The power of **MODELING**

IN YOUR SCIENCE CLASSROOM

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What do these two scenarios have in common?

Kindergarten students:

*How does someone little bump someone big off the end of a playground slide?

AP chemistry students:

*Where does the heat go in our coffee?
In both, students can reason deeply about the science through modeling

Kindergarten students:
How does someone little bump someone big off the end of a playground slide?

AP chemistry students:
Where does the heat go in our coffee?
What we’ll talk about today

• What is modeling?
• How does it fit in with other science practices?
• What tools and routines do I and my students need to do this work?
• How can modeling help my students learn in more meaningful ways?
Role of teacher is shifting: Supporting changes in student thinking over time

- Supports students in revising explanations and models, over time.
- Create opportunities, every day, for students’ sense-making talk.
- Help students learn to identify and use resources (science ideas, their own ideas, science practices, tools, materials, information, etc.) to do this work.
Let’s generate data as a group about what your experiences have been

**Poster A: Frequency.** Place yourself 1-5 on
- Your use of modeling as a science practice in the past year
(1-have not, 2-once or twice, 3-three or four times, 4-used in most units that I teach, 5-used in nearly every unit that I teach)

**Poster B: Comfort level.** Place yourself 1-5 on
- Comfort level with your understanding of modeling
(1-not at all, 2-I know just a little/enough to be dangerous, 3-I am modestly comfortable that my students can learn from our modeling attempts, 4-I feel I am proficient at it, 5-I have really come to understand how to use it in the classroom.)

**Poster C: Making headway (pick 2).** To make better use of modeling in my classroom, I would want to know more about:
- 1-how to find science ideas or events appropriate for modeling
- 2-how to organize students’ drawing of models, keep them from chaos
- 3-how to get students to revise models based on evidence, new information
- 4-how to coordinate modeling with other science practices
- 5-how to give students feedback about their models
- 6-how to give students grades on their models
What are scientific models? Representations of things, ideas, events, or processes (they show relationships)

Physical models: ball and stick molecule

Graphs: dissolved oxygen in creek locations of different temperatures

Computer simulations: tsunami wave heights in West Bengal 1762
Models used differently by scientists and teachers

Models used in classrooms often as static representations of “finished science”

- To illustrate a concept to students ("Here are the parts of the cell")
- To show how something works ("Here is how forces interact")
Models used differently by scientists and teachers

Scientists use models to advance knowledge

• To allow a community to visualize a tentative explanation in order to improve it
• To recognize what they might experiment with in order to test a part of the model
• To predict how a system will act under certain conditions

Model of hydrothermal vents on the ocean floor
What is modeling?

- A scientific practice, in which representations of phenomena are created, tested, and revised over time.

Evolution of DNA double helix model
Starts with images from Rosalind Franklin’s notebook
Our students produce models that are always **pictorial**, and of events that can have **more** than one viable explanation.

- **4th grade**  Sound energy
- **11th grade**  Force & motion
- **8th grade**  Gas laws
Models always label what is unobservable to explain what is observable.

Sound waves cause glass to vibrate, resonate.

Air molecules outside tanker exert pressure.

Friction forces allow runner to push off the wall.
Modeling means revising in response to new evidence, ideas.
Why is modeling a valued practice?

- It makes students’ thinking visible to you
- Allows students to show more of what they currently know, and in variety of ways
- Makes their reasoning available to their peers
- Helps students see that it is valuable to change their thinking in response to new evidence and ideas
This student has used drawing, writing, and formulas to make sense of the “coffee event.”

Before Calorimetric Process

During Calorimetric Process

After Calorimetric Process

Key:
- Force vector
- H2O molecule
- Ice system molecule:
- Coffee system molecule:

The vectors in the coffee pot water are much longer because the liquid is at a higher temp. and therefore have a higher velocity. The ice is in a solid form, closer together, and have a lower velocity.

The systems mix; ice melts and the energy from the coffee pot molecules move to the ice molecules making the vector arrows shorter and the ice vectors longer.

The two systems are in equilibrium, therefore the vector arrows are the same length and they have the same amount of energy.
His classmates have different mini-theories, and different ways of expressing ideas
This student brings \textit{equilibrium} into the picture, isn’t that worth talking about with the whole class?
This student shows what may be happening with a cut-away view.
Using *Anchoring Events* to guide units of instruction

A puzzling event or process whose full explanation requires a wide range of science ideas to be coordinated with one another and with evidence.
What happened after wolves were re-introduced to Yellowstone?

1995
- Aspen
- Elk
- Short willow

2015
- Ravens
- Young aspen trees
- Prong-horned deer
- Beaver
- Cut-throat trout
- Boreal chorus frog
- Water birds
Real events: Ask students to model & explain an actual phenomenon, the context matters!

This is OK as a teaching tool

But students should be striving for an explanation of this

This is OK as a teaching tool

But students should be striving for an explanation of this
General phenomena

• How are volcanoes formed?

• How organisms interact in an ecosystem?

• What is homeostasis and why is it important to our body?

Contextualized phenomena

• Why do Mt. Rainier and Hawaiian volcanoes erupt differently?

• Why did the re-introduction of wolves change the Yellowstone ecosystem so dramatically?

• What’s happening to a high school cross country runner before, during, and after a heat stroke?
How could the re-introduction of so few wolves to Yellowstone, cause such dramatic changes in the ecosystem?
Our “checklist” for finding good anchoring events + essential question

Topic is mitosis

Why did I get skin cancer from too much sun? Will it spread?

- It is a phenomenon, something that unfolds over time (it’s not a theme)
- It is a contextualized situation, takes place at a particular time, under unique circumstances
- Explanation requires many core science ideas to be integrated with one another
- Students can pull together core ideas in different ways to explain
The “arc” of our tanker unit

- Initial models
- Jigsaw on molecules
- Can crushing as model
- Revise models
- Marshmallow & syringe
- Computer simulation on pressure
- Using math
- Final models

Eliciting ideas
The “arc” of our tanker unit

- Eliciting ideas
- Initial models
- Jigsaw on molecules
- Can crushing as model
- Revise models
- Marshmallow & syringe
- Computer simulation on pressure
- Using math

Drawing initial models
The “arc” of our tanker unit

Initial models
Jigsaw on molecules
Eliciting ideas

Jigsaw on molecules
Can crushing as model

Computer simulation on pressure
Marshmallow & syringe

Using math

Final models

Jigsaw readings on molecular motion
The “arc” of our tanker unit

Eliciting ideas

Initial models

Jigsaw on molecules

Can crushing as model

Revise models

Marshmallow & syringe

Computer simulation on pressure

Using math

Final models

Can crushing as model
The “arc” of our tanker unit

- Eliciting ideas
- Initial models
- Jigsaw on molecules
- Can crushing as model
- Marshmallow & syringe
- Computer simulation on pressure
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- Final models

Revise models
The “arc” of our tanker unit

Initial models

Jigsaw on molecules

Can crushing as model

Revise models

Marshmallow & syringe

Computer simulation on pressure

Using math

Final models

Marshmallow & syringe

Eliciting ideas
The “arc” of our tanker unit

Initial models

Jigsaw on molecules

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Can crushing as model

Revise models

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Final models

Computer simulation on pressure
The “arc” of our tanker unit

Initial models
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Eliciting ideas

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Revise models

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Using math

Charles’ Law

\[ \frac{V}{T} = k \]

\[ \sqrt{V_1}, T_1; \sqrt{V_2}, T_2 \]
The “arc” of our tanker unit

Initial models
Jigsaw on molecules
Can crushing as model

Revise models

Marshmallow & syringe

Computer simulation on pressure

Using math

Final models

Create final models
The “arc” of our tanker unit

Initial models
Jigsaw on molecules

Can crushing as model

Revise models

Computer simulation on pressure

Marshmallow & syringe

Using math

Final models

Modeling and revising explanations

Where might students get the chance to engage in other science practices?

- Asking questions
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information
Modeling + Explanation are “keystone” science practices

Models either motivate the other science practices (like asking questions, deciding what to test via investigations), or they change as a result of other science practices (data analysis, argument) —and they are tightly coupled with explanations.

For good reasons, the NGSS is asking that the Scientific Method NOT be taught as the “way science works.”
Avoid creating “posters”

Modeling is not just drawing. If students are reproducing something that could be found in any textbook, then it is not modeling.

If there is nothing genuinely puzzling or students all have the same models, it is not modeling (we call this “posterizing”).

The Rock Cycle
Revising in principled ways

“We think according to our sneakers and socks activity it supports part of our model, but we would like to change that sneakers matter and traction with the wall and ground matters should be added to make it even more accurate.”
• We can’t just say “Go and do this.”
• It requires scaffolding.
Ensemble of practices =
Investigation + modeling +
arguing from evidence
(scaffolding how to change models
in response to evidence)
Templates

• You can get students to “show the most of what they know” by adding scaffolds to the final model template.
Draw and label what caused the tanker to implode the way it did.
In each phase—before, during, after—label what you can see and what is unobservable.

“Gotta-have” checklist:

- How molecules cause pressure
- About differences in conditions inside versus outside the tanker
- How heat energy is transferred in the tanker
- How changes in the volume of a container affects pressure

Please use zoom-ins.

This is what we think is causing what we see in each phase:
When the stops are released he is pulled upward because the helium is lighter than the air and it has an upward force. There is enough helium to pull the weight of the chair and his body up.

Before and after template for 9th grade unit on forces
The forces acting directly on Eric are gravity pulling him to the earth and the normal force of the chair preventing him from falling by pushing up on him. The helium balloons are providing buoyant forces but the balloons are only directly acting on the ropes. The ropes have a tension force that is holding the chair up. Only the chair is acting directly on Eric. In the experiment with the ball and the water, the ball floated on top of the water because it was like the balloons because it had a buoyant force.
Question: How is Erik Roner able to successfully fly and safely land using helium balloons attached to a lawn chair?

Directions: 1. In the four drawings below, draw what is happening that you can’t see that causes Erik to move at each point in time.
   Use dotted arrows (-----) to show motion and solid arrows (-----) to show forces in the picture.
2. In the boxes, draw and label a force diagram showing all the forces acting on Erik.
3. After drawing your models, use the lines to write an explanation about what is happening at each point in time.
4. For each picture, be sure to include the ideas from the Gotta Have Checklist.
5. After completing your model, provide evidence from one class activity that supports one of your ideas.

Gotta Have Checklist: include in every box
- Show all the forces acting on Erik using a force diagram
- Identify whether the forces are balanced or unbalanced
- Describe Erik’s motion, including direction and type of motion (constant speed or acceleration)
- Describe how the forces cause any changes in motion

Provide Evidence: include for one point in time
- Look at your original model. How has your thinking changed over time? Are there any ideas you have added or removed from your model?
- Pick one class activity in which you collected data that supports a change in your thinking. Write your evidence on a sticky note and stick it to the relevant picture.
Assessing models

<table>
<thead>
<tr>
<th>Meeting standard</th>
<th>Clearly explains HOW biotic and abiotic factors interact to cause changes in ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Niches in Ecosystem</strong></td>
<td>Uses specific species and their niches in the ecosystem as compelling evidence to explain why wolf removal caused the observed changes. Communicates the role of 5 or more species through writing AND diagrams.</td>
</tr>
<tr>
<td><strong>Biotic &amp; Abiotic Factors</strong></td>
<td>Clearly explains HOW biotic and abiotic factors interact to cause changes in ecosystem. Communicates multiple biotic and abiotic factors through writing AND diagrams.</td>
</tr>
<tr>
<td><strong>Energy Flow</strong></td>
<td>Uses energy flow in the ecosystem as compelling evidence to explain why removal of a relatively small number of wolves caused changes in such a large number of organisms. Communicates energy flow through writing AND diagrams.</td>
</tr>
<tr>
<td><strong>Population Dynamics</strong></td>
<td>Uses population dynamics as compelling evidence to explain why wolf removal caused the observed changes. Communicates population dynamics through writing AND diagrams.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Score</th>
<th>Exceeding (A)</th>
<th>Meeting (B)</th>
<th>Approaching (C)</th>
<th>Initial (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Percentage</td>
<td>95%</td>
<td>93%</td>
<td>90%</td>
<td>87%</td>
</tr>
</tbody>
</table>
Here is what is most effective to promote deep scientific reasoning with modeling

1) Models should represent an event or process
2) The phenomenon should be context-rich, meaning that it is about a specific event that happens in a specific place and time under specific conditions.
3) It helps if students’ models are pictorial, meaning that there is some visual resemblance between the representations on paper and the process or event being modeled.
4) Ask students to draw the unobservable to explain what is observable—they need to tell a causal story, not a descriptive one.
5) Models need to be revised in response to new evidence and information.
6) Allow the models to look different, you are NOT reproducing textbook explanations.
Put these tips in your back pocket

• **Show time passing**: Have students produce representations that show how the event or processes *change over time*, for example in “before-during-after” panels. Some of the most illuminating conversations among students involve what they think is going on before an event happens and why they think an event stops.

• **How will we draw?** Agreement about drawing conventions is important.

• **Provide simple templates**: For drawings that may be hard to sketch out, provide a template with outlines for students to use as a guide.

• **Have students keep track of what they learn from the unit’s activities**: Keep a public record of all the activities that were done over the course of a unit and how these activities contributed to students’ thinking about the final phenomenon.

• **Avoid model fatigue**: Have students change the model only once or twice in the middle of the unit, not every other day. They will get “model fatigue” if you go back to the drawings too often.

• **Multi-modal communication**: Writing + drawing is really important.

• **Can’t do it all**: The phenomenon *cannot* be the anchor for all the ideas one needs to teach in a unit of instruction, but it can tie together most of the major ideas. You will have to have some lessons that are not directly tied to the