesTotals 3
 VariableValuesTotals 2
 VariableValuesTotals 8
 VariableValuesTotals 1
 VariableValuesTotals 1
 VariableValuesTotals 1

Potential energy disappears as kinetic energy is created.

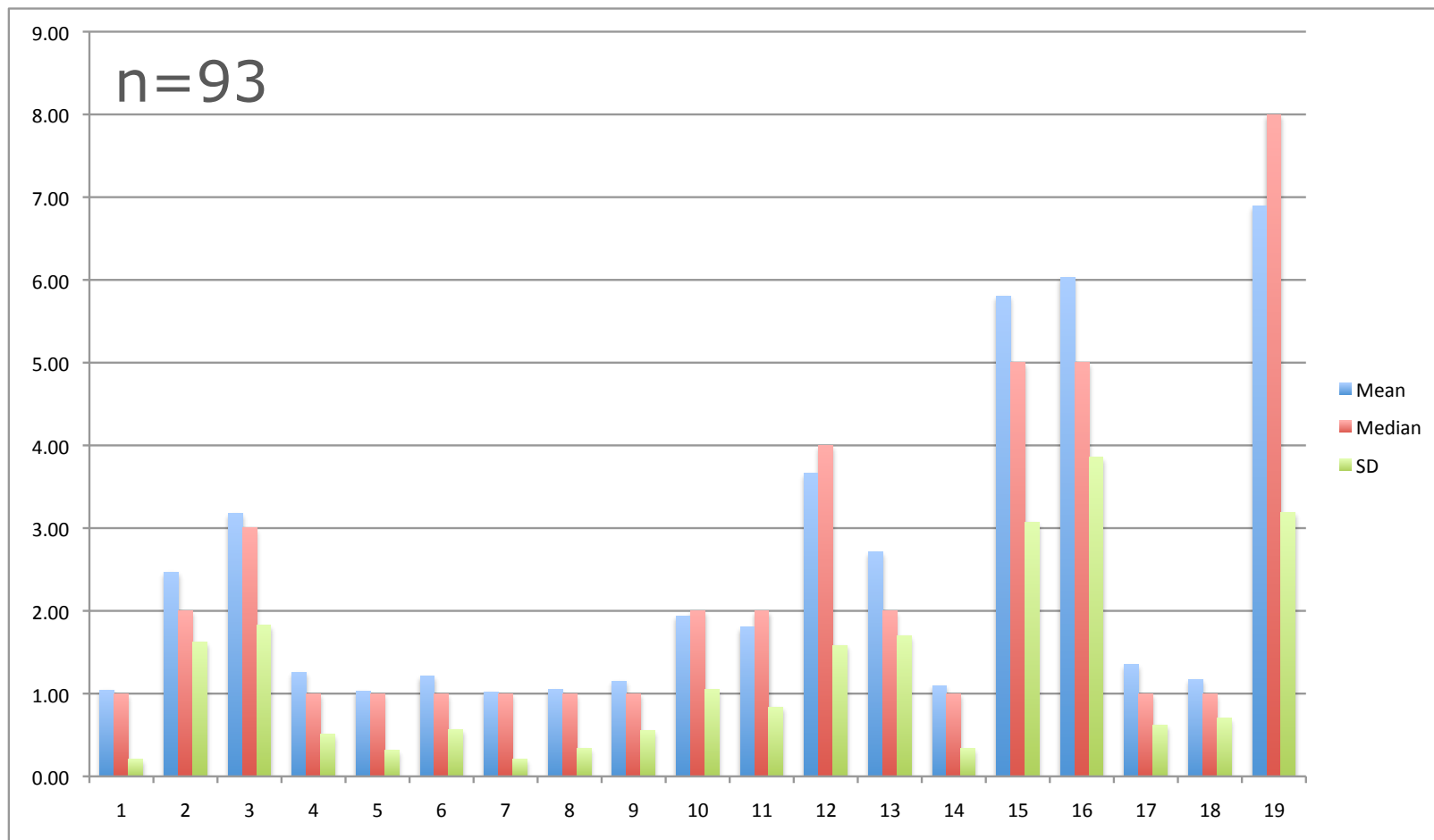
Yes
 No

Variable Values [1,0,1,1] VariableValuesTotals 4
 Variable Values [1,1,0,0,0,0,1] VariableValuesTotals 3
 Variable Values [1,1,0,0,1,1] VariableValuesTotals 1
 Variable Values [1,1,0,0,1] VariableValuesTotals 1
 Variable Values [1,1,0,1] VariableValuesTotals 2
 Variable Values [1,1,1,0,0,0,0,1] VariableValuesTotals 1
 Variable Values [1,1,1,1,1,0,1] VariableValuesTotals 1
 Variable Values [1,1,1,1,1,1] VariableValuesTotals 1
 Variable Values [1,1,1,1,1] VariableValuesTotals 2
 Variable Values [1,1,1,1] VariableValuesTotals 1
 Variable Values [1,1,1] VariableValuesTotals 5
 Variable Values [1,1] VariableValuesTotals 13
 Variable Values [1] VariableValuesTotals 26

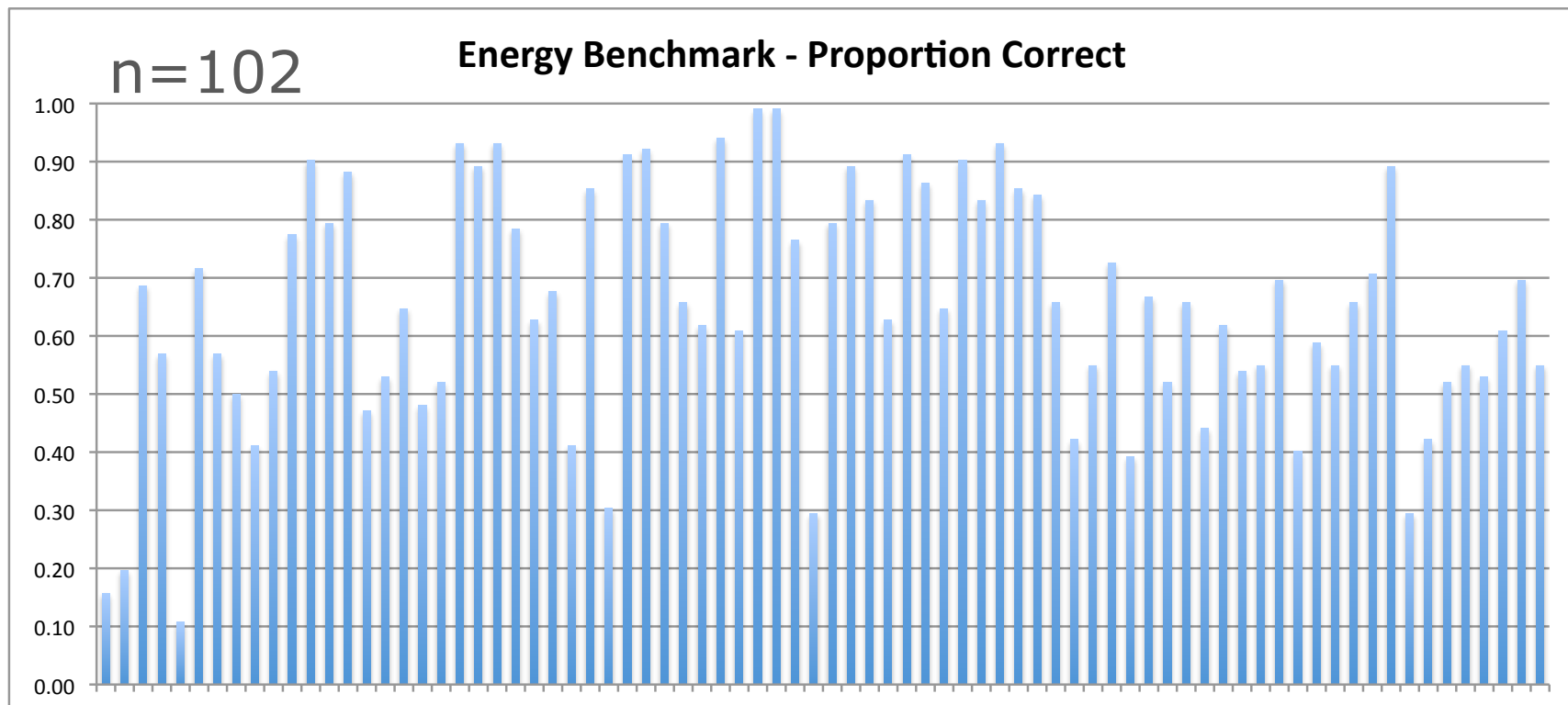
Grand Total 98

Embedded Assessment 2

Number of Tries to Correct



Benchmark Assessment Proportion Correct



Next Steps

Complete feasibility testing

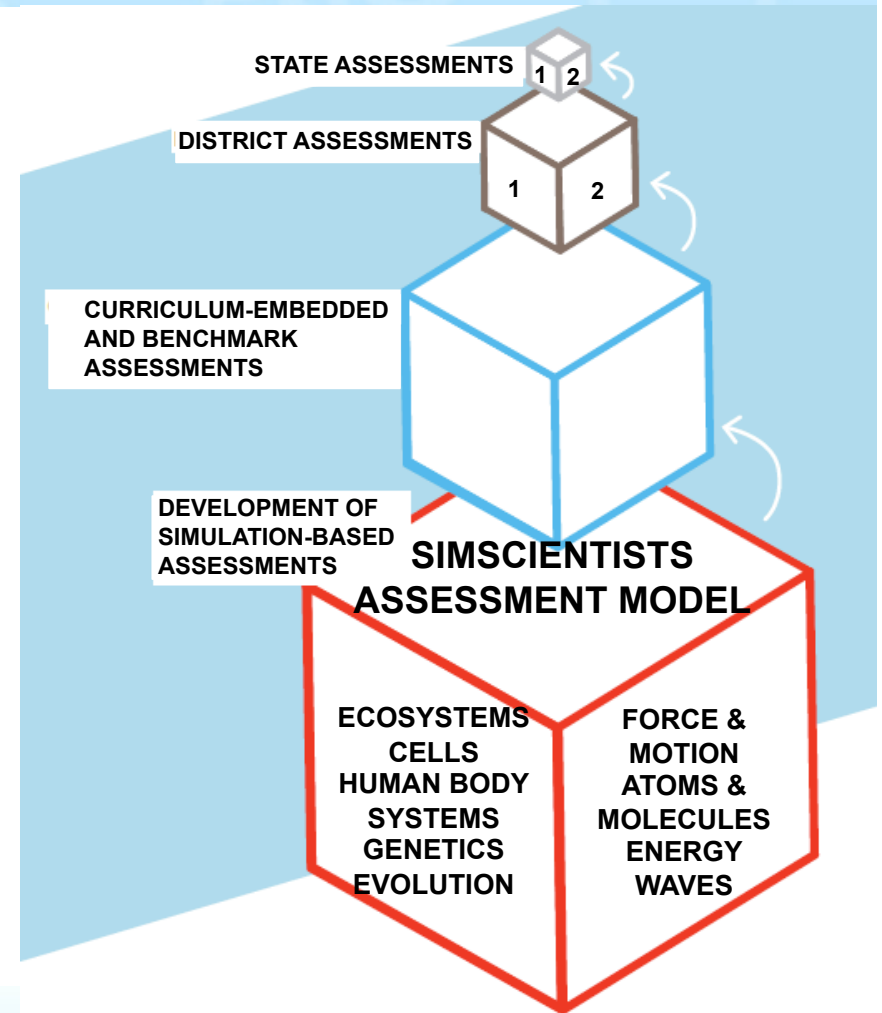
Revise assessments

Pilot and validation study (2015)

Cross-validation (2016)

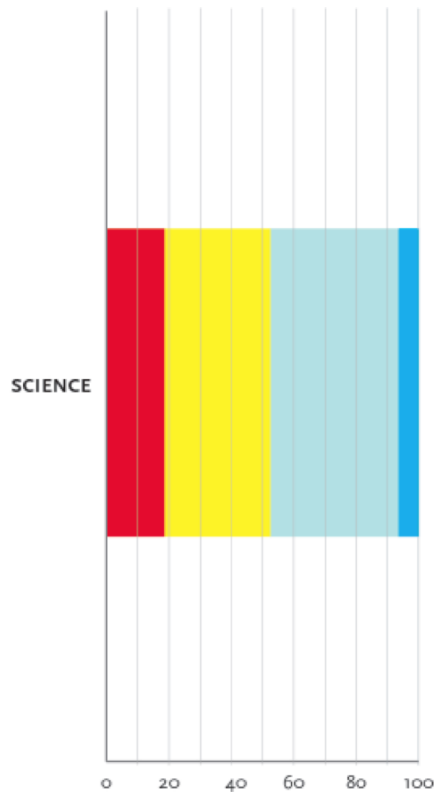
Balanced Multilevel Assessment Systems

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

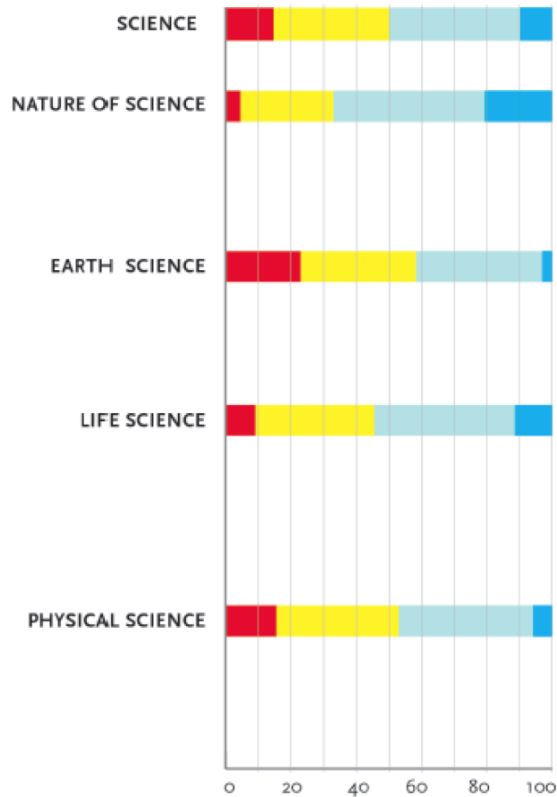


Side-by-Side Model

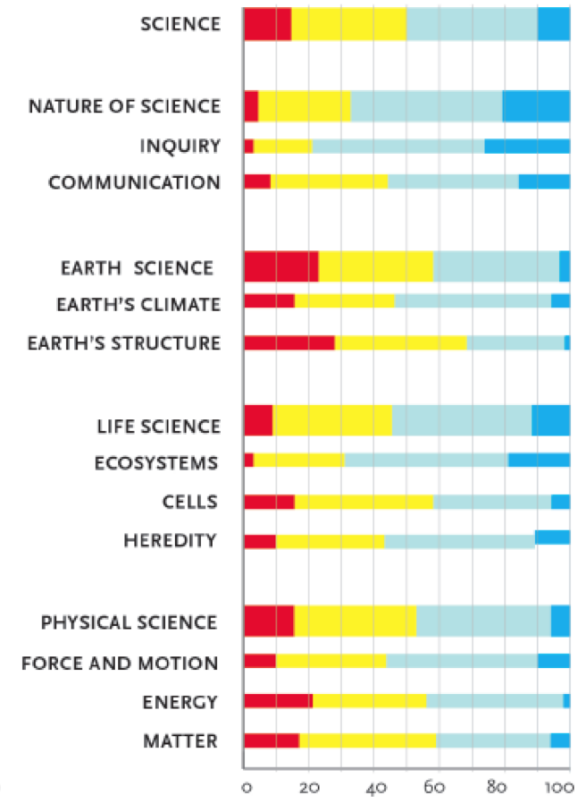
STATE ASSESSMENT



DISTRICT ASSESSMENT



CLASSROOM ASSESSMENT

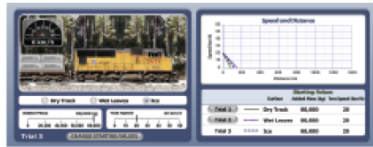


■ BELOW BASIC ■ BASIC ■ PROFICIENT ■ ADVANCED

Signature Task Model

State Test Forms

Matrix Sampling



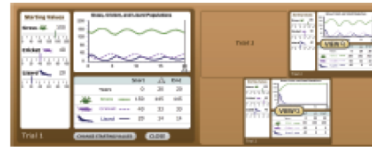
The caption from state assessment: "Read the text below on the track that bring you back. Will the train leave to their property from the track?"

Design an experiment to test how and how often affect the distance needed to stop the train compared to an dry track.

- Use the slider buttons to select a track setting.
- Use the sliders to observe the values of added mass and track length.
- Click back to see what happens.
- Save three trials that show how different variables affect the stopping distance of the train.

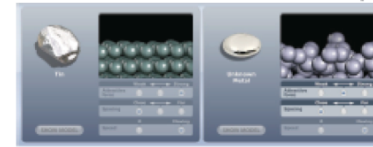


Observe the trend in the simulation. Where does the trend occur? Explain it to your teacher.



The variables involved in this simulation are: the number of rabbits, the number of foxes, and the number of sheep. They want to have populations of 1000 rabbits, 1000 foxes, and 1000 sheep for 10 years.

- Design three trials to have both the rabbit and the sheep populations double in 10 years.
- Use the sliders to change the starting numbers of rabbits and sheep.
- Click back to see what happens.



Use the sliders to observe the distance between the atoms in the molecule. The distance between atoms is 0.1 nm (10⁻¹⁰ m).

- Use the sliders to observe the distance between the atoms.
- Use the sliders to observe the distance between the atoms.
- If you want to change the model, click on different atoms.

Simulation-based task item bank

Specifications and Simulation environments



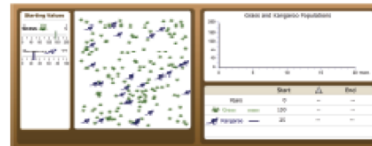
Allow sliding. It is important to know how you use the sliders. The sliders will change the speed of the train. The sliders will change the mass of the train. The sliders will change the length of the track.

- In your experiment, use the sliders to change the speed of the train.
- Use the sliders to observe the values of added mass and track length.
- Click back to see what happens.
- Save three trials that show how different variables affect the stopping distance of the train.



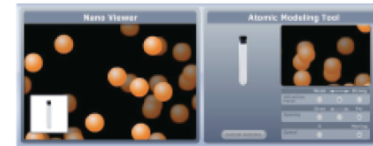
Check the highlighted arrows. Just because an animal is large does not mean that it eats smaller animals. Click on the highlighted arrows and observe what the kangaroo eats.

- To slide on arrows, click and drag them and not to double click.
- To double click on arrows, double click on it.



Now there is a lot of grass for the kangaroo to eat. If the kangaroo eats 10 kangaroos, what will happen to the kangaroo and sheep populations during the first three years?

- Predict that the kangaroo population will:
 - increase
 - decrease
 - stay the same.
- Predict that the sheep population will:
 - increase
 - decrease
 - stay the same.



The sliders will be used to observe the distance between the atoms in the molecule.

- The sliders will be used to observe the distance between the atoms in the molecule.
- The sliders will be used to observe the distance between the atoms in the molecule.

Simulation-Based Classroom Assessments

SimScientists Recent Publications

- Davenport, J. L., & Quellmalz, E. S. (in press). Assessing science inquiry and reasoning using dynamic visualizations and interactive simulations. Forthcoming chapter in *Learning from Dynamic Visualizations: Innovations in Research and Practice*.
- Quellmalz, E. S., Davenport, J. L., Timms, M.J., DeBoer, G.E., Jordan, K.A., Haung, C., & Buckley, B.C. (2013). Next-generation environments for assessing and promoting complex science learning. *J Ed Psych*, 51, 523-554.
- Buckley, B. C., & Quellmalz, E. S. (2013). Supporting and assessing complex biology learning with computer-based simulations and representations. In D. Treagust & C.-Y. Tsui (Eds.), *Multiple Representations in Biological Education* (pp. 247-267). Dordrecht: Springer.
- Quellmalz, E. S., Timms, M. J., Silberglitt, M. D. & Buckley, B. C. (2012). Science assessments for all: Integrating science simulations into balanced state science assessment systems. Invited article, *Journal of Research in Science Teaching (JRST)*, 49, 363–393.
- Quellmalz, E. S., Timms, M. J., Buckley, B. C., Davenport J., Loveland, M., & Silberglitt, M. D. (2012). 21st century dynamic assessment. In M. Mayrath, J. Clarke-Midura, & D. H. Robinson (Eds.), *Technology-based assessments for 21st century skills: Theoretical and practical implications from modern research* (pp. 55–90). Charlotte, NC: Information Age.
- Quellmalz, E. S., Silberglitt, M. D., & Timms, M. J. (2011). How can simulations be components of balanced state science assessment systems? *Policy brief*. San Francisco: WestEd.
- Quellmalz, E. S., Timms, M. J., & Buckley, B. C. (2010). The promise of simulation-based science assessment: The Calipers project. *International Journal of Learning Technologies*, 5(3), 243–265.
- Quellmalz, E. S., DeBarger, A. H., Haertel, G., Schank, P., Buckley, B., Gobert, J., Horwitz, P., & Ayala, C. (2008). Exploring the role of technology-based simulations in science assessment: The Calipers Project. In J. Coffey, R. Douglas, & C. Stearns (Eds.), *Science assessment: Research and practical approaches* (pp. 191–202). WDC: National Science Teachers Association.

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