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

Flow chart of human circulatory system
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 a watershed affects habitats”)
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 is child’s play

Pushes and pulls get you up the slide in the first place

Gravity pulls “all the way down”
Modeling means *revising* in response to new evidence, ideas.

Kevin’s initial model

Kevin’s model later
Why is modeling a valued practice? It’s not so kids to act like “little scientists”

- It makes students’ thinking visible to you
- Allows students to show more of what they currently know 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
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.
Anchoring events can be about everyday occurrences.
What happened after wolves were re-introduced to Yellowstone?

1995:
- Aspen
- Coyote
- Short willow

2015:
- Ravens
- Young aspen trees
- Prong-horned deer
- Beaver
- Water birds
- Cut-throat trout
- Boreal chorus frog

Elk
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 do volcanoes erupt differently?

• How do plants reproduce?

• How did an apple tree start growing in the meadow, a mile from other apple trees?

Contextualized phenomena

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

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

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

How do bats find their prey in the dark?

How can a singer break a glass with just the sound from his voice?

Checklist for finding good anchoring events. Which anchor for 4th grade Sound Waves Unit?
Anchoring events require students to coordinate many different science ideas in order to explain them (a singer shatters glass with his voice)

- Sound as compression waves
- Sounds transferring energy through gases, liquids, solids
- Air as medium of transmission
- Conservation of energy
- Resonance
- Propagation of sound waves in all directions at once
The “arc” of a unit on sound energy
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 to make it more accurate.”

“We think (evidence from summary table) supports PART of our model, but we would like to change to make it more accurate.”

“ADD a New idea: supports our model, but it also tells us that should be added to make it even more accurate.”

“REPLACE or FIND OUT MORE: contradicts in our original model, and that we need to rethink about it.”

QUESTIONS: “We still have about ___.”

“We think that according to our Sneakers and Socks activity is 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.”

“WALL

These steps are particularly IMPORTANT

because in order to flip in the air, he needs to
get enough for gravity and to stay in the air
and flip. He needs the right momentum to do this.”

STEPS:

1. He uses the wall

2. He uses the power of

3. His legs are in

4. His legs are open

5. He is back on

“GROUND

PARADISE AND MYTH

BY: TRALONDA, MICHAEL

GREGGS”
• 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 Rosner 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 (FORCE acting ON ___ BY ___)
- 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.
Meeting standard + Clearly explains HOW biotic and abiotic factors interact to cause changes in ecosystem

<table>
<thead>
<tr>
<th>Niches in Ecosystem</th>
<th>Meeting the Standard (B)</th>
<th>Approaching the Standard (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Meeting] + Uses specific species and their niche in the ecosystem as compelling evidence to explain WHY wolf removal caused the observed changes.</td>
<td>Accurately describes the impact of wolf removal on ecological processes, specifically highlighting how changes in one trophic level can affect the entire ecosystem.</td>
<td>Attempts to describe the impact of wolf removal on multiple species.</td>
</tr>
<tr>
<td>Communicates the role of 5 or more species through writing AND diagrams.</td>
<td></td>
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<thead>
<tr>
<th>Biotic &amp; Abiotic Factors</th>
<th>Meeting the Standard (B)</th>
<th>Approaching the Standard (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Meeting] + Clearly explains HOW biotic and abiotic factors interact to cause changes in ecosystem.</td>
<td>Accurately describes the flow of energy through the forest ecosystem food web, incorporating the terms biomass, respiration, herbivory, energy transfer, primary producer, primary consumer, secondary consumer, and prey-predator cycle.</td>
<td>Attempts to describe changes in biotic and abiotic factors in ecosystem.</td>
</tr>
<tr>
<td>Communicates multiple biotic and abiotic factors through writing AND diagrams.</td>
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</tbody>
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<tr>
<th>Energy Flow</th>
<th>Meeting the Standard (B)</th>
<th>Approaching the Standard (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Meeting] + 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.</td>
<td>Accurately describes the flow of energy through the forest ecosystem food web, incorporating the terms biomass, respiration, herbivory, energy transfer, primary producer, primary consumer, secondary consumer, and prey-predator cycle.</td>
<td>Attempts to describe the flow of energy through the food web.</td>
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<tr>
<td>Communicates energy flow through writing AND diagrams.</td>
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<tr>
<th>Population Dynamics</th>
<th>Meeting the Standard (B)</th>
<th>Approaching the Standard (C)</th>
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<tbody>
<tr>
<td>[Meeting] + Uses population dynamics as compelling evidence to explain WHY wolf removal caused the observed changes.</td>
<td>Accurately describes the impact of wolf removal on elk population dynamics, incorporating the terms population density, birth, death, exponential growth, logistic growth, carrying capacity, predation, and disease.</td>
<td>Attempts to describe the impact of wolf removal on elk population dynamics.</td>
</tr>
<tr>
<td>Communicates population dynamics through writing AND diagrams.</td>
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</tbody>
</table>

Overall Score

<table>
<thead>
<tr>
<th>Overall Percentage</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>
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</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