Scientific Modeling across the K-12 Continuum: Alignment Between Theoretical Foundations and Classroom Interventions

NSF DR K-12 PI Meeting

June 2, 2016

Modeling Practice: Opportunities

- Scientific Modeling Core Practice in Science
  - Modeling is a powerful way to embody and test ideas about the world – for learners and scientists
  - One of the eight NGSS practices
- What is modeling/model?
  - Developing, using, evaluating and revising models that predict and explain the world
  - Not every representation is a model; a model is only a model if used to predict and explain (Passmore, Gouvea & Giere, 2014)

Modeling Practice: Challenges

- Scientific Modeling is challenging for teachers and students to understand and enact meaningfully in classrooms
  - E.g., pasta cell models (if only to describe parts and not for predicting or explaining)
  - E.g., any student idea is a model
  - E.g., "Here are the things you should have in your model"
- The science education community has different ideas about what the practice means, and how to support and assess it.

Key Questions

1. <u>THEORY</u> → What are the core aspects of scientific modeling for K-12 settings? What should be foregrounded?
   - What are its fundamental elements?
   - How is modeling different or similar from other practices such as explanation, comp/math thinking, etc. ?

2. <u>DESIGNS/INTERVENTIONS</u> → How can teachers and students be supported to engage in modeling?

3. <u>ASSESSMENT</u> → How can modeling practice be assessed in a way that keeps the practice meaningful (e.g., doesn't lend itself to rote actions)?

Session Goals

1. Explore and highlight alignment between
   - conceptual perspectives on scientific modeling
   - project resources/models/tools
   - assessment

2. Discuss how these examples contribute to a broader, shared understanding of scientific modeling that can advance systemic efforts to communicate about and support scientific modeling in K-12 classrooms

Agenda for Session

- Session Introduction (5 minutes)
- Individual Project Overviews (3-5 min each)
- Posters (30 minutes)
- Synthesis Discussion (symposium participants and attendees - 25 minutes)
- Wrap-up (5 minutes)

Participants

- **Cory Forbes** – Modeling Hydrologic Systems in Elementary Science
- **Christina Schwarz** – Supporting Scientific Practices in Elementary and Middle School Classrooms
- **Joe Kracjik** - Developing and Testing a Model to Support Student Understanding of the Sub-Microscopic Interactions that Govern Biological and Chemical Processes
- **Dan Damelin** - Supporting Secondary Students in Building External Models
- **Nanette Marcum-Dietrich** - Teaching Environmental Sustainability: Model My Watershed
- **Cindy Passmore** - Modeling Scientific Practice in High School Biology: A Next Generation Instructional Resource

Synthesis Discussion

1. THEORY → What are the core aspects of scientific modeling for K-12 settings? What should be foregrounded?
   - What are its fundamental elements?
   - How is modeling different or similar from other practices such as explanation, comp/math thinking, etc ?
2. DESIGNS/INTERVENTIONS → How can teachers and students be supported to engage in modeling?
3. ASSESSMENT → How can modeling practice be assessed in a way that keeps the practice meaningful (e.g., doesn't lend itself to rote actions)?

Wrap-Up

- Modeling presents unique challenges for both teachers and students
- Importance of communicating a coherent message to educators
- Evidence of unique theoretical foundations, RMTs, and assessment efforts of modeling-focused DR K-12 projects
- Identification of key questions, issues, and/or tensions requiring further work

Next Steps

- Issues and next steps
  - Areas of consensus and disagreement
  - Assessment work – Insights? Guidelines?
- We look forward to moving the field forward

Modeling Hydrologic Systems in Elementary Science (MoHSES)

Cory Forbes[1], Tina Vo[1], Laura Zangori[2], & Christina Schwarz[3]

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[2]University of Missouri-Columbia

[3]Michigan State University

2016 NSF DR K-12 PI Meeting

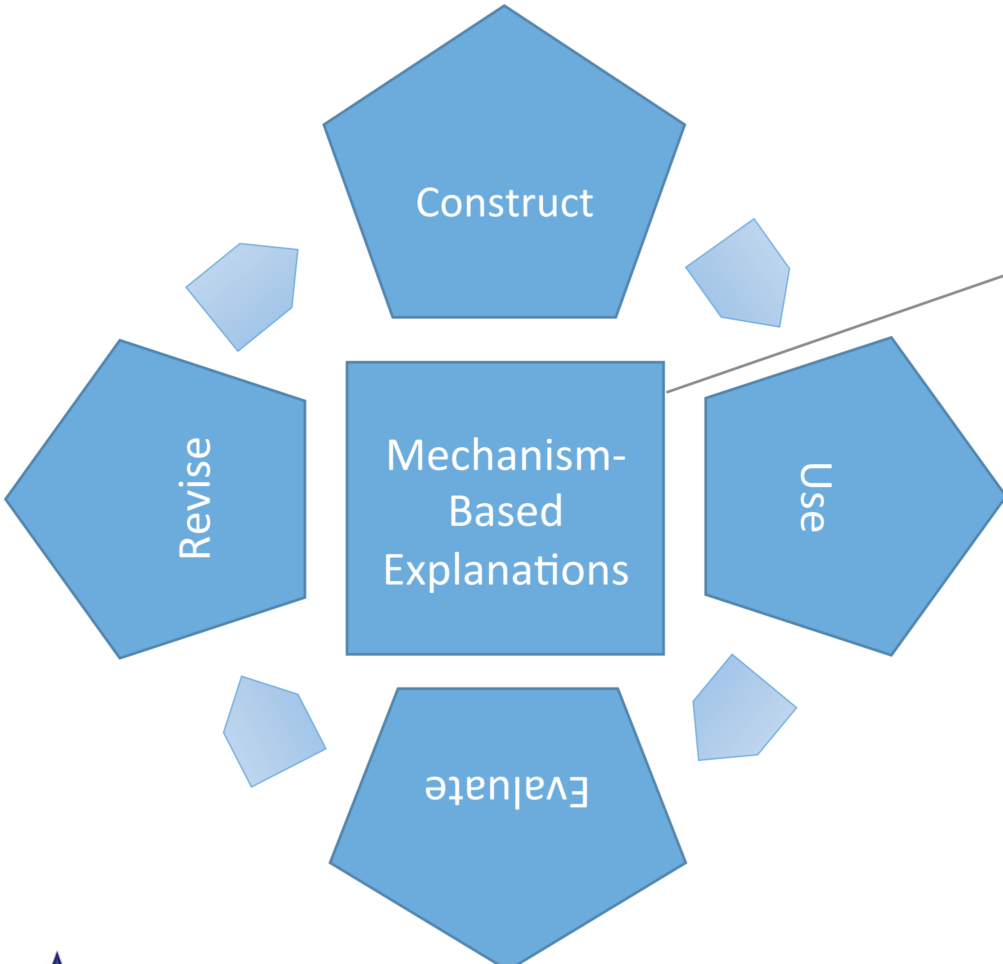
MoHSES Project

- Exploratory DR K-12 (2012-Present)
- 3rd-grade teachers and students
- Two goals
  - Promote 3rd-grade students' model-based reasoning about water through curriculum materials enhancement and instruction
  - Research to investigate elementary students' model-based reasoning about water
- Design-based research around FOSS *Water* module

Theoretical Foundations

- <u>Models</u> are "…abstracted, multi-modal representations of systems, not exact recreations, which are used within communities to illustrate, predict, and explain system-specific phenomena" (Forbes et. al., 2015)
- <u>Modeling</u> defined by 3 dimensions
  - Modeling practices (develop, use, evaluate, revise)
  - Epistemic considerations
  - Disciplinary concepts (i.e., science ideas)
- Learning performances (Krajcik, McNeill, & Reiser, 2007; Shin et al., 2010)

Theoretical Foundations



__Features of Mechanism-Based Explanation__

Components
Sequences
Mapping
Scientific Principle
Explanatory Process

(Berland et al., 2016; Braaten & Windschitl, 2011; Clement, 2000; Forbes et al., 2015; Gilbert, 2004; Schwarz et al., 2009; Scientific Practices Group, n.d.)

Learning Performance Framework

		Modeling Practices		
		Construct (CON)/*Revise* (REV)	*Use* (USE)	*Evaluate* (EVL)
Epistemic Commitments	*Generality/Abstraction* Goal = represent the system Process = Representation	Students construct and revise generalized models that account for specific cases related to the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students use generalized models to help them account for specific cases related to the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students evaluate generalized models for how well they help them account for specific cases related to the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.
	Evidence Goal = investigate the system/test a model Process = designing and conducting investigations	Students construct and revise models that help them investigate, interpret data, and are grounded in evidence about the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students use models to help them investigate, interpret data, and are grounded in evidence about the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students evaluate models for how well they help them investigate, interpret data, and are grounded in evidence about the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.
	Mechanism Goal = explain the system/ accounting for mechanism Process = Explanation	Students construct and revise models that help them explain the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students use models to help them explain the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students evaluate models for how well they help them explain the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.
	Audience Goal = convince/persuade others of system explanation Process = Argument	Students construct and revise models that help them communicate and persuade others of their explanations for the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students use models to help them communicate and persuade others of their explanations for the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.	Students evaluate models for how well they help them communicate and persuade others of their explanations for the forms and locations of water on Earth, the processes and conditions under which it changes forms, and the impact of water on the geosphere.

Curricular Intervention

- Redesigned ≈1/3 of the Water unit
- Pre/Post-unit supplemental lessons focused on modeling
- Systems modeling task
- Modifications to four unit investigations
  - Use model to predict, interpret observations, and explain
  - Develop 'sub-models' for each phenomena
  - Evaluate and revise model over the course of the unit

Assessment

- Integration of modeling practices, epistemic considerations, and disciplinary concepts
- Performance assessment
- Evidence-centered design (Mislevy & Haertel, 2006)
- Systems modeling task
  - Aligned with learning performances
  - Iterative and repeated across discrete phenomena
  - *Immediate* or *close* assessment (Ruiz-Primo, 2014)

For More Information

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MOHSES
Modeling Hydrologic Systems in Elementary Science

MICHIGAN STATE UNIVERSITY | College of Education
Department of Teacher Education

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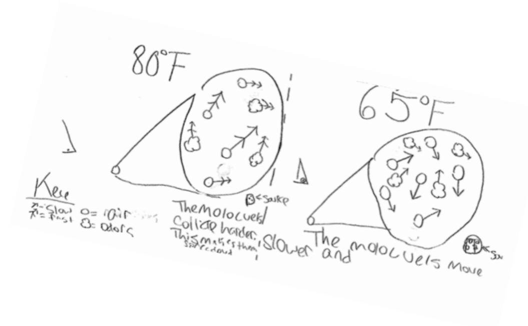

Supporting Scientific Practices in Elementary and Middle School Classrooms (Scientific Practices)

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DRK12 PI Meeting, June 2, 2016

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DRL 1020316

Scientific Practices Project Goals

To investigate how learners develop proficiency in argumentation, explanation, and modeling.

- How can we make scientific practices meaningful for learners in classrooms?
- How do students develop increasing sophistication in their understanding about and performance of scientific practices? (5th-8th grade)

Curriculum Context & Activities

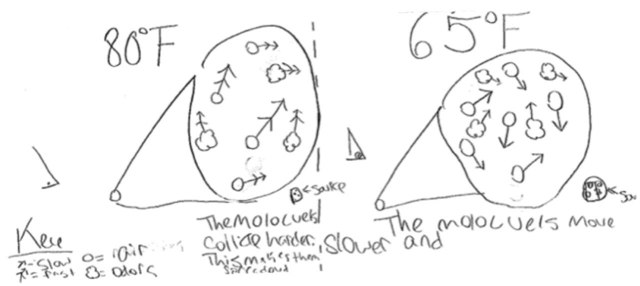
5th-8th comprehensive MoDeLS & IQWST project-based units. Engaged students in scientific practices and content to understand phenomena (e.g., particle nature of matter & smelling; light & seeing, ecosystems, etc.)

Theory: Core Aspects of Modeling

- Develop, test, revise explanatory models that answer how and why phenomena occur.

  Diagrammatic representations and written/oral text

  In social context to negotiate critical aspects e.g., model evaluation & consensus building

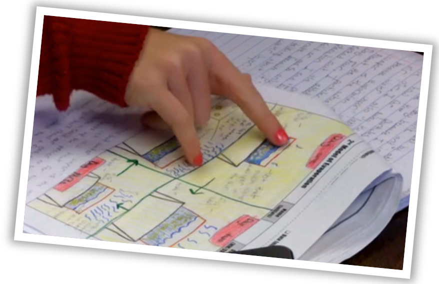


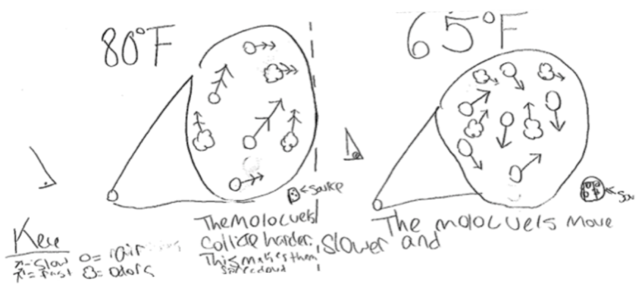
- *Models are abstracted and simplified representations of core aspects of theory*
  - *Scientific (theory) models vs. data and computational models*

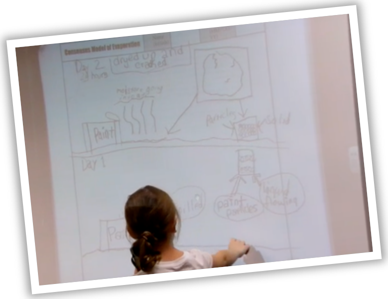
Theory: Core Aspects of Modeling

Epistemic Considerations:

- ***Nature**: What kind of answer or account are we working to provide?*
    - *Facts & definitions (right answer with details) -> mechanistic explanatory accounts*
- ***Generality**: How do the ideas we are working with relate to other ideas and phenomena?*
    - *Only specific phenomenon -> explain a range of phenomena and ideas are connected*
- ***Justification**: How do we justify our ideas?*
    - *We don't, it's just true -> interpreting and triangulating across multiple sources of information*
- ***Audience**: Who will use our ideas and how?*
    - *The teacher to evaluate -> we collaboratively construct and use our ideas with our audience*

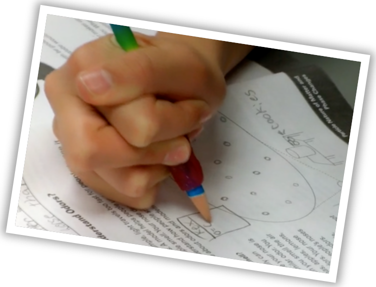






Support for Modeling

- Curriculum & PD
- Epistemic considerations and progressions towards making sense of and applying ideas to the world
- Discourse norms and negotiations



Assessments

- **Written assessments:** Pre/post model-based explanations, embedded with reflections
- **Student interviews**: Reflections on model-based explanations, applications, reflections and class processes
- **Classroom discourse**: Classroom talk and interactions

Analysis

- Epistemic Considerations - Nature, Generality, Justification, & Audience
- Nature of engagement (reflective talk; meaningful interactions)
- Teacher practice and impacts
- Effects of contexts (subject matter, focus of the unit, prior experiences over time, etc.)

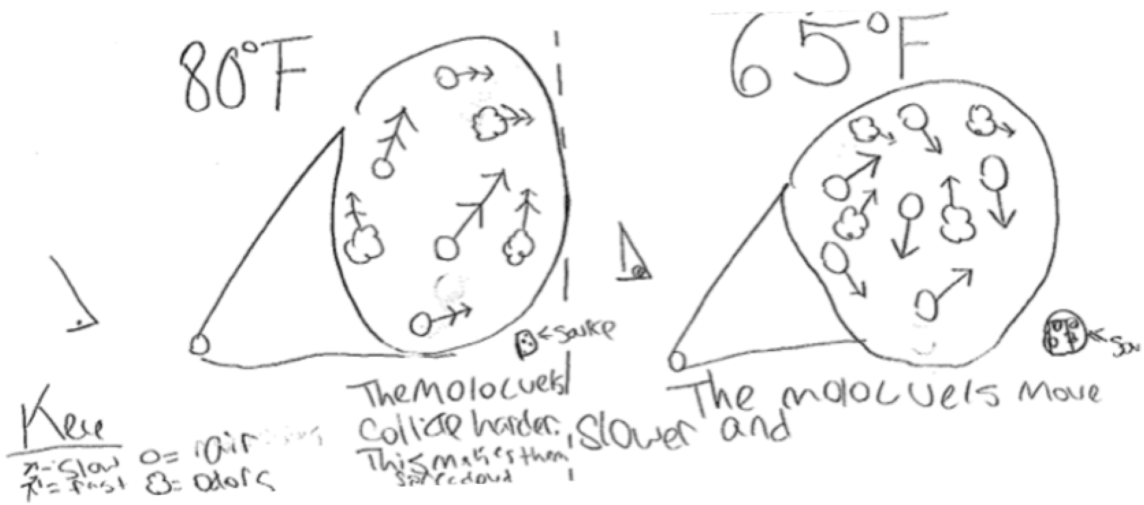
Written Assessment Item: 6th grade chemistry

Ms. Watson made freshly baked cookies for class for two days.

On the first day, her room is really hot (80°F) and the students smell cookies as they enter the room. On the second day, the room is cooler (65°F), and the students do not smell cookies until they sit in their seat.

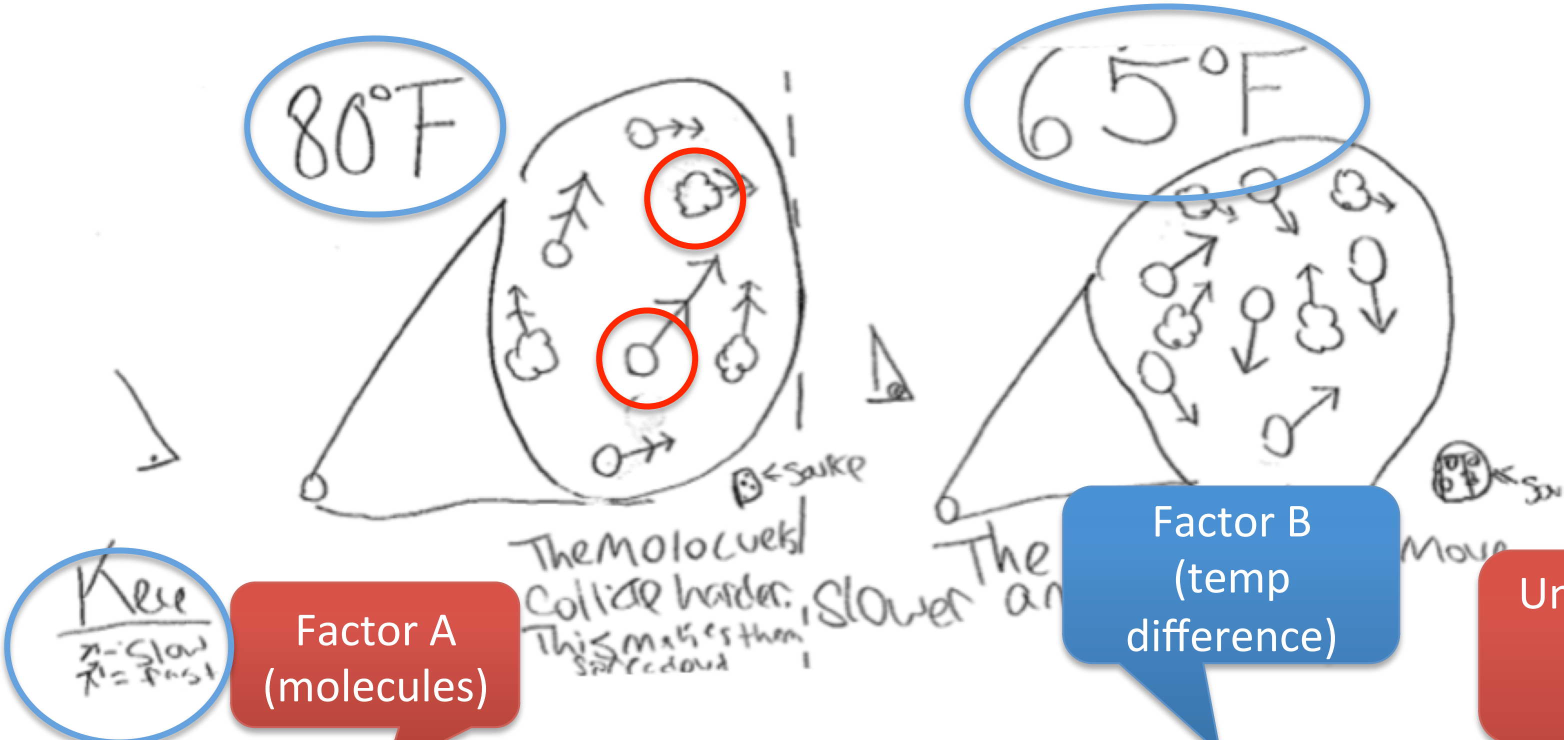
The students smelled the cookies faster when the room was warmer.

[Draw a model/ Construct a scientific explanation] that answers the question **"How and why did the room temperature affect how fast students were able to smell the freshly baked cookies?"**



Analysis of Written Assessment: Nature

What kind of answer should we provide?



Factor A (molecules)

Factor B (temp difference)

Unpacking A (move, collide)

"The molocules (sic) move faster when it is warmer because the molocules (sic) move faster and collide harder. The harder they collide the more they spread out letting them smell them faster."

Connecting to aggregate level

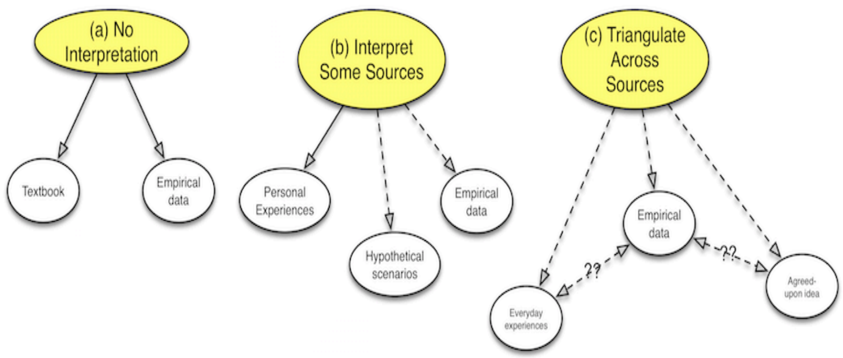
Unpacking B (faster, harder)

Analysis of Classroom Talk: Justification

How do we justify our ideas? (C. Krist, 2016)

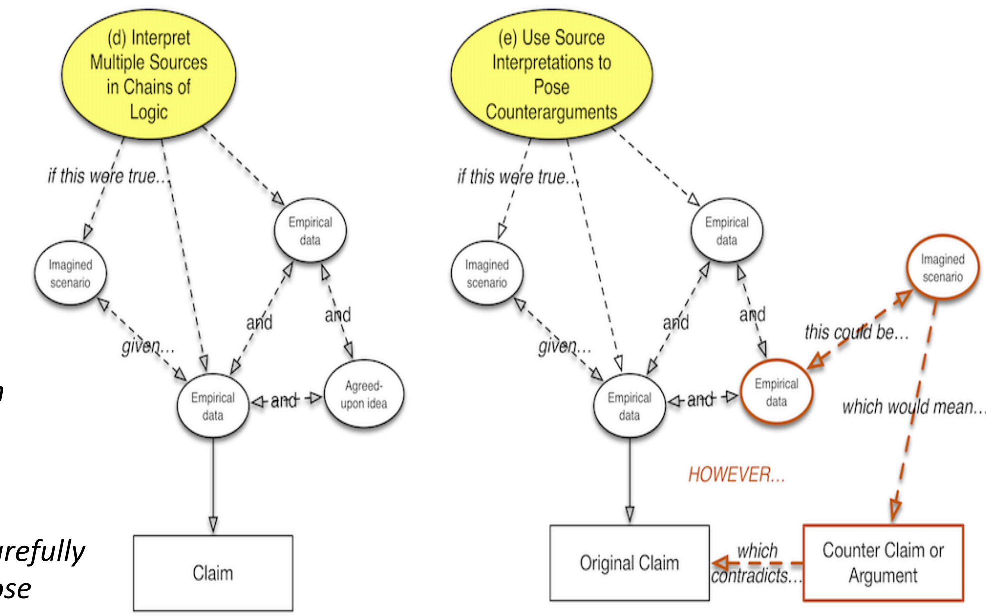
We don't; it's just true

Interpreting and triangulating across multiple sources of info



Identifying source information → *Interpreting* source information

6 Chemistry



Interpreting and triangulating sources → Carefully observing phenomena and triangulating those observations with principles

7 Physics

Interpreting multiple sources in complex chains of logic → Drawing on complex interpretations to pose counterarguments

8 Earth Science

Thank You!

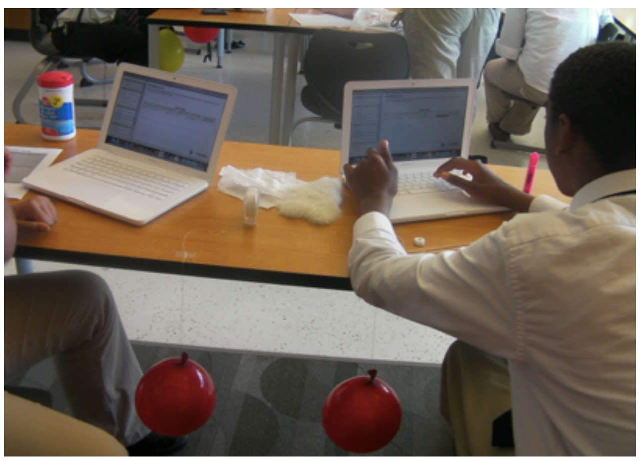
- Participating students and teachers

- Scientific Practices
- National Science Foundation

Supporting high school students in understanding electrical interactions at the microscopic level

Joseph Krajcik
CREATE for STEM
Michigan State University

Dan Damelin
Concord Consortium



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CREATE for STEM Institute

Purpose and Goals

New approaches of teaching interactions governed by electric forces

- Focusing on the electrical interactions among atoms and molecules will support students in understanding inter- and intra molecular bonding and avoid an over-dependence on memorized rules (Levy Nahum, 2007; Taber & Coll, 2002).

- Students need support to understand and apply scientific ideas and models that explain a broad range of phenomena related to electrical interactions.

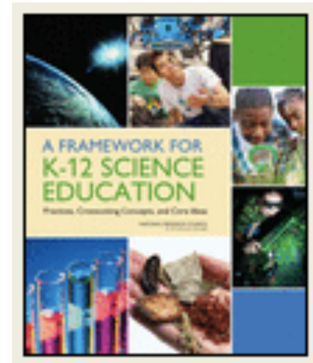
Promote students building explanations and models about key phenomena in various disciplines

Support students understanding of interactions governed by electric forces

Provide a foundation for a broad range of future STEM learning

Design principles

Link to the Framework and NGSS



- **Core idea**
  - PS1: Matter and its interactions
  - PS2: Motion and stability: Forces and interactions
  - PS3: **Energy**
- **Scientific practices**
  - Developing and using models
  - Analyzing and interpreting data
  - Constructing explanations
  - Obtaining, evaluating, and communicating information
- HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
- MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Design principles

Learning goal focused

- **Performance driven** learning goals for task development
  - **<u>Develop and use models of electrostatic interactions</u> to provide mechanistic causes for and make predictions about the behavior of one or more charged objects.** (Part 1)
    - *By the end of this part, students should have models of electrostatic interactions that includes: patterns in the way that charged objects interact, representations of electrostatic interactions within the electric fields to represent a qualitative concept of Coulomb's Law.*

Contextualization

- Phenomena and examples from everyday life
- Use of Driving Questions
  - **<u>Why do some things stick together while other things don't?</u>**

What is three 3-Dimensional Learning Learning?

- The working together of the three dimensions (core ideas, crosscutting concepts and scientific and engineering practices) to focus instruction and assessment on explain phenomena and design solutions to problems

- Three-dimensional learning shifts the focus of the science classroom to environments where students use core ideas, crosscutting concepts with scientific practices to **explore, examine, and use science ideas** to explain how and why phenomena occur and/or to design and explain solutions to problems.

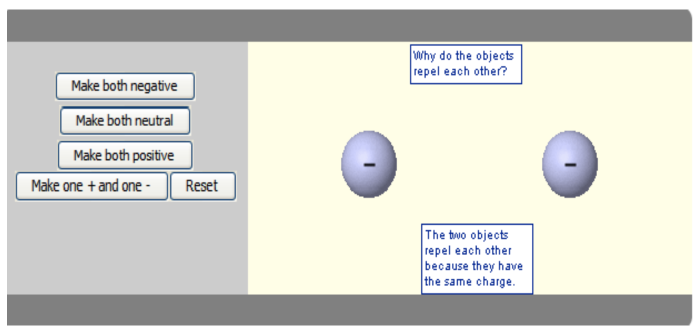
Design principles

Coherence

- Developed storyline to support intra and inter connection
- Revisiting previous activities and revise students' ideas

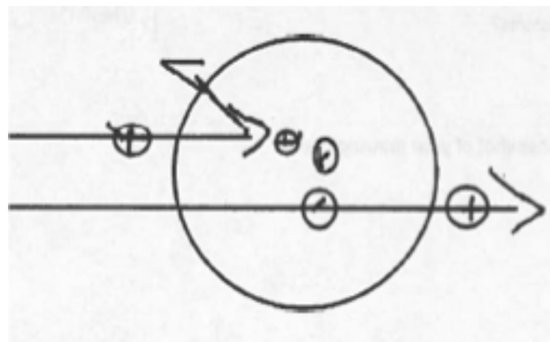
Multiple representation

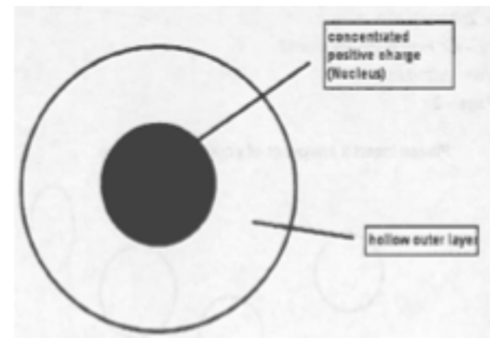
- Electronically delivered student material
- Combination of physical representation and computer representation
- Interpreting various representation and building own models by hand-on activity in which learners experience phenomena, using simulation and drawing tools



Developing and using scientific models

- A scientific model…
  - …represents the objects and the relationships among them to *explain and predict phenomena*
  - …provides a *causal mechanism* that accounts for the phenomenon
  - …could be depicted as a drawing, diagram, 3-D, or other *representation*
  - …but *only r*epresentations that explain and predict phenomena are scientific models





Models explain or predict ***how*** and ***why*** phenomena happen

Core Components Across Models

1. Identification and specification of the *components* or *variables* important for the system being analyzed
2. Description or representation of the *relationship* or interactions among the components or variables
3. The collection of relationships provides a description or causal account of the *phenomena*

Steps in developing a model

- Plan: What objects do you need in your model? What factors or variables are associated with each of the objects?
- Build: What relationships exists between each of the factors/variables?
- Use/Test: Do the set of relationships you developed, provide a causal account (i.e., does it explain the phenomena? does it account for all the evidence?)?
- Revise: Does your model still provide a causal account for any new evidence or other phenomena? How should it be changed? Based upon feedback and further evidence, how can the model be revised to explain the phenomena?
- Share: What feedback do others have of your revised model?

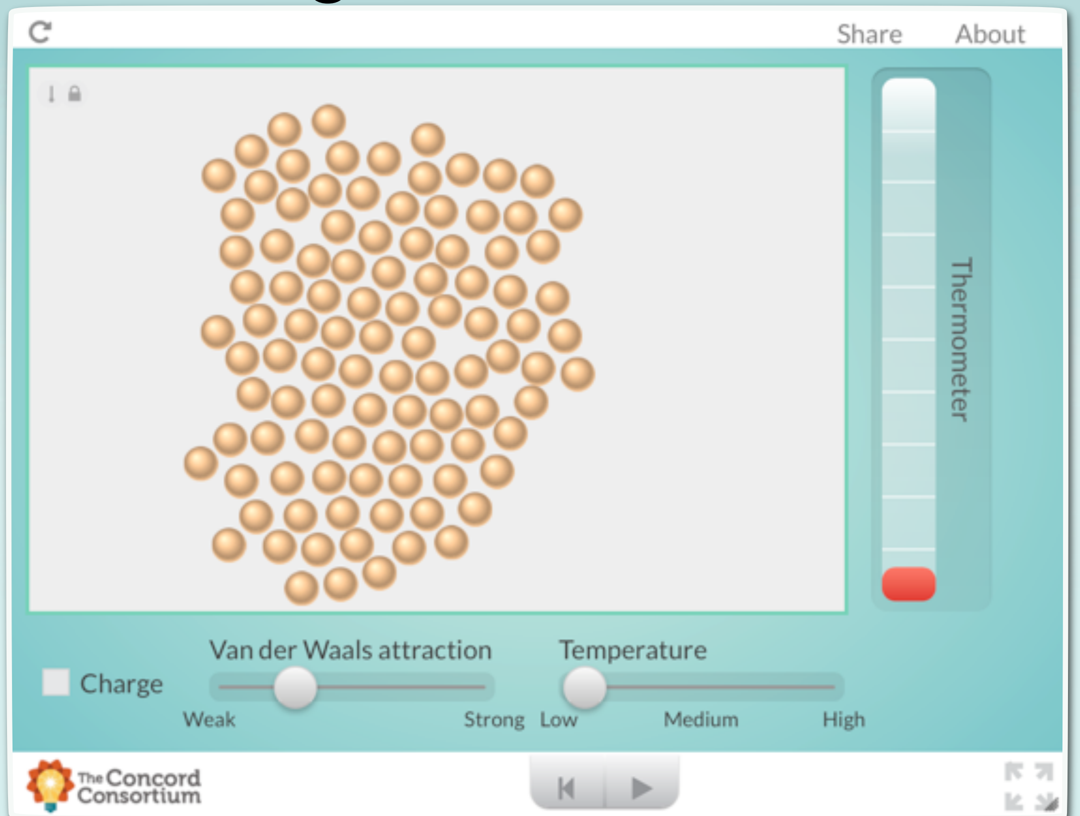
Using SageModeler to Facilitate Student Conceptual Development

Daniel Damelin, The Concord Consortium
Joe Krajcik, CREATE for STEM at MSU

The development of this program was funded by the National Science Foundation. Any opinions, findings, and conclusions or recommendations expressed in the materials associated with this program are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Engagement in Modeling Practice

- Use existing models



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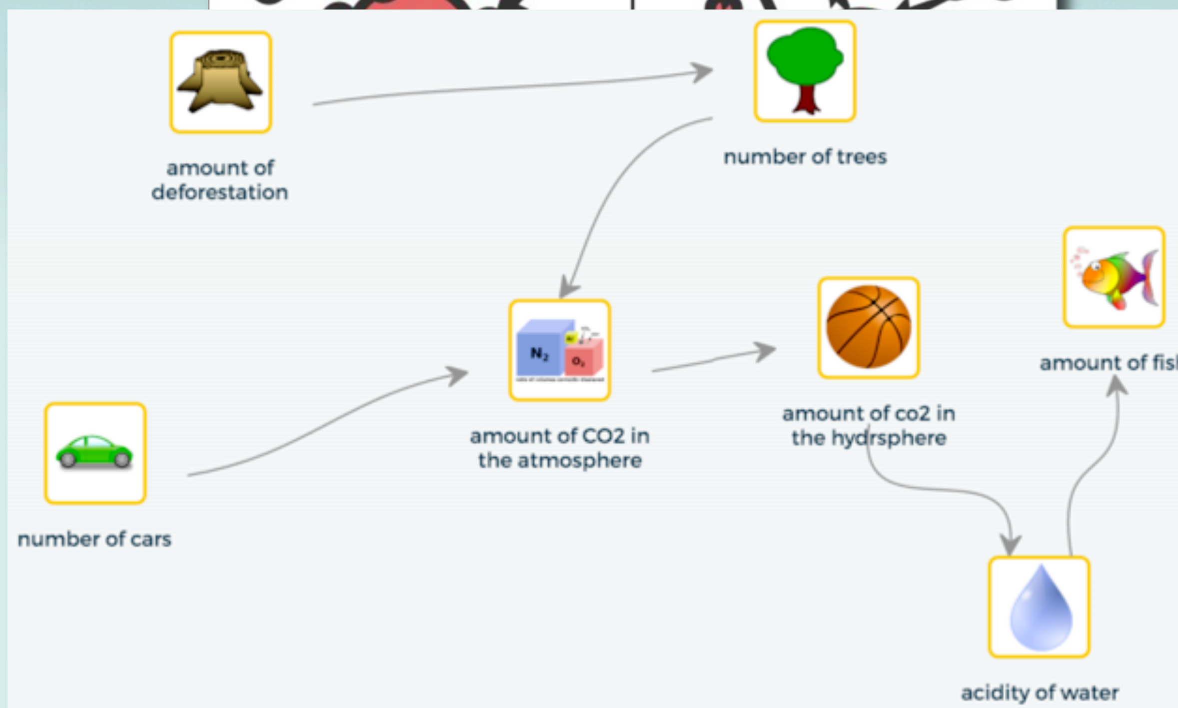
Engagement in Modeling Practice

- Use existing models

- Create models



Building Models Project Goals

- Create an intuitive tool that supports and scaffolds model building for middle and high school students.
- Investigate if and how students develop more sophisticated conceptual frameworks for understanding phenomena.

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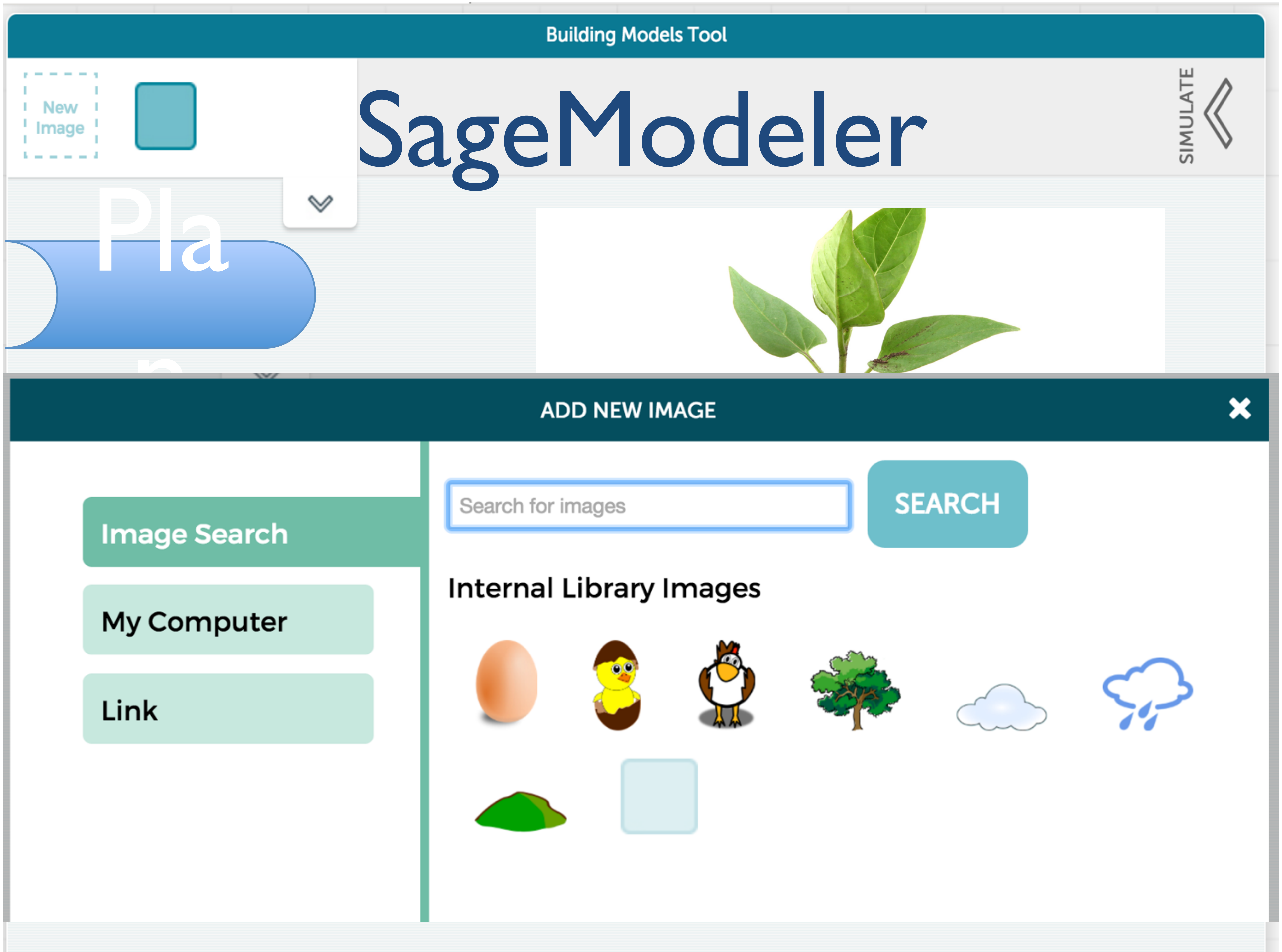
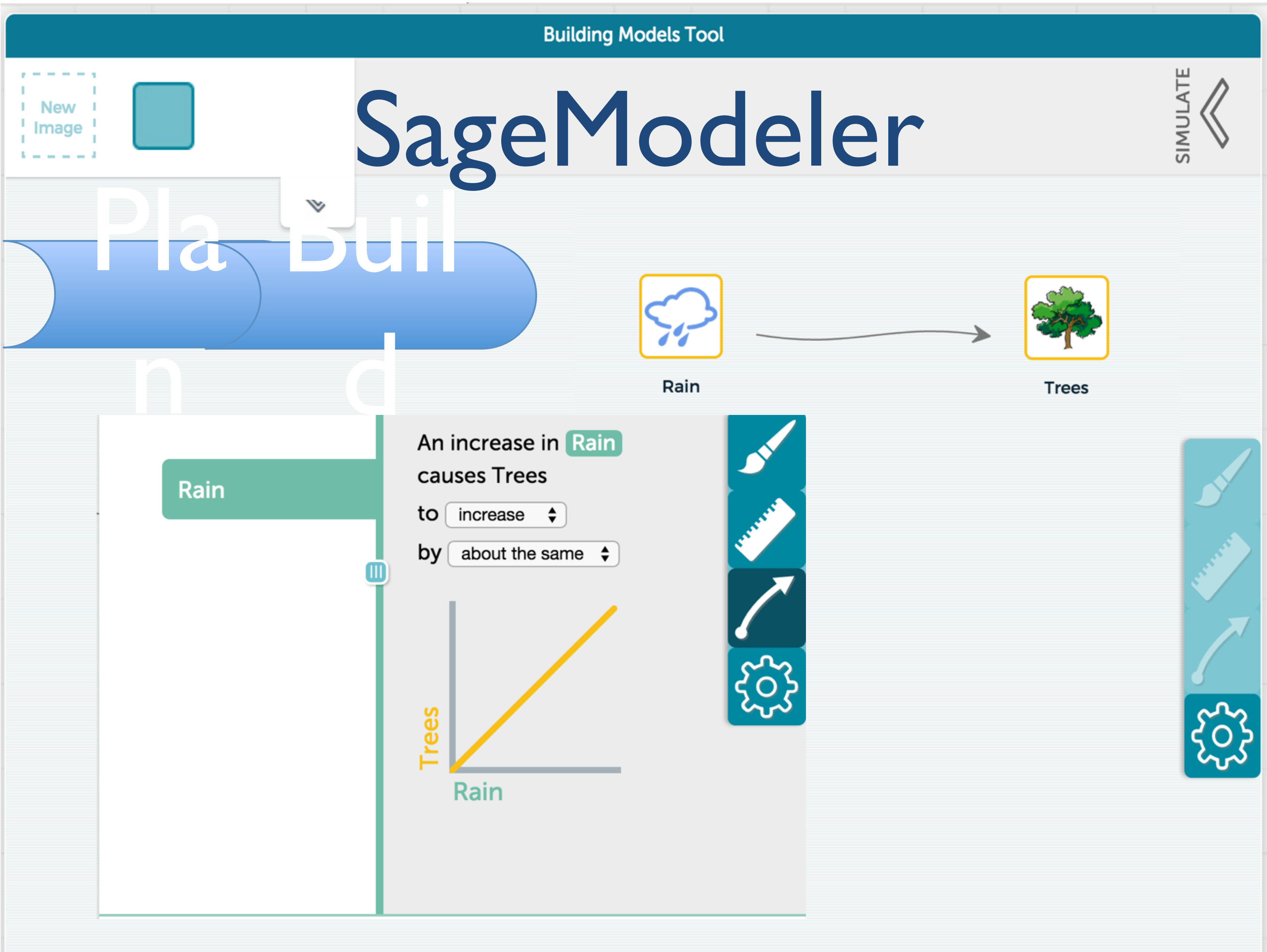
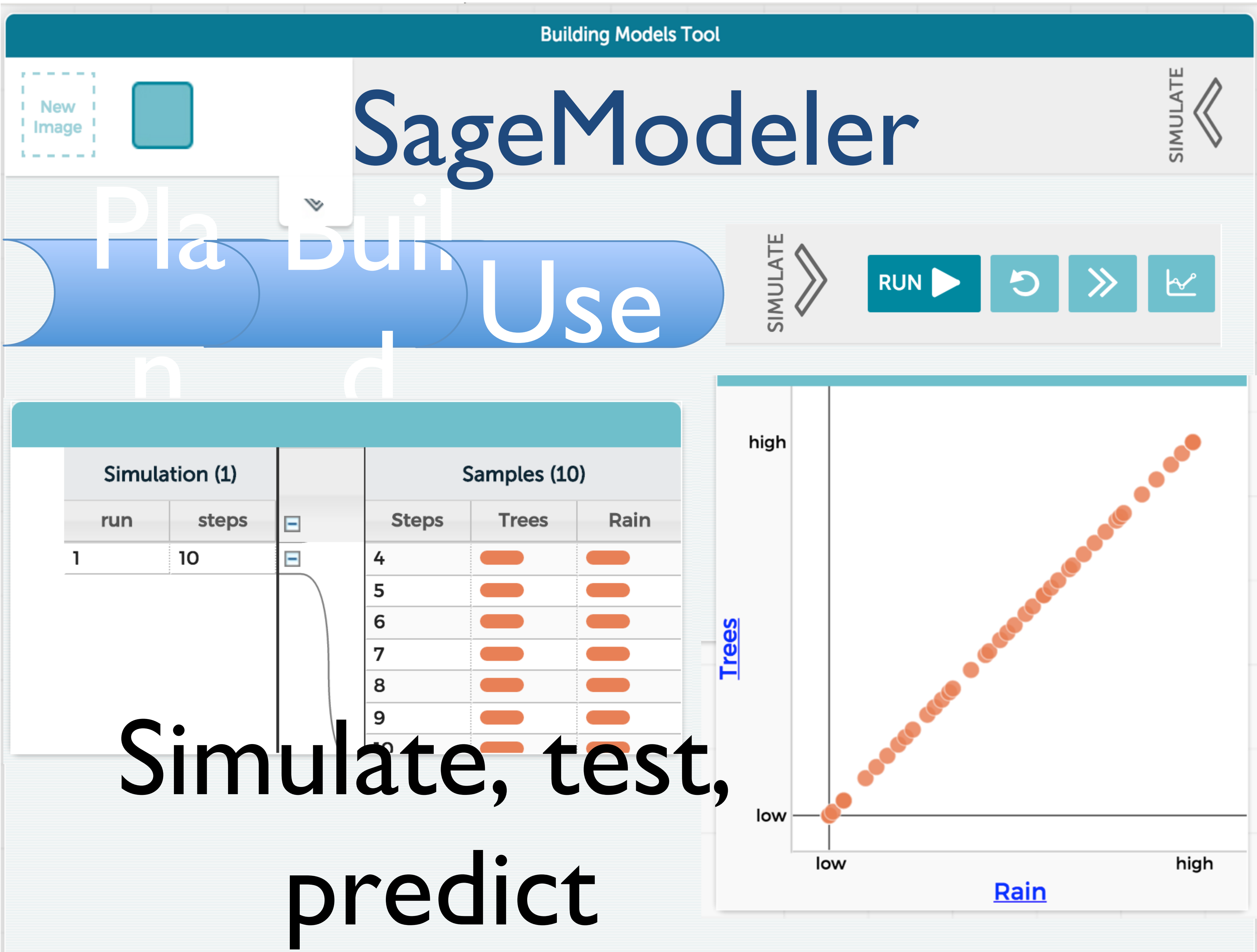

Building Models Tool
New Image
SageModeler
SIMULATE
ADD NEW IMAGE
Search for images
SEARCH
Image Search
My Computer
Link
Internal Library Images

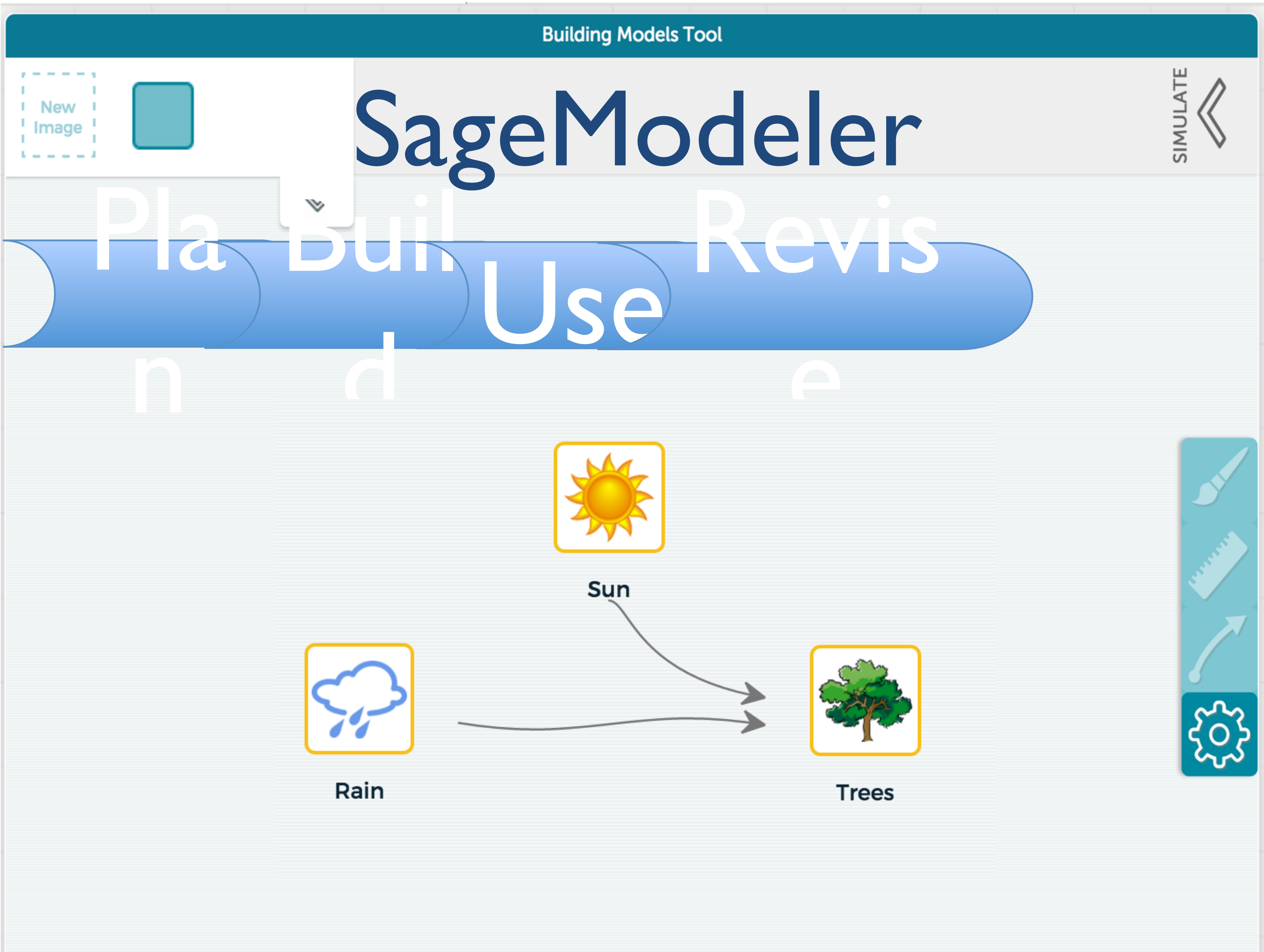


Building Models Tool
SageModeler
New Image
SIMULATE
Plan
Build
Rain
Trees
Rain
An increase in Rain causes Trees
to increase
by about the same
Trees
Rain

SageModeler



Simulate, test, predict


Building Models Tool
New Image
SageModeler
SIMULATE
Plan
Build
Use
Revise
Sun
Rain
Trees

Building Models Tool

New Image

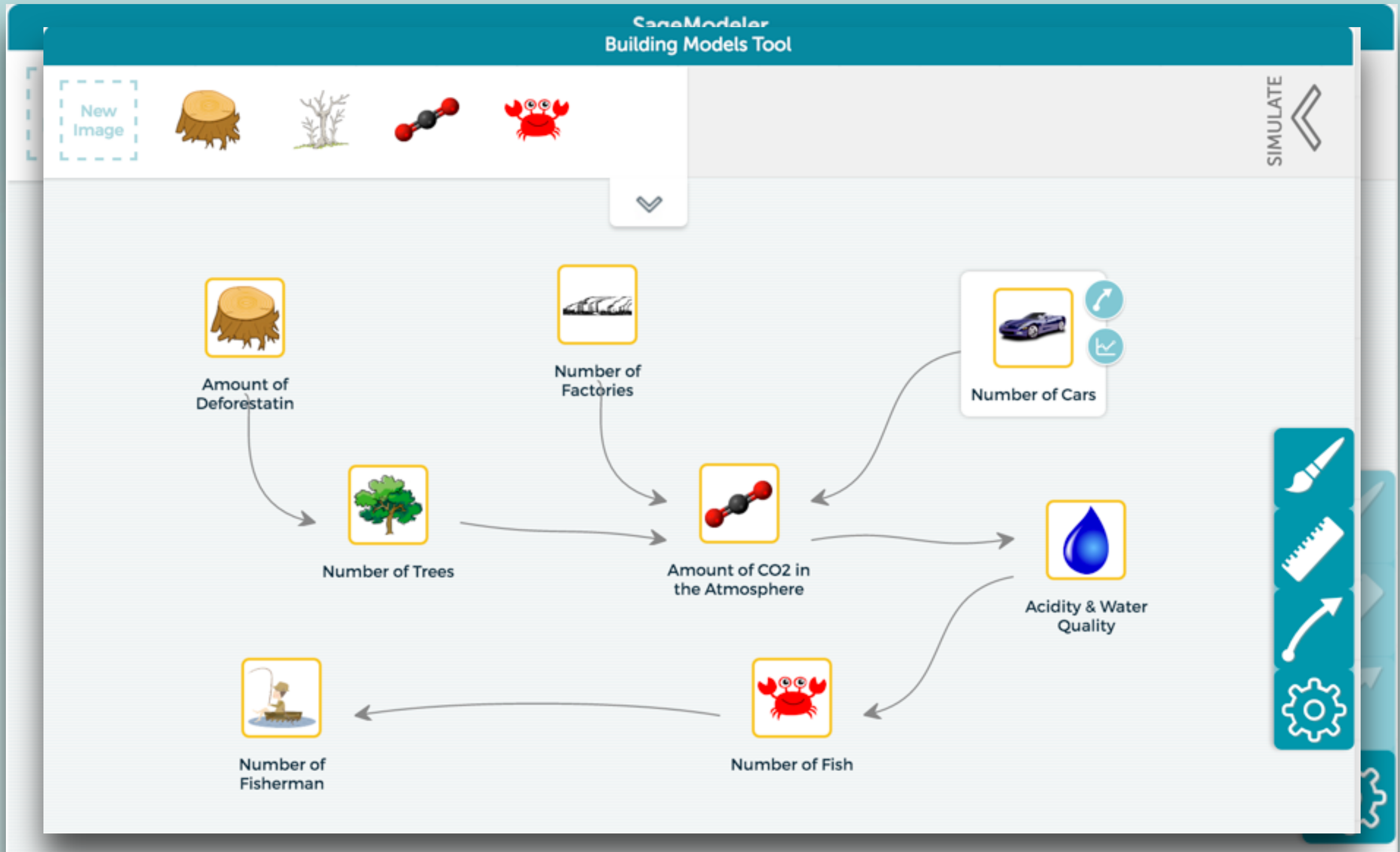
SIMULATE

SageModeler

Plan → Build → Use → Revise → Share


Why do Fishermen Need Forests?
Photo credit:

Examples of Student Models



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Teaching Environmental Sustainability: Model My Watershed

Melinda Daniels (PI), Anthony Aufdenkampe, Steve Kerlin
Stroud Water Research Center

Nanette Marcum-Dietrich (PI) Millersville University of Pennsylvania

Carolyn Staudt (PI) The Concord Consortium

Project Introduction

Full Design and Development project within the Implementation Research Strand

Develop an interdisciplinary, place-based, problem-based, hands-on set of resources, models and tools (RMTs) aligned to the Next Generation Science Standards (NGSS. Achieve, 2013) to research “critical incidents” motivating high-school students to further explore environmental sciences

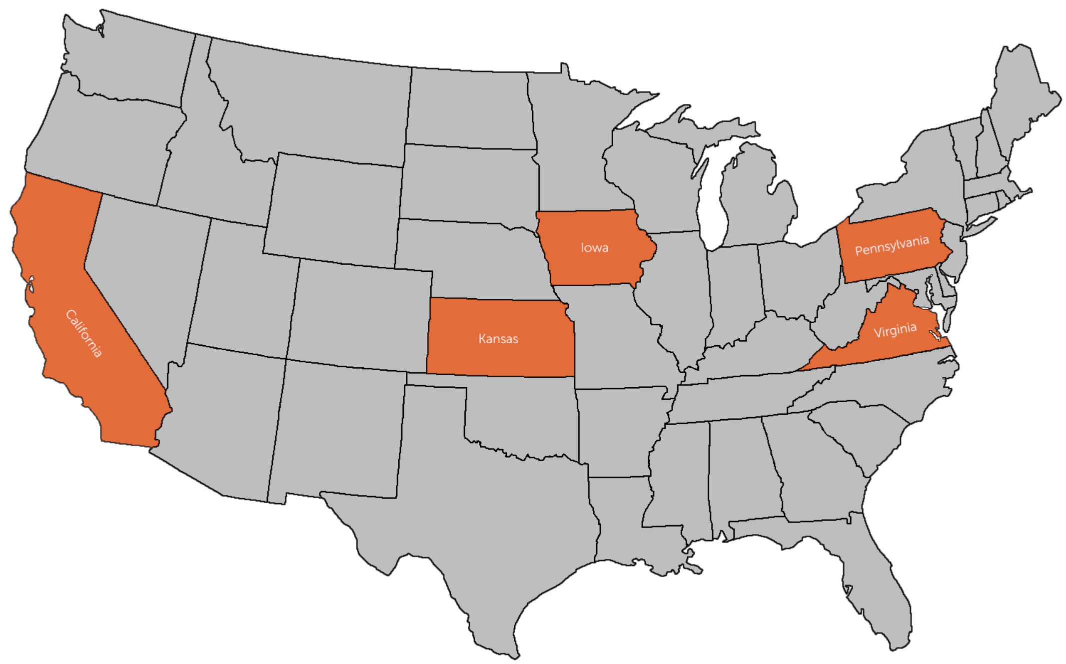
Watershed Hydrology and Water Quality

Millersville University

Project Introduction

Enable students across the continental US to learn and apply geospatial analysis and systems thinking to their local environmental issues

Research, place-based curriculum and teacher professional development in CA, IA, KS, PA, and VA.



Millersville University

Project Introduction

Systems thinking and systems modeling approaches to learning science address the fundamental aspects of nature and inform the way humans attempt to understand it

Information and knowledge are foundations of a functional democracy.

- Informed citizenry is key to protecting watersheds, but …
- Lack of scientific model literacy

Real data
in **real** places
using **real** models & tools

Millersville University The Concord Consortium azavea STROUD Water Research Center

Core Model

- **Model My Watershed®**
  - watershed modeling web-application
  - simulate and visualize storm-water runoff and water quality impacts
  - using professional-grade models and real land-use, soil and topographic data
- **Innovative Technology and Science Inquiry (ITSI)** portal
  - Customizable curriculum activities with direct model links

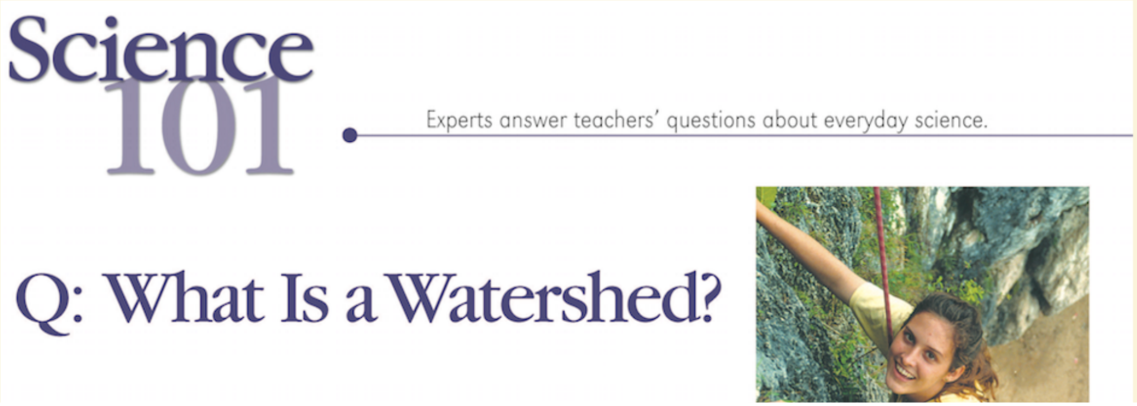
Activity: Part I: Exploring My Watershed

Introduction

How can you be a good watershed neighbor?

Do you live in a watershed? Every person who lives on the land lives in a watershed so unless you live on a boat floating in the middle of the ocean, the answer is yes! In addition to your home address, you also have a “watershed address" and you are part of a wider watershed community. Each member is a neighbor of the watershed plays a role in protecting the water and land in the local watershed.

So what is a *watershed neighbor*? A watershed neighbors is any house, business, school, landfill, industry, farm, ranch, forest, grassland, town, city, etc. that is present within your watershed boundary.



Science 101

Experts answer teachers' questions about everyday science.

Q: What Is a Watershed?

0.0 cm
Precipitation

0.0 cm
Evapotranspiration

0.0 cm
Runoff

0.0 cm
Infiltration

ET
R
I
Water Column

Precipitation for 24-hour storm event

Land Cover

- Water
- Developed, Open Space
- Developed-Low
- Developed-Med
- Developed-High
- Barren Land
- Forest
- Shrub/Scrub
- Grassland
- Pasture/Hay
- Crops
- Wetlands

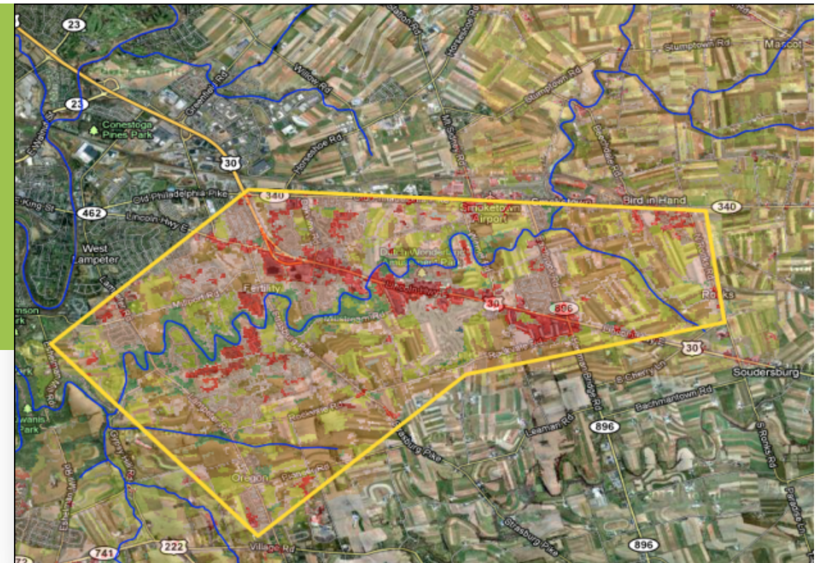
Hydrologic Soil Group

- A - High Infiltration
- B - Moderate Infiltration
- C - Slow Infiltration
- D - Very Slow Infiltration

Apply our Site Storm Model to your watershed. Info and help at

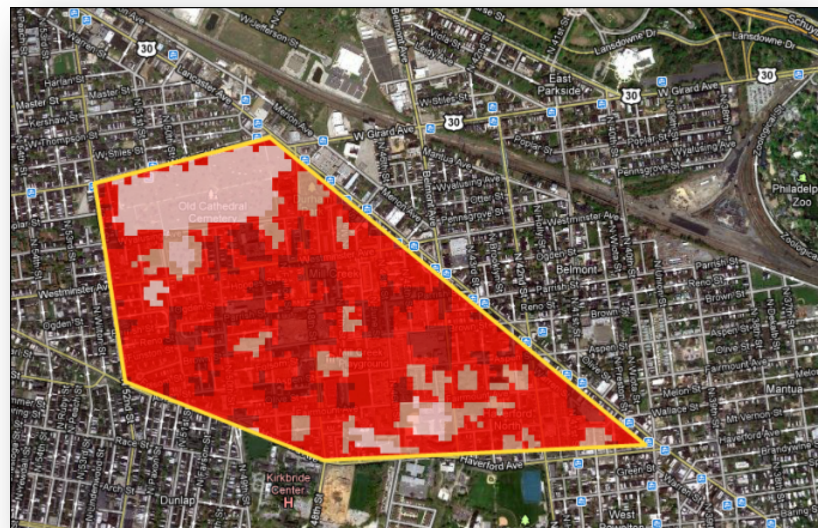
Millersville University · The Concord Consortium · azavea · Stroud Water Research Center

Model My Watershed



A professional-grade modeling toolkit designed for the public.

- High-performance geospatial analysis from a web-browser
- Advanced terrain and flowpath analysis
- Storm water runoff prediction
- Water quality impact prediction
- Interactive scenario development and prediction of future impacts
- Mapping of water impact hot-spots and protection opportunities

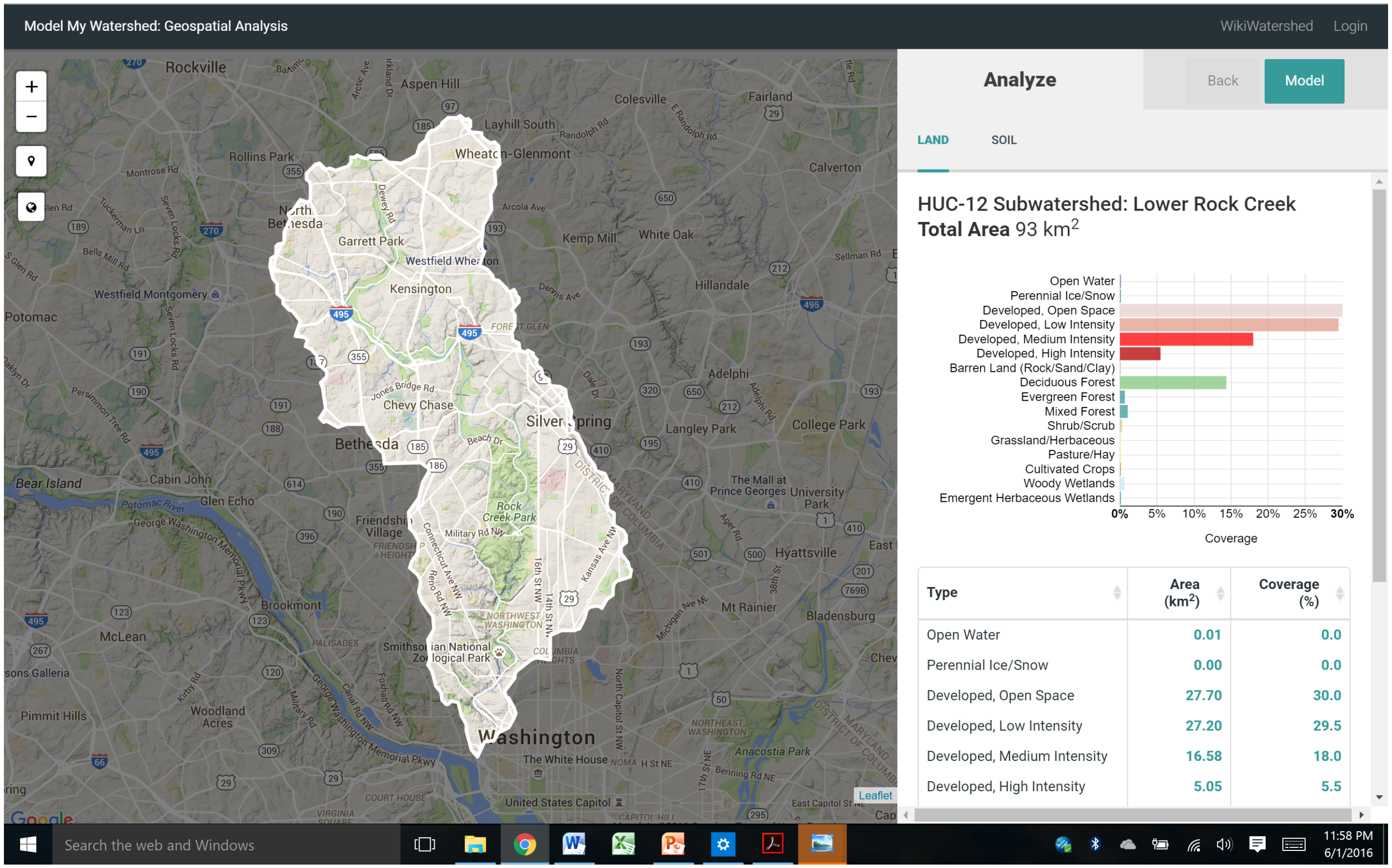


NSF Millersville University The Concord Consortium azavea STROUD WATER RESEARCH CENTER

Model My Watershed

http://wikiwatershed.org

Students interacting with real models and real data in their geographies



Millersville University

The Concord Consortium

azavea

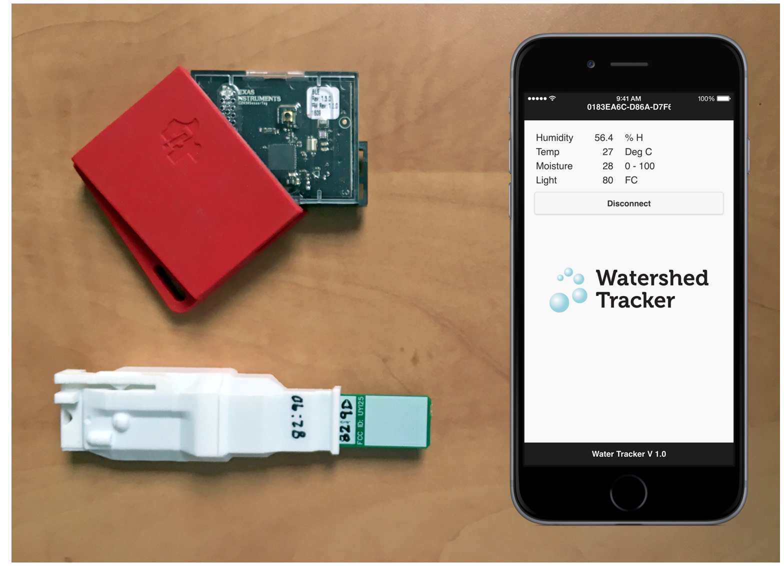
STROUD Water Research Center

Model My Watershed

Student engagement in water resource monitoring

- Interactive web portal to integrate physical, chemical, & biological water-quality data from many sources

- **https://itsi.portal.concord.org/itsi#high-school-environmental-science**



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Modeling Scientific Practice in High School Biology: A Next Generation Instructional Resource

AKA: Model-Based Educational Resource-Biology

MBER-BIO

CADRE PI Meeting

2016

The proposal

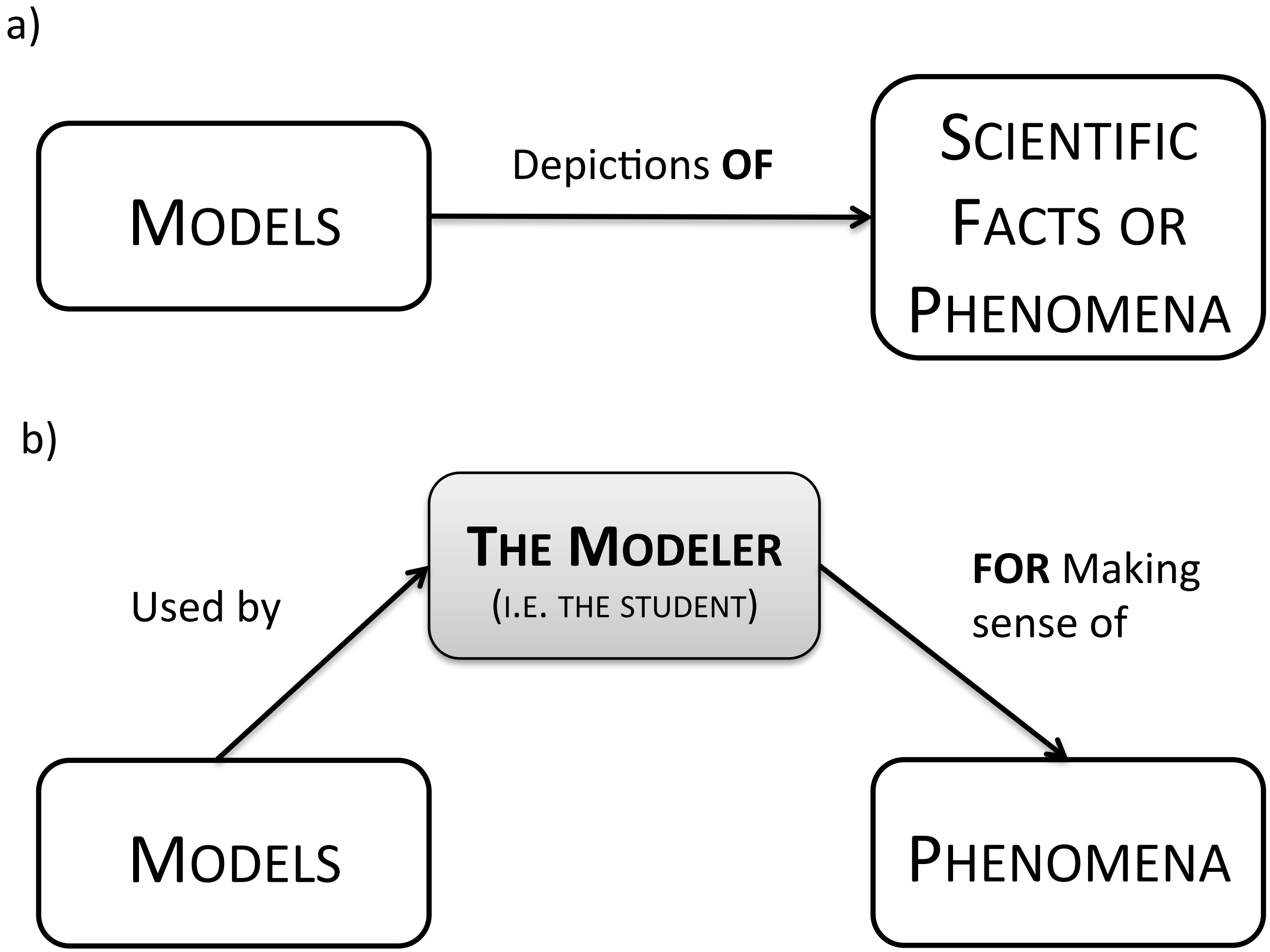
- Modify, sequence and augment existing curricular supports and resources to create a FULL YEAR sequence/resources for high school biology
- Align to NGSS (DCIs & Practices)
- Conduct Teacher and student learning research

The end goal: A yearlong NGSS-aligned curricular resource package for high school biology

Program year	Year One Oct 1, 2013- Sept 30, 2014	Year Two Oct 1, 2014- Sept 30, 2015	Year Three Oct 1, 2015- Sept 30, 2016

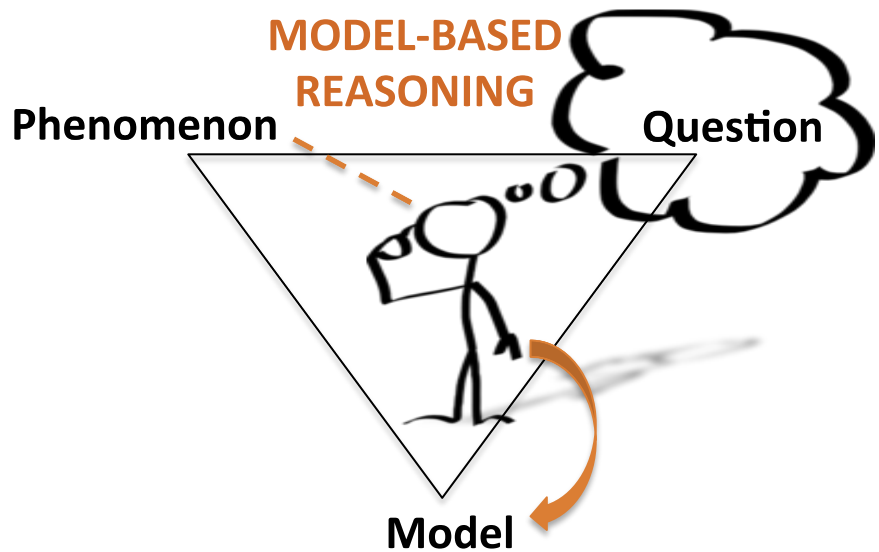
Phase	Design	Pilot & Refine	Implement & finalize	Disseminate

Assume a no cost extension year


a)
Models
Depictions OF
Scientific Facts or Phenomena
b)
The Modeler
(i.e. the student)
Used by
FOR Making sense of
Models
Phenomena

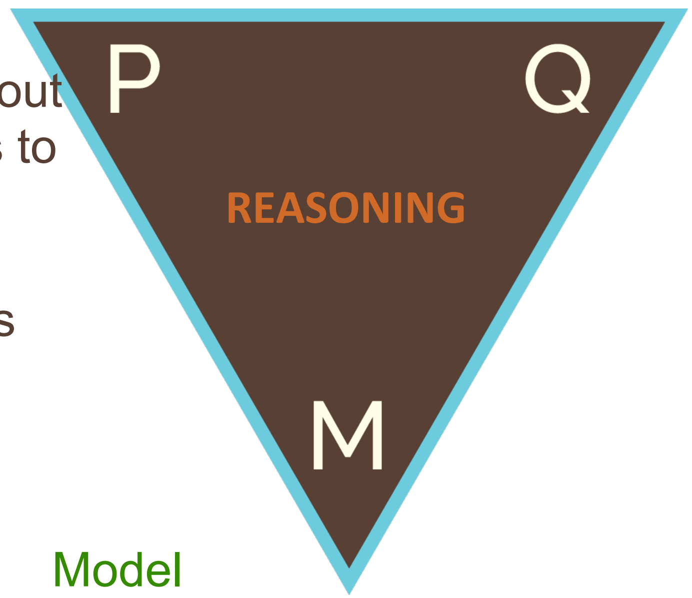
Models and Modelling

- Reasoning tools that are developed and used by cognitive agents for the purpose of generating and refining explanations that address questions about phenomena in the world (Gouvea and Passmore, *in review*)



- In the classroom, models are socially constructed to facilitate sense-making about the phenomenon under study.

Reasoning Triangles as Design Tools



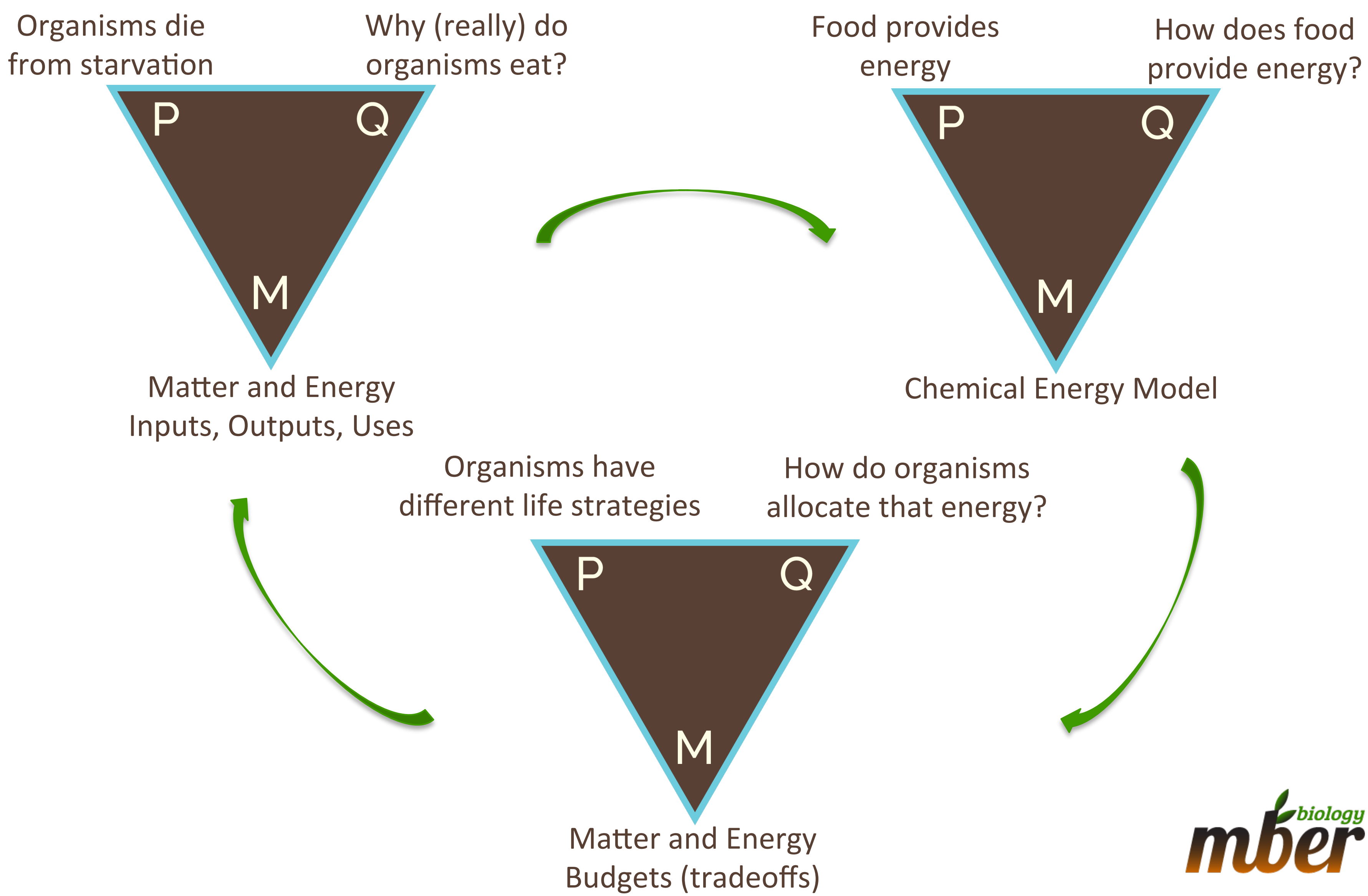
Phenomenon
- What are the puzzling patterns in the world about which we want students to reason?
- How to engage students with that phenomenon?

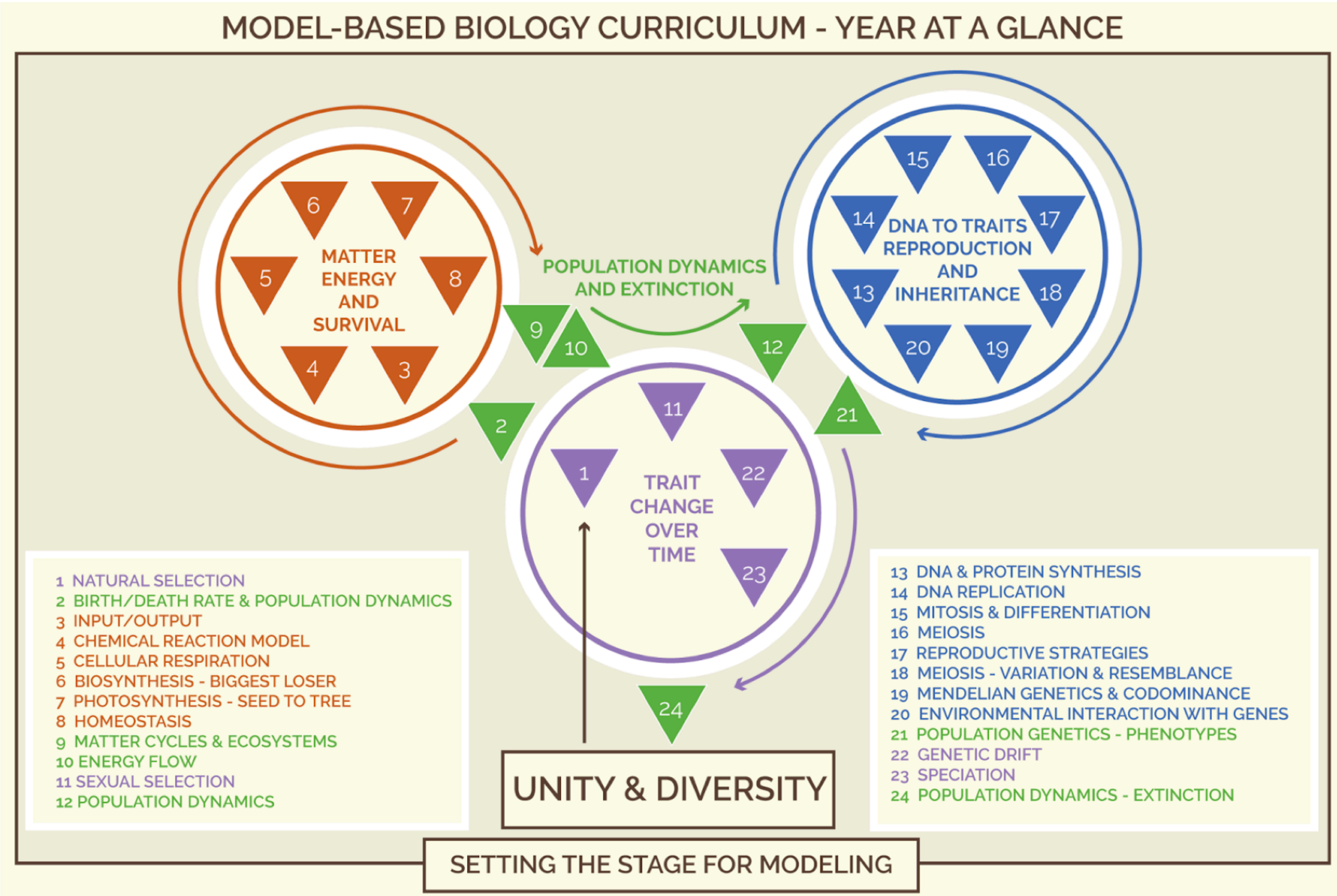
Question
- How to focus the classroom activities/ lessons?
- What is the explanation we want students to be able to generate?

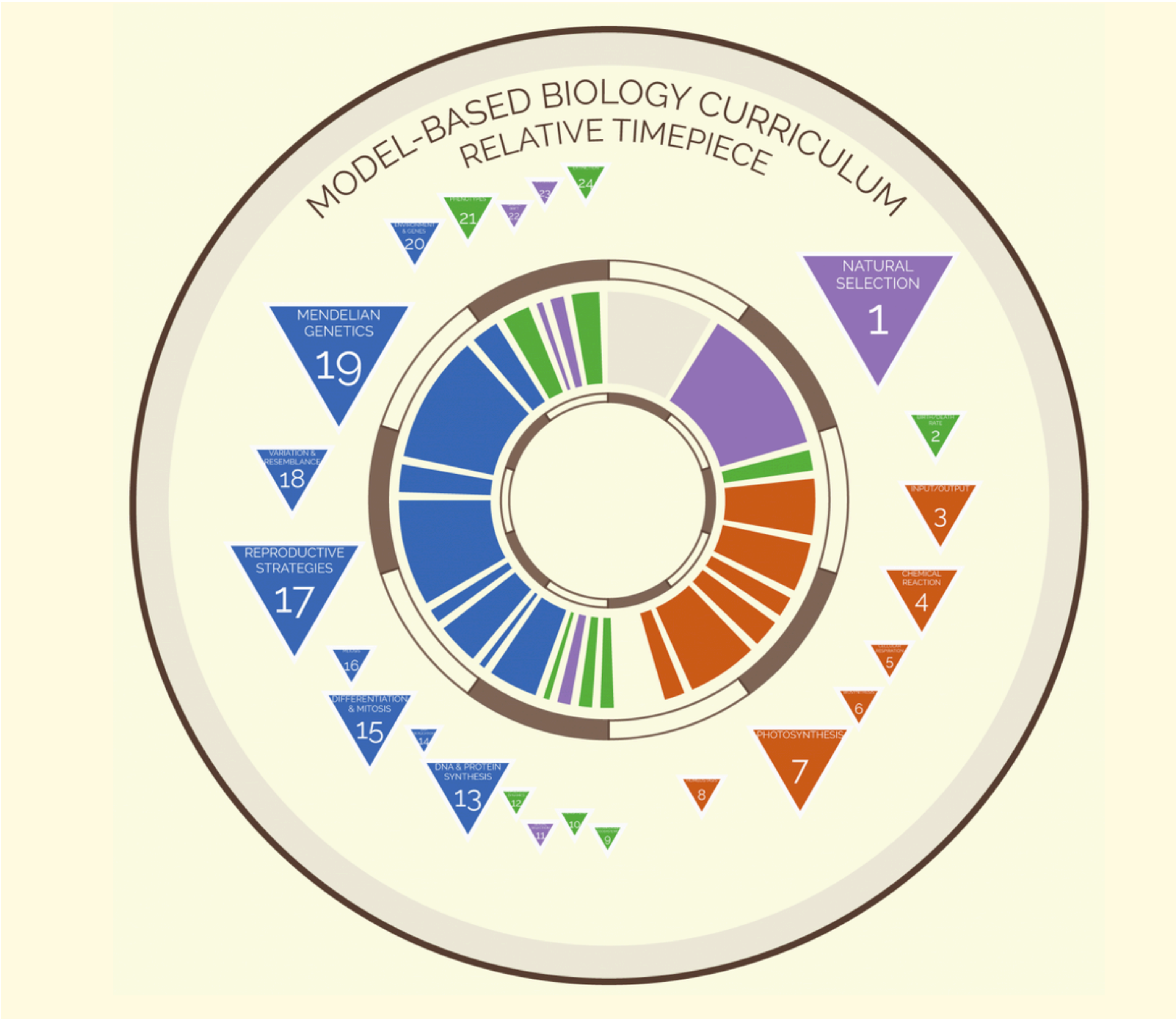
Model
- How to make the relevant ideas clear and public for students?
- How to represent those ideas?

mber biology

Designing for connections between reasoning triangles




MODEL-BASED BIOLOGY CURRICULUM - YEAR AT A GLANCE
MATTER ENERGY AND SURVIVAL
6
7
5
8
4
3
POPULATION DYNAMICS AND EXTINCTION
9
10
2
12
21
DNA TO TRAITS REPRODUCTION AND INHERITANCE
15
16
14
17
13
18
20
19
TRAIT CHANGE OVER TIME
11
1
22
23
24
UNITY & DIVERSITY
SETTING THE STAGE FOR MODELING
1 NATURAL SELECTION
2 BIRTH/DEATH RATE & POPULATION DYNAMICS
3 INPUT/OUTPUT
4 CHEMICAL REACTION MODEL
5 CELLULAR RESPIRATION
6 BIOSYNTHESIS - BIGGEST LOSER
7 PHOTOSYNTHESIS - SEED TO TREE
8 HOMEOSTASIS
9 MATTER CYCLES & ECOSYSTEMS
10 ENERGY FLOW
11 SEXUAL SELECTION
12 POPULATION DYNAMICS
13 DNA & PROTEIN SYNTHESIS
14 DNA REPLICATION
15 MITOSIS & DIFFERENTIATION
16 MEIOSIS
17 REPRODUCTIVE STRATEGIES
18 MEIOSIS - VARIATION & RESEMBLANCE
19 MENDELIAN GENETICS & CODOMINANCE
20 ENVIRONMENTAL INTERACTION WITH GENES
21 POPULATION GENETICS - PHENOTYPES
22 GENETIC DRIFT
23 SPECIATION
24 POPULATION DYNAMICS - EXTINCTION



MODEL-BASED BIOLOGY CURRICULUM
RELATIVE TIMEPIECE
NATURAL SELECTION
1
2
INPUT/OUTPUT
3
CHEMICAL REACTION
4
5
6
PHOTOSYNTHESIS
7
8
9
10
11
12
DNA & PROTEIN SYNTHESIS
13
14
DIFFERENTIATION & MITOSIS
15
16
REPRODUCTIVE STRATEGIES
17
VARIATION & RESEMBLANCE
18
MENDELIAN GENETICS
19
ENVIRONMENT & GENES
20
21
22
23
24

OVERVIEW

Transition from Previous Working Model: Our Natural Selection model explains how the distribution of traits in populations of organisms changes over time. We now turn our attention to factors that affect population sizes over time. Students have already discussed the "struggle to survive". Here they track that struggle by examining fluctuations in natural populations.

As they explore the details of natural biological systems, students begin to construct a population model that depends on the fundamental processes of birth and death and make explicit their connection to rates of population growth and decline.

Transition to Next Working Model: As resource limitation in the form of starvation is identified as a primary cause of death, it leads us to ask the question "Why must organisms have food to survive?"

MODEL IDEAS

- Population change over time (in the absence of emigration and immigration) depends upon death and birth rates in the population.
  - *If death rate exceeds birth rate the population declines.*
  - *If birth rate exceeds death rate the population increases.*
- Some factors that affect death rate include: availability of resources, predation, disease, and environmental conditions.
- Birth rate can be affected by the same factors, but it can also be influenced by other factors, such as mate availability.

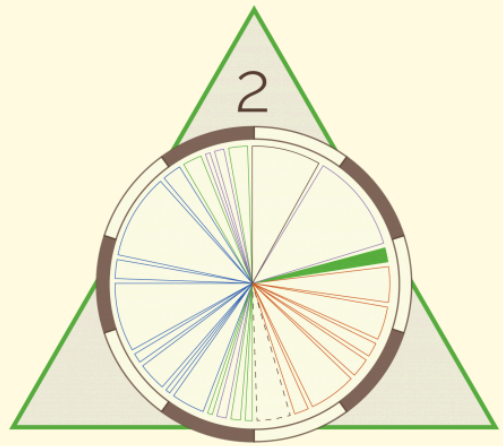
PHENOMENON

Population size changes over time.

Phenomenon Specific Case:

The **Isle Royale** dataset provides 50 years of moose and wolf counts from a protected island park in Lake Superior. The data show that populations change in surprising ways and are coupled with extensive natural history data from the system.

Changes in population size can be examined in a number of species in a number of systems. However, the intended reasoning around any chosen phenomenon should be to have students connect factors that drive population number back to the core model processes of birth and death. Any dataset to be used in this endeavor must therefore meet two criteria: (1) it must track population numbers or at least trends across some defined time interval, and (2) there must be some information about the likely drivers and their connection to birth and death rates. These data allow students to connect the phenomenon to the explanatory model.



Birth/Death Rate

QUESTION

How/Why do population sizes change over time?

Specific Question:

What factors might affect the moose and wolf population sizes over the course of the 50 year data set? Can we generalize these factors to other populations?

SUGGESTED LESSON SEQUENCE

There are two different possible sequences for the Isle Royale dataset that can be used to engage students in building a model of population change over time. To see these options, **go to the Isle Royale page.**

Time: 2-3 days (for either option)

Option A engages students in wondering about the factors regulating populations by introducing them first to the near extirpation of wolves from the United States.

Option B instead asks students to predict changes in populations of wolf and moose given some information about their life histories, including their intimate connection as predators and prey.

Both options lead students to connect details of wolf biology, moose biology, and environmental trends on Isle Royale to the changes in population number of the two large mammals in this system and lead them to create model statements about the important processes regulating natural populations.

LEARNING SEGMENT DETAILS

Time: 8-10 traditional periods.

1. Pose question: "What about plants? Do they need to eat? Do they give off CO_2?" (Q)
2. Investigate role of CO_2 in plants. (Q->P)
3. Construct and share model ideas. (P->M)
4. Light and Dark Four Corners Activity: When is respiration taking place? (apply M)
5. Map photosynthesis onto energy diagram. (apply M)
6. Figure out rest of the reactants and products of photosynthesis. (refine M)
7. Return to the Ecosphere (if that is how you motivated the discussion in step 1)and finalize the discussion of the interdependence of the algae and the shrimp. (M->P)
8. Apply models 3, 4, 5, 6, and 7 to Sprout to Tree activity. (M->P)

Phenomenon to Question

Pose question: "What about plants? Do they need to eat? Do they give off CO_2?"

Question to Phenomenon

Investigate role of CO_2 in plants

Phenomenon to Model

Construct and Discuss Model Ideas

Phenomenon to Question

Light and Dark Four Corners Activity: When is respiration taking place?

Model

Map photosynthesis onto energy diagram.