Students' use of physical models to experience key aspects of scientists' knowledge creation process

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April 8, 2013

Bridging the Gap between Tabletop Models and the Earth System

Physical Setting/
Earth Science

Core Curriculum

Our teachers—excellent though they are—do not view teaching about models as a goal of Regents Earth Science

STANDARD 4:

Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

STANDARD 6
Interconnectedness: Common Themes

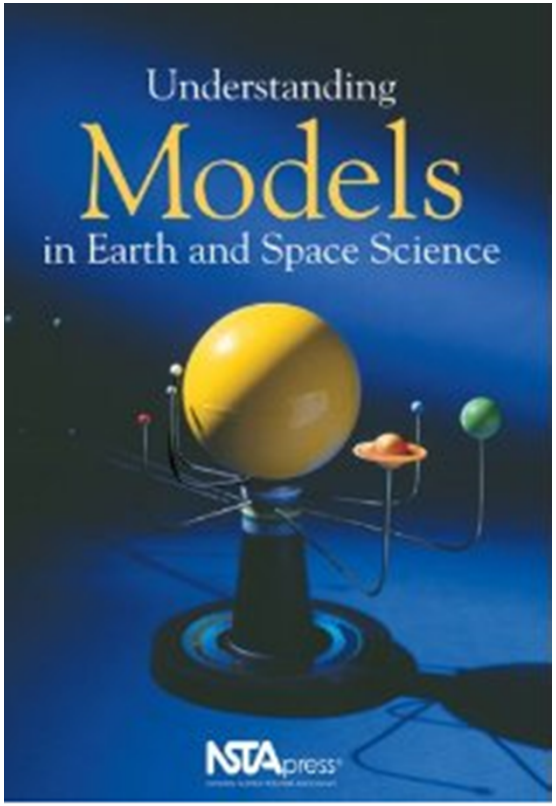
MODELS:

In our professional development, we discussed…

Students aren't just learning about moon phases, or seasons, or deposition…

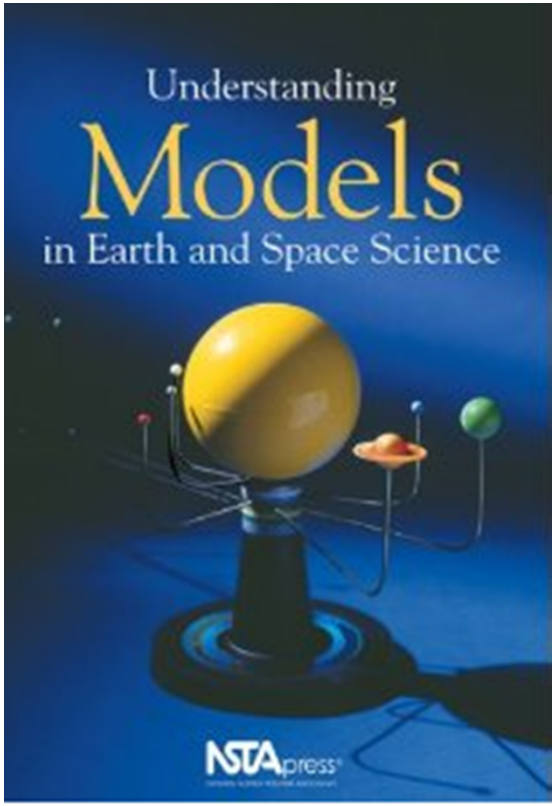
At the same time, they are learning about models and modeling.

Strategic Decision: How overt do you want to be about discussing the scientific practice of modeling?



Kinds of models

- Expressed models
  - Physical (concrete) models
    - Static scale models
    - Runnable physical models
  - Diagrammatic models
  - Mathematical models
  - Computer models
- Mental models



Kinds of models

Conceptual Model

- Physical (concrete) models
  - Static scale models
  - Runnable physical models
- Diagrammatic models
- Mathematical models
- Computer models

All are "simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design."

"Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design."

- Models help us explain our ideas more clearly to other people.

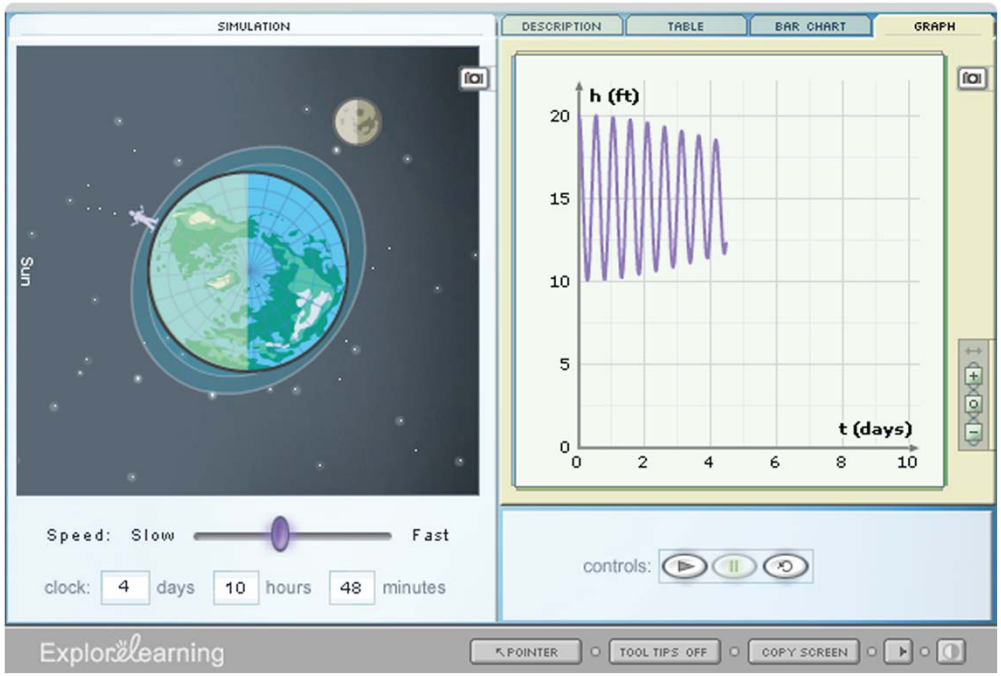
- Models get our ideas out there in public where we can argue about them with other people and test their validity against data.

- Model + Brain can answer harder questions and solve harder problems than brain alone.

Models are not toys for children; models are brain-extenders for scientists.

Expressed runnable models are not just for communicating or demonstrating or revealing what scientists already know….

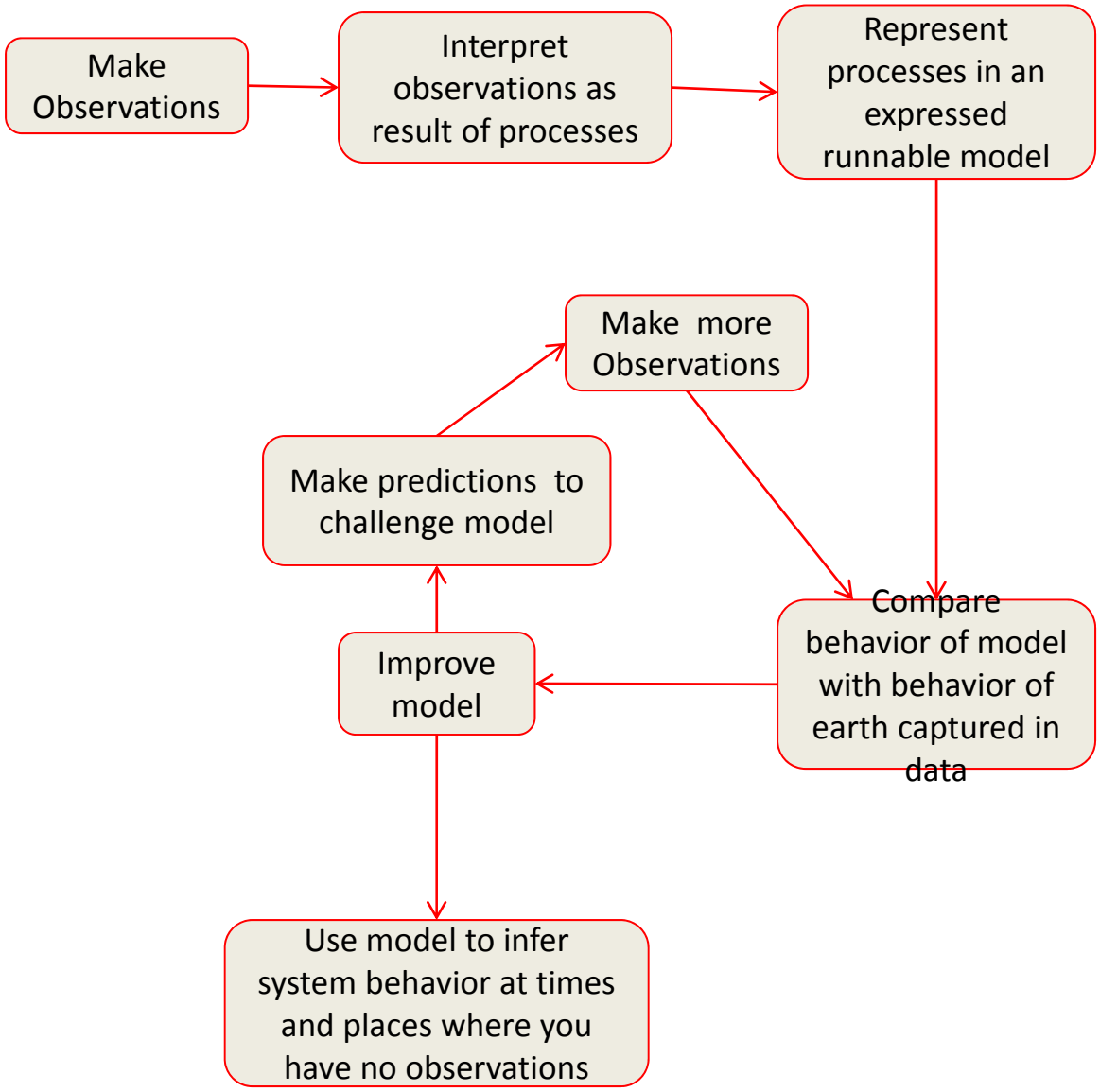
physical model



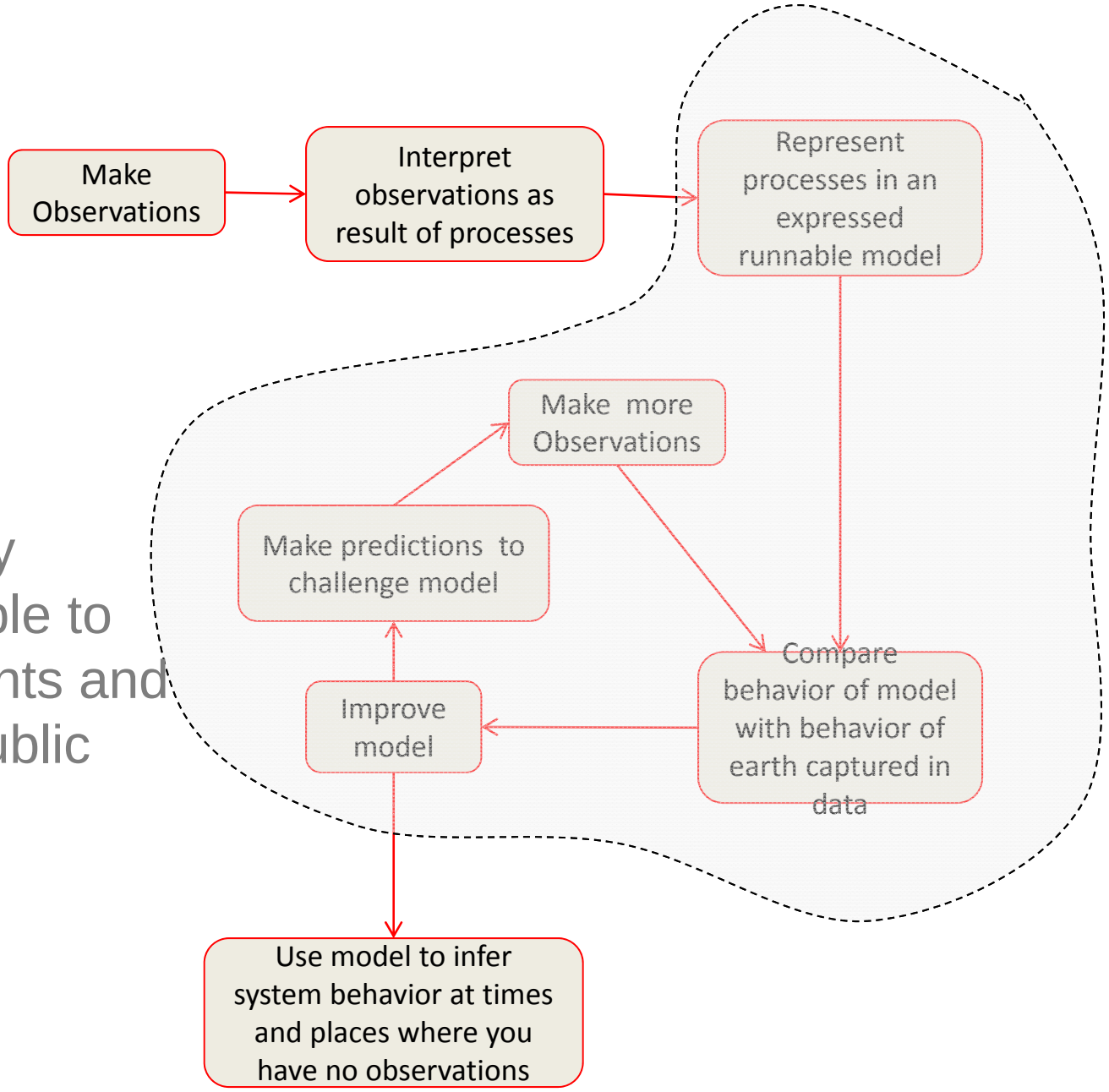
computational model

Such models are tools for creating new knowledge.

OK. So how does this brain-extending process work when scientists learn from external runnable models?

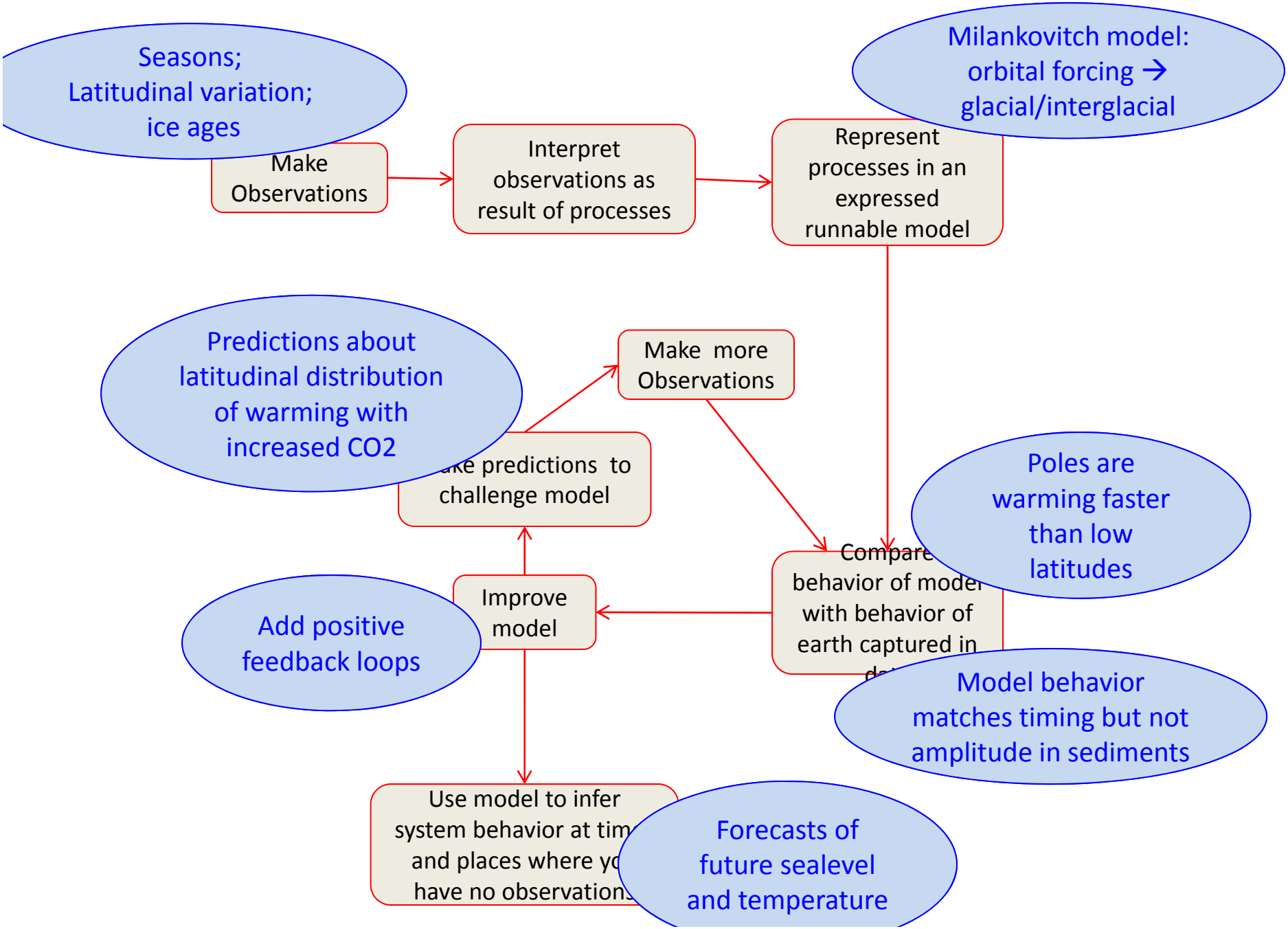


The problem:

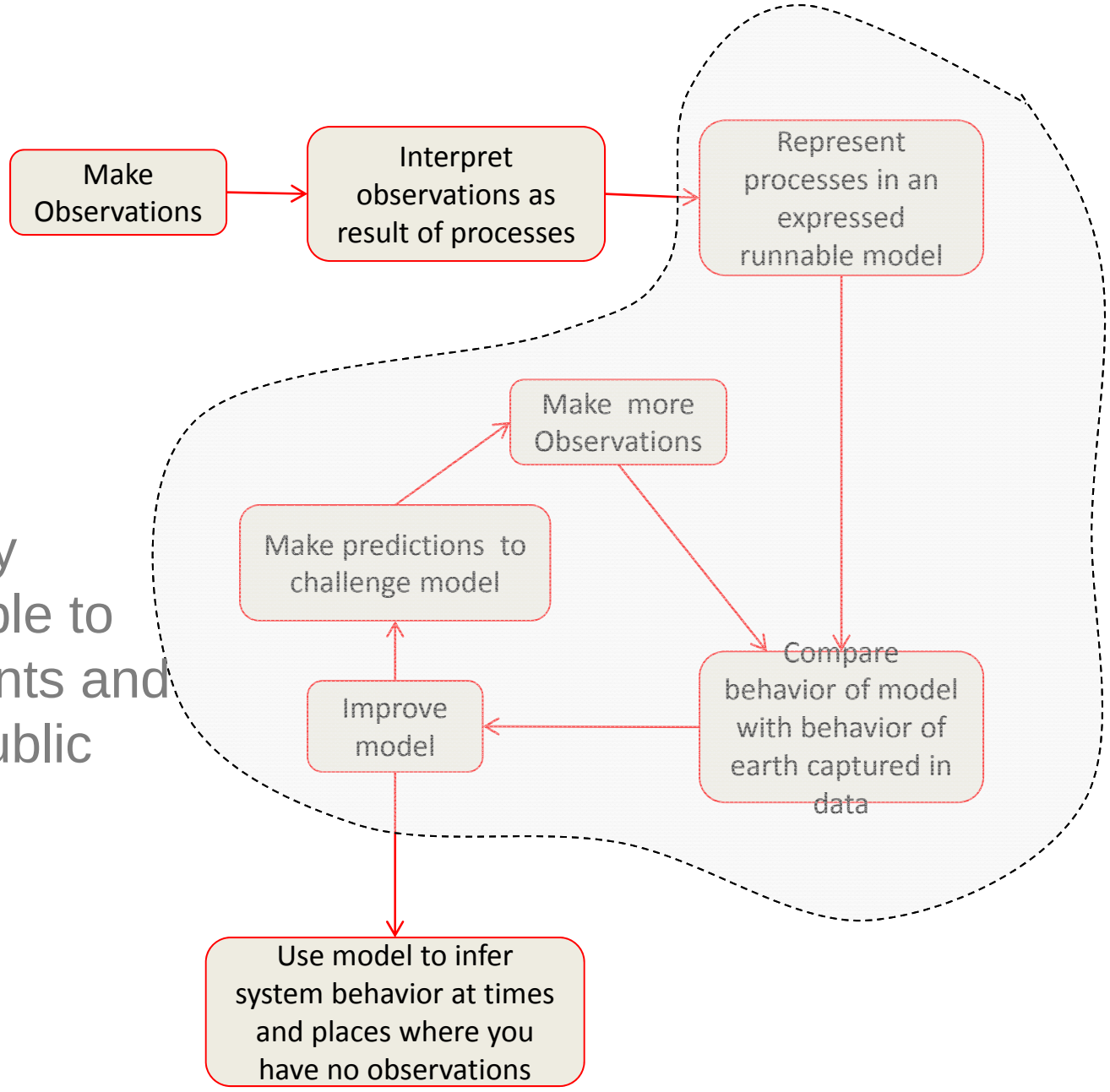


Nearly invisible to students and the public

Earth Science example: Global climate model



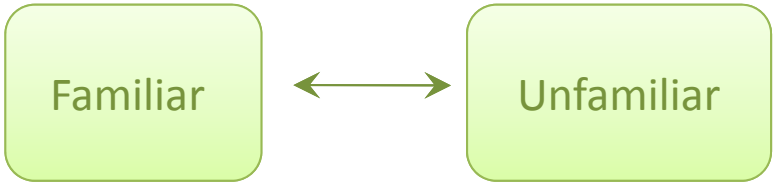
How can we make the obscured steps more salient?



Nearly invisible to students and the public

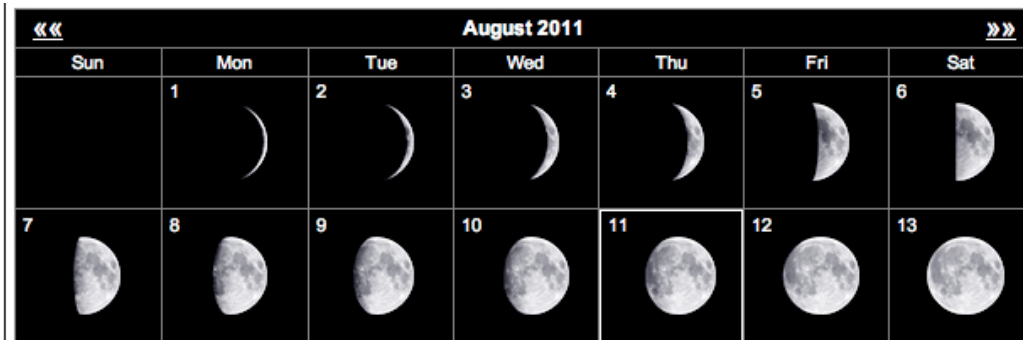
Our project developed three candidate strategies for better teaching and learning with models

(a) Explicitly teach and practice analogic mapping, articulating correspondences and non-correspondences



(b) Use models as a tool for solving problems and answering questions.

(c) Use models as a tool for reasoning about Earth data.



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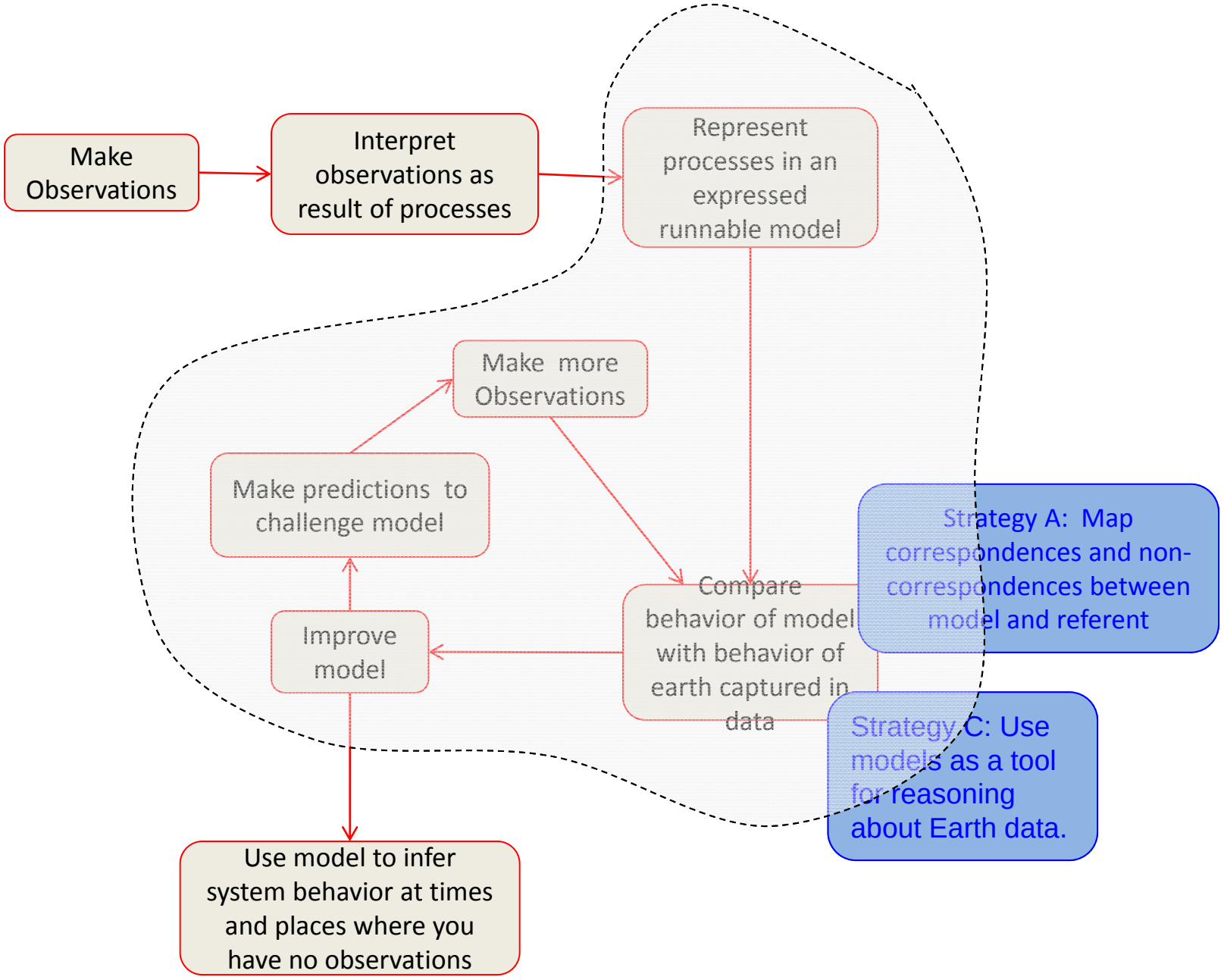
Strategies suggested in our project:

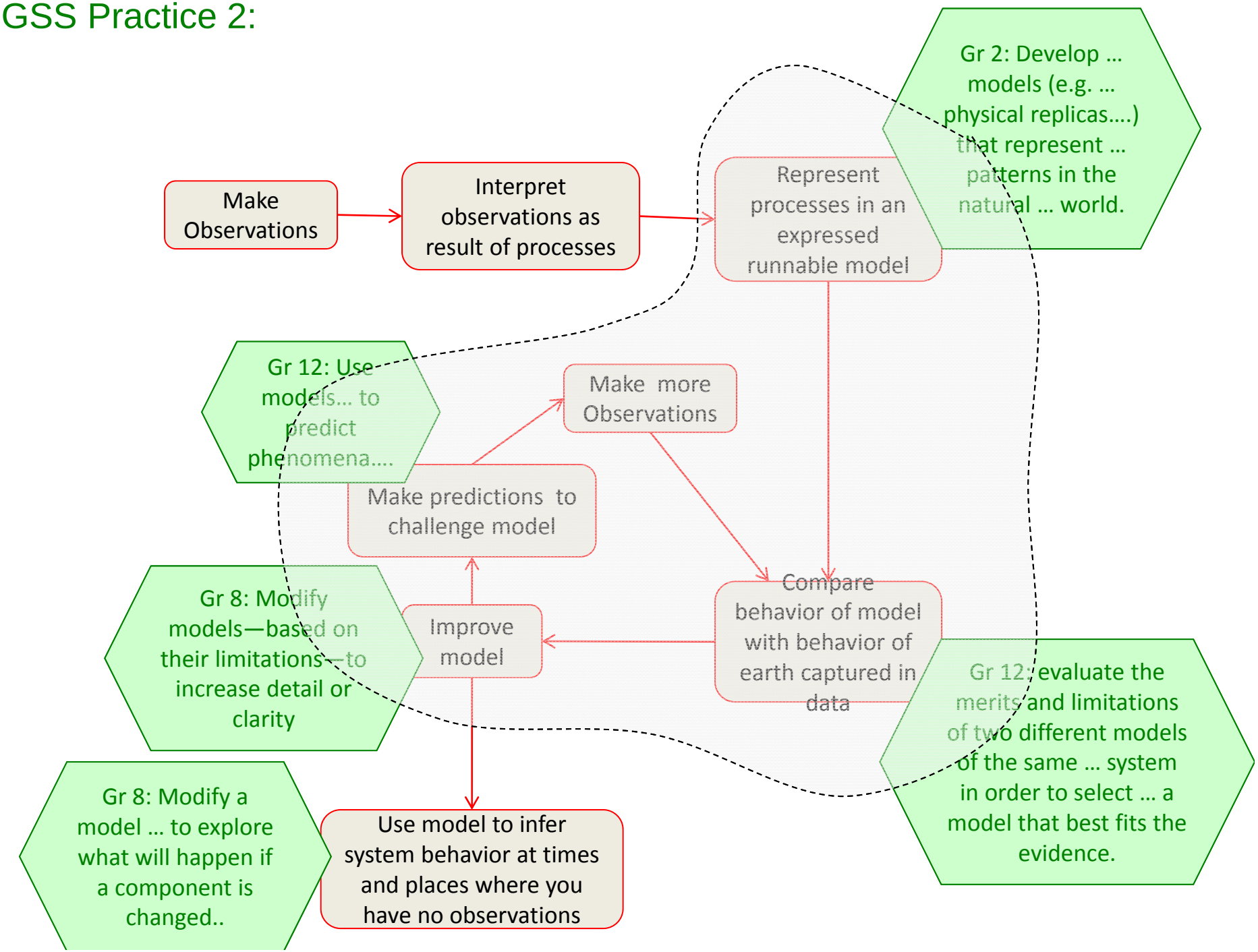


NEXT GENERATION SCIENCE STANDARDS
For States, By States

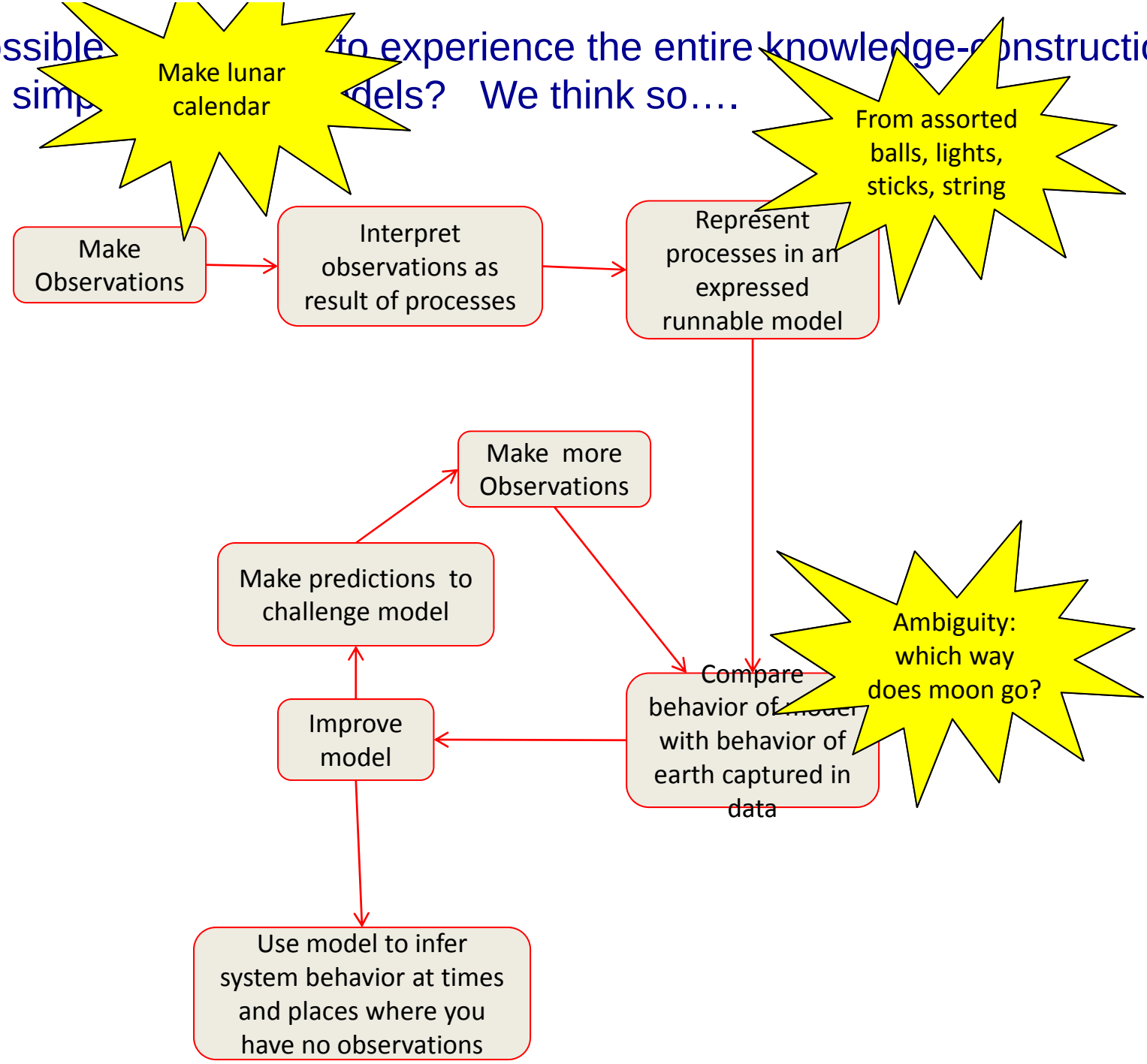
Appendix F: Scientific & Engineering Practices
Practice 2: Developing and Using Models

Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions. • Distinguish between a model and the actual object, process, and/or events the model represents. • Compare models to identify common features and differences. • Develop and/or use models (i.e., diagrams, drawings, physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed worlds. • Develop a simple model that represents a proposed object or tool.	Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions. • Develop and revise models collaboratively to measure and explain frequent and regular events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Use simple models to describe or support explanations for phenomena and test cause and effect relationships or interactions concerning the functioning of a natural or designed system. • Identify limitations of models. • Develop a diagram or simple physical prototype to convey a proposed object, tool or process. • Use a simple model to test cause and effect relationships concerning the functioning of a	Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. • Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. • Develop models to describe unobservable mechanisms. • Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed. • Use and develop models of simple systems with uncertain and less predictable factors. • Develop a model that allows for manipulation and testing of a proposed object, tool, process or system. • Evaluate limitations of a model	Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world. • Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. • Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. • Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. • Design a test of a model to ascertain its reliability. • Develop a complex model that allows for manipulation and testing of a proposed process or

NGSS Practice 2:

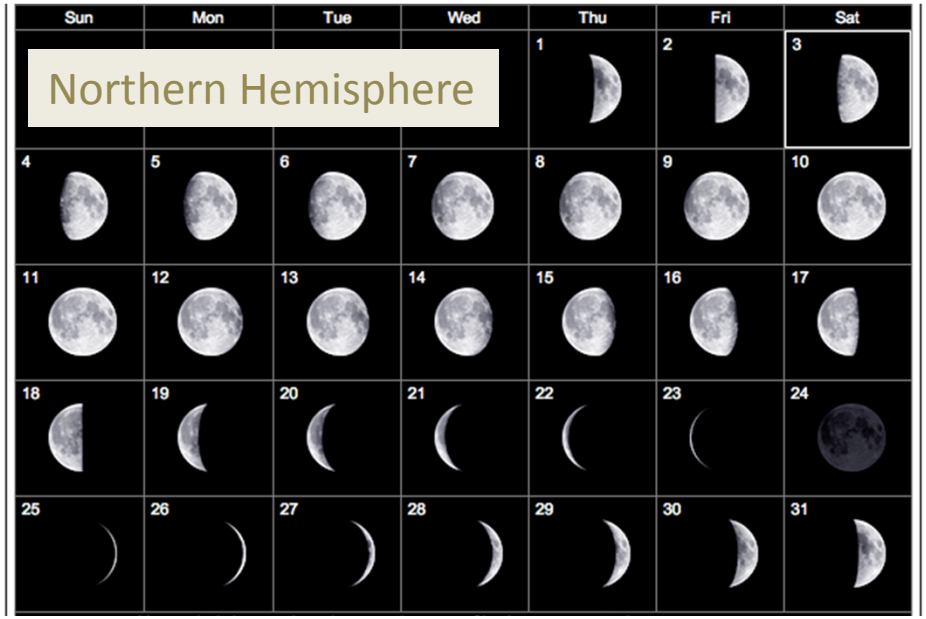


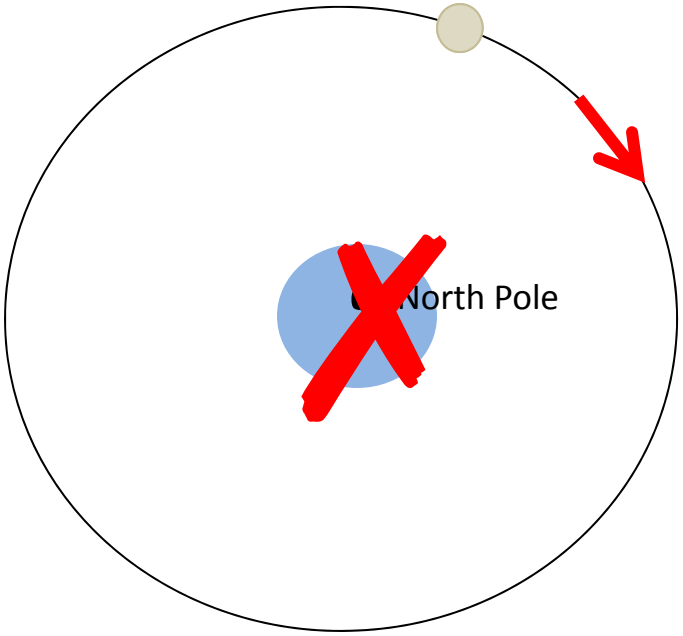
Would it possible [illegible] to experience the entire knowledge-construction cycle using simp[illegible]dels? We think so….

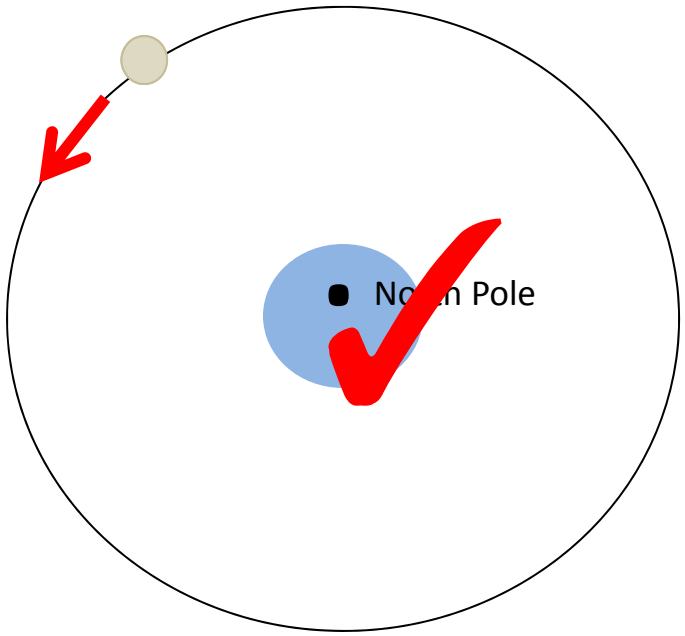


Improve model

Compare behavior of model with behavior of earth captured in data







Ambiguity: Which direction does the Moon go around the Earth?

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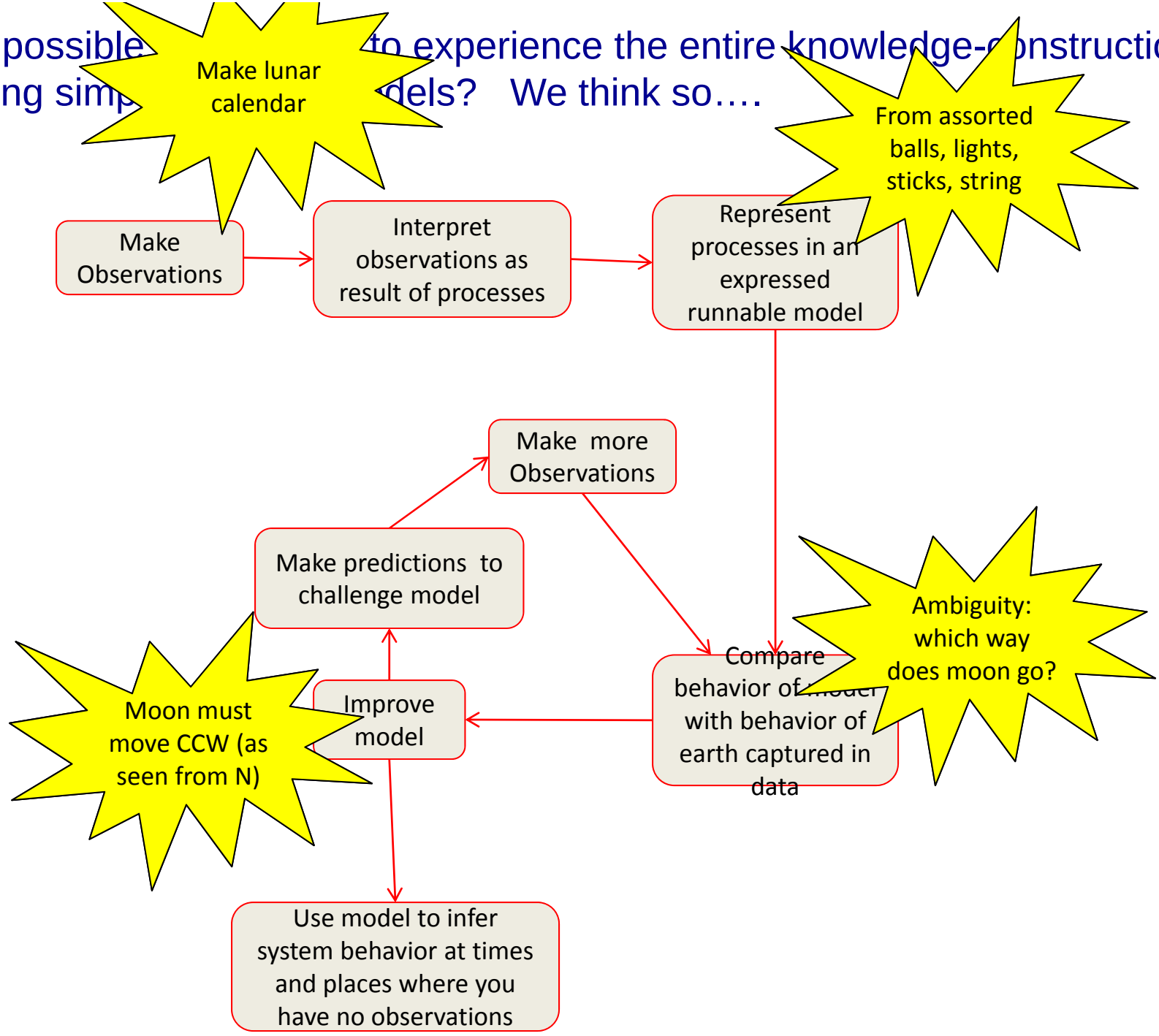
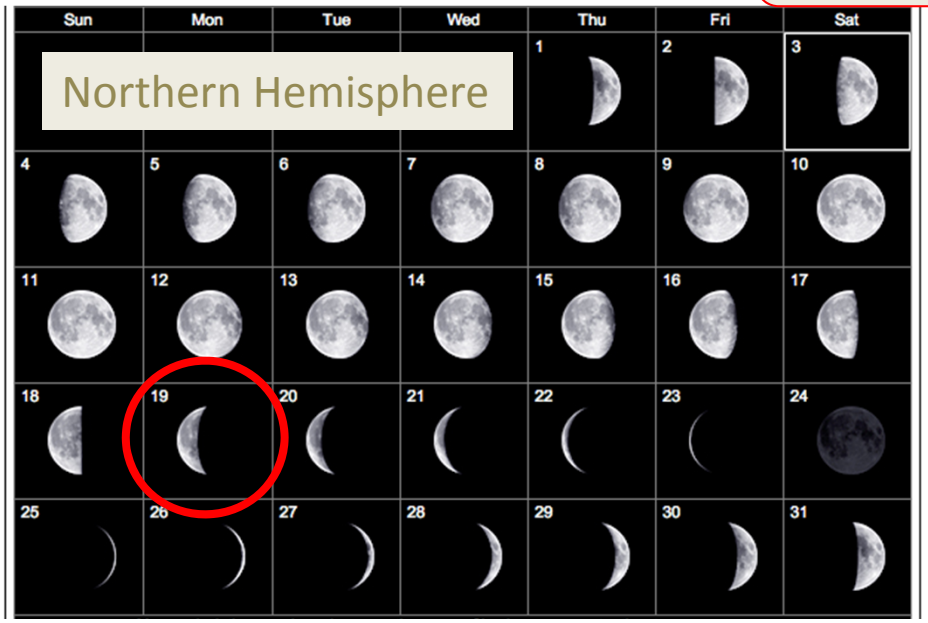
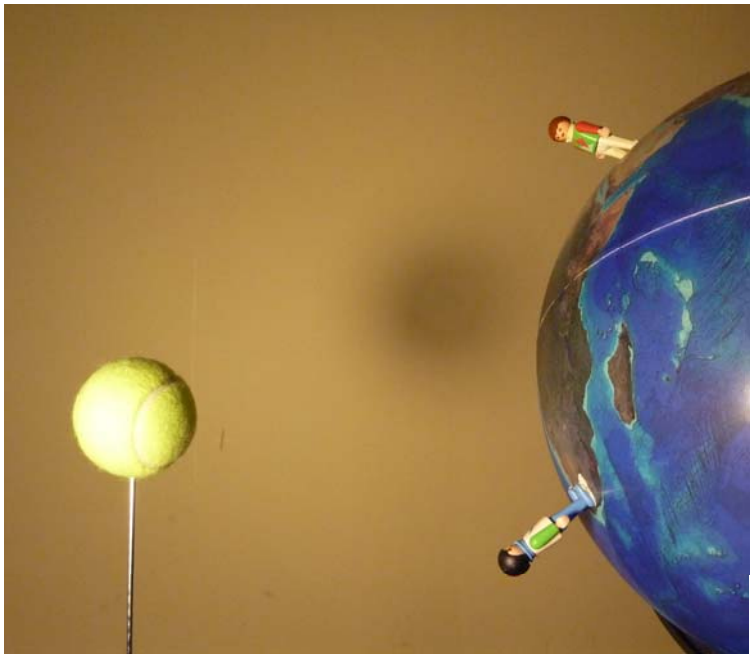
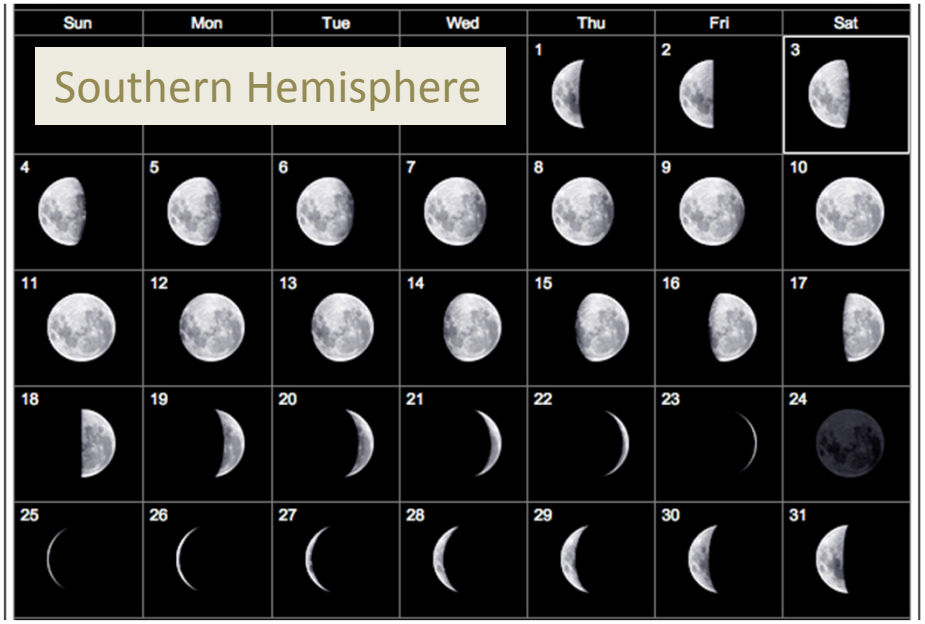


Make predictions to challenge model



SUN	MON	TUES	WED	THURS	FRI	SAT
Southern Hemisphere				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31





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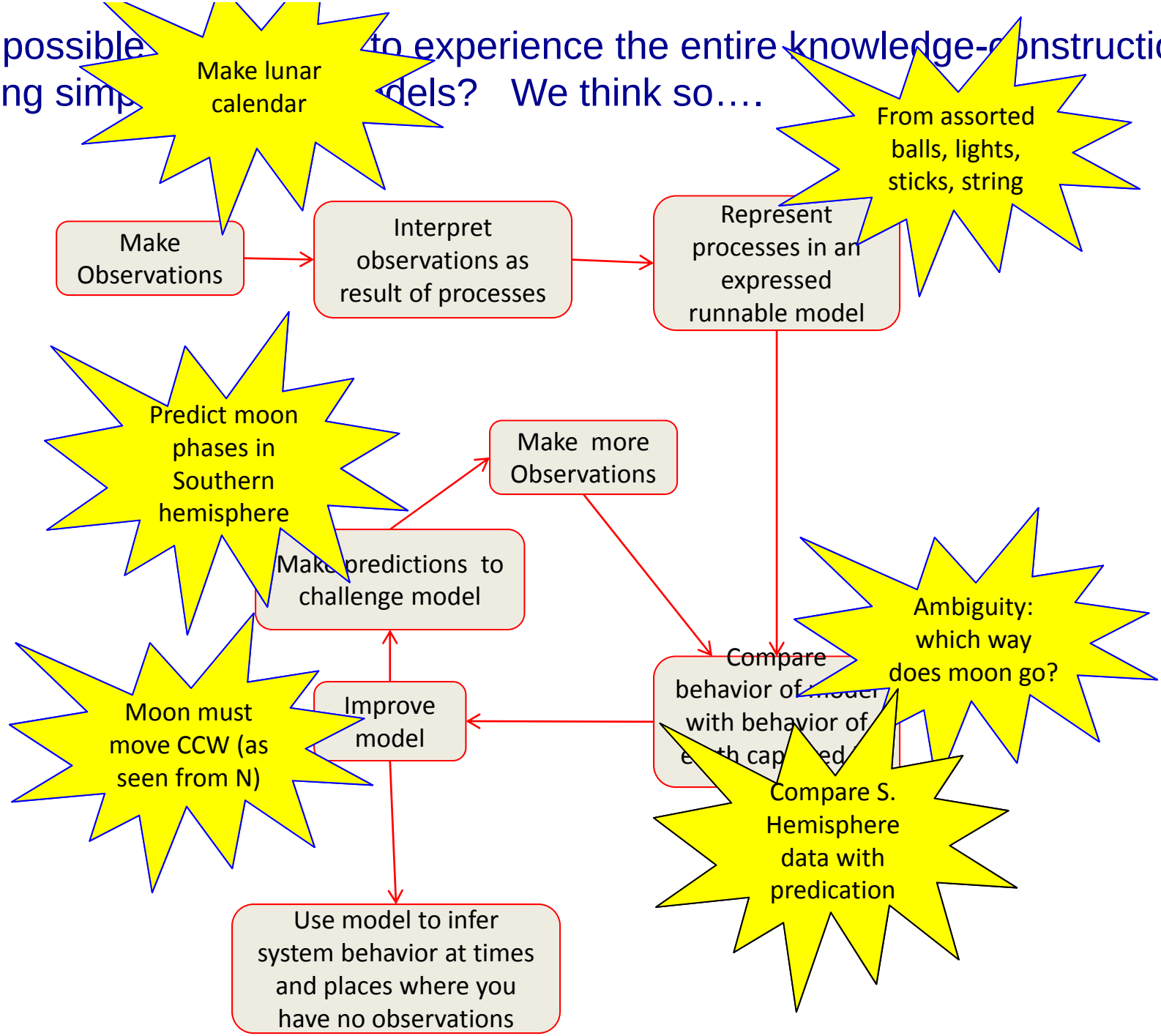

Take-home messages

- The way in which scientists use expressed runnable models to create new knowledge (as opposed to demonstrating existing knowledge) is obscure to most students, teachers, and the public.
- This is a problem, because expressed runnable models underlie many of the most important and controversial advances in modern science.
- It should be possible to build learning experiences that work through the scientists' model-using knowledge-creation process, even using simple, transparent physical models.

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Questions?

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