

Inquiry Learning

Marcia C. Linn

University of California, Berkeley

Wednesday, April 30, 2014

Network of Academic Programs
in the Learning Sciences (NAPLeS)



VISUAL



Marcia Linn Background



Apple II GS

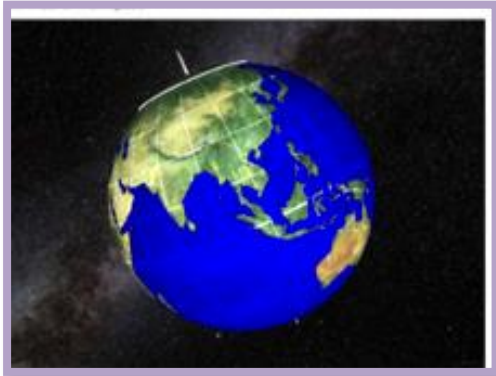
- **Apple Wheels for the Mind** grant awarded in 1985 for The Computer as Lab Partner (CLP)
- Apple introduced the new Apple II GS , bundled with an Apple 3.5 drive, for \$999 (not including a monitor) in 1986.
 - An exuberant Steve Wozniak quipped, "It's Amazing!"
 - CLP made a film showcasing the new computer.
- 1988 Director of Instructional Technology at UC Berkeley.
- 2006 NSF Technology Enhanced Learning in Science (TELS)

Thank you

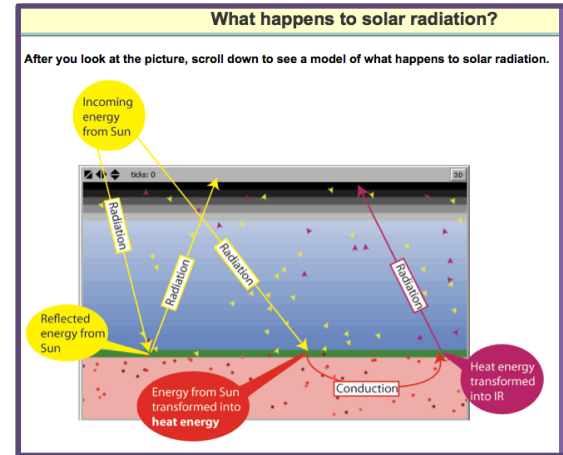
Libby Gerard, Jennifer King Chen,
Dermot Donnelly, Geoffrey Kwan,
Kevin Lai, Jonathan Lim-Breitbart,
Doug Kirkpatrick, Lydia Liu (ETS),
Jacqueline Madhok, Camillia Matuk,
Kevin McElhaney, Vanessa Svihla
(UNM), David Miller (Northwestern
University), Elissa Sato, Jim Slotta
(University of Toronto), Hiroki
Terashima, Jonathan Vitale, the Linn
Research Group



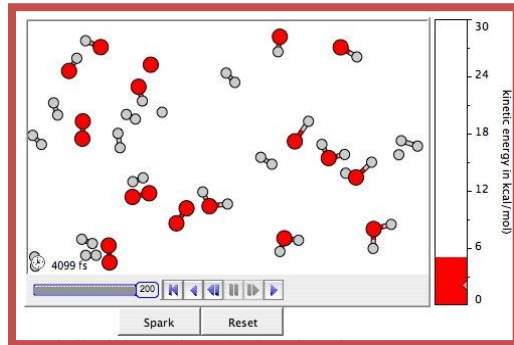
How Can Visualizations Engage Learners in Inquiry?



Solar System



Global Climate Change



Molecular Workbench



Chloroplast

Eliciting Ideas

- What causes global global climate change or global warming?
- What answers might students in middle school, college, or MOOCs give?

Visintainer, Y. & Linn, M. C. (2013). **Sixth Grade Students' Progress in Understanding the Mechanisms of Global Climate Change**, submitted.

Warming Mechanisms

“The garbage it...starts to decompose...it puts off a lot of heat and that can make the planet warmer.”

“Well animals die from the oil in the water...it could be separating the ice.”

“The ozone layer is opening, and it’s letting in ultraviolet radiation and it's getting hotter.”

“My dad got a car, I saw...there was kind of smoke coming out of the car and it was really hot. Every car that I see pass by I see that coming out.”

“To get electricity for your computer, you can burn coal and the smoke turns a turbine and it conducts energy....and more pollution is going into the air.”

Building on Warming Mechanisms

“The garbage it...starts to decompose...**it puts off a lot of heat** and that can make the planet warmer.”

“Well animals die from the oil in the water...it could be separating the ice.”

“The ozone layer is opening, and it’s letting in **ultraviolet radiation** and it's getting hotter.”

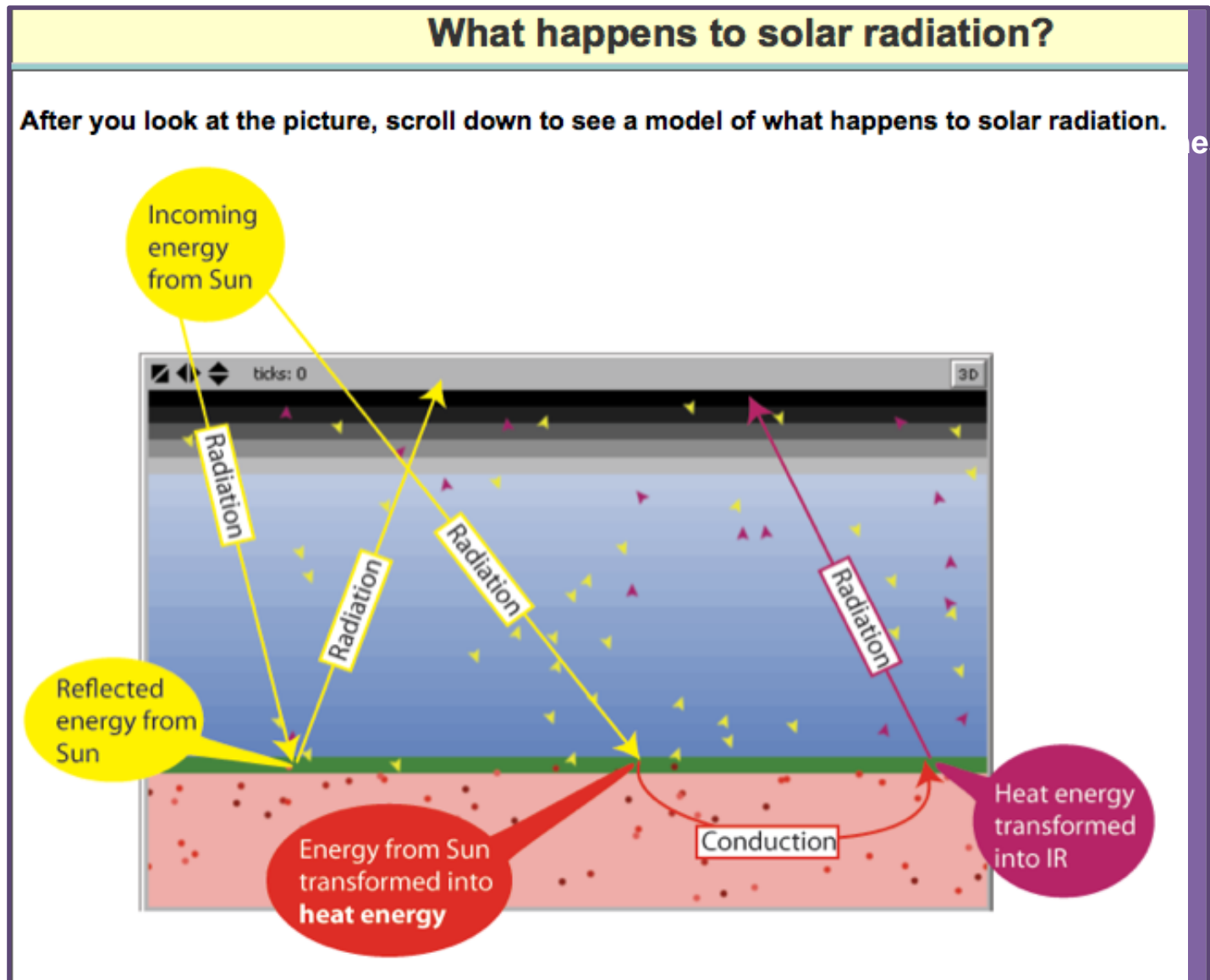
“My dad got a car, I saw...there was kind of smoke coming out of the car and **it was really hot**. Every car that I see pass by I see that coming out.

“To get electricity for your computer, you can burn coal and the smoke turns a turbine and it conducts energy....and more **pollution is going into the air**.”

Why Elicit Ideas?

- Identify ideas that cause confusion
 - Something about ozone.....
 - Scientists are unsure
- Identify ideas to build on
 - Exhaust, garbage, produce heat
 - Pollution adds gases to the atmosphere
- **Research shows value of predictions;**
 - **Predict – Observe – Explain: White & Gunstone (1992)**
 - **Predict versus Observe: Linn & Songer (1983)**
 - **Predict before instruction: Mayer, Dow, and Mayer (2003)**

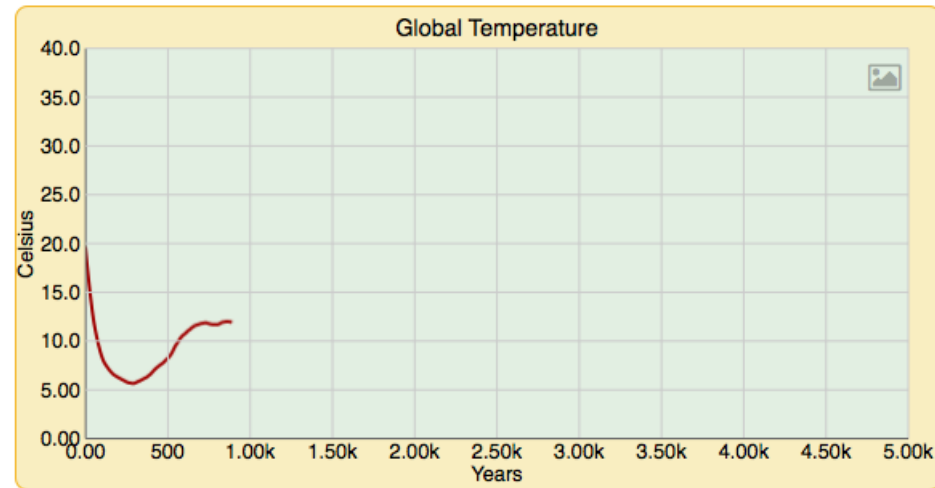
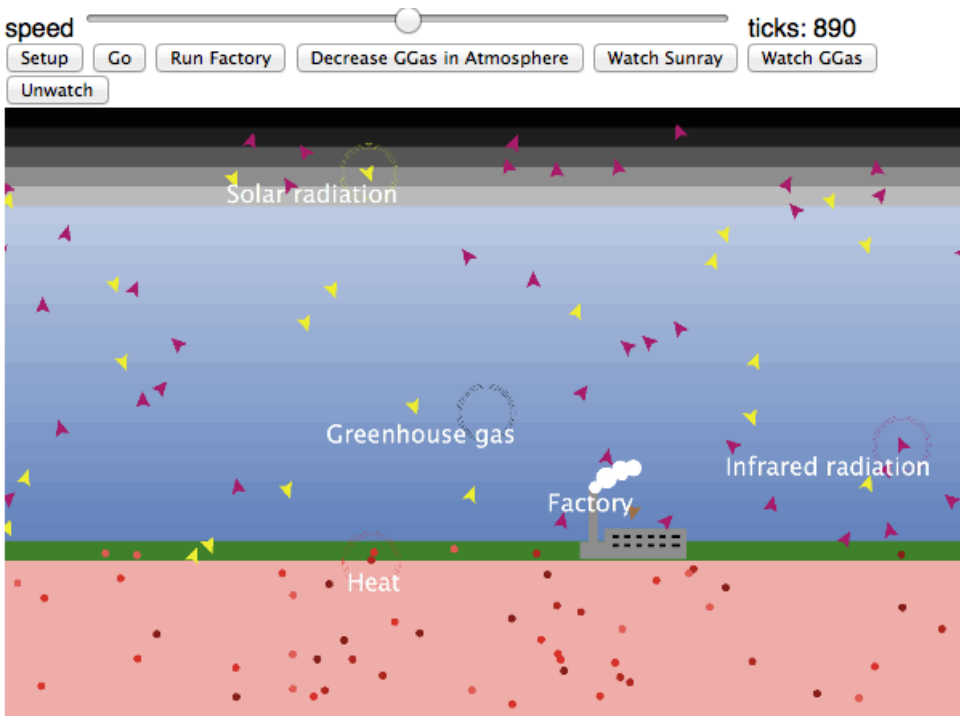
ADD Ideas Global Climate Visualization



Explore A Visualization of Greenhouse Gases

- Launch this web page in a browser. Firefox or Chrome are preferred.
- http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html
- Hit setup to reveal the visualization.
- Hit Go, then hit Stop.
- Note that when you stop the visualization the labels appear
- Explore go, stop, watching sunrays.

Launch the page, hit setup, hit go, hit stop



http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html

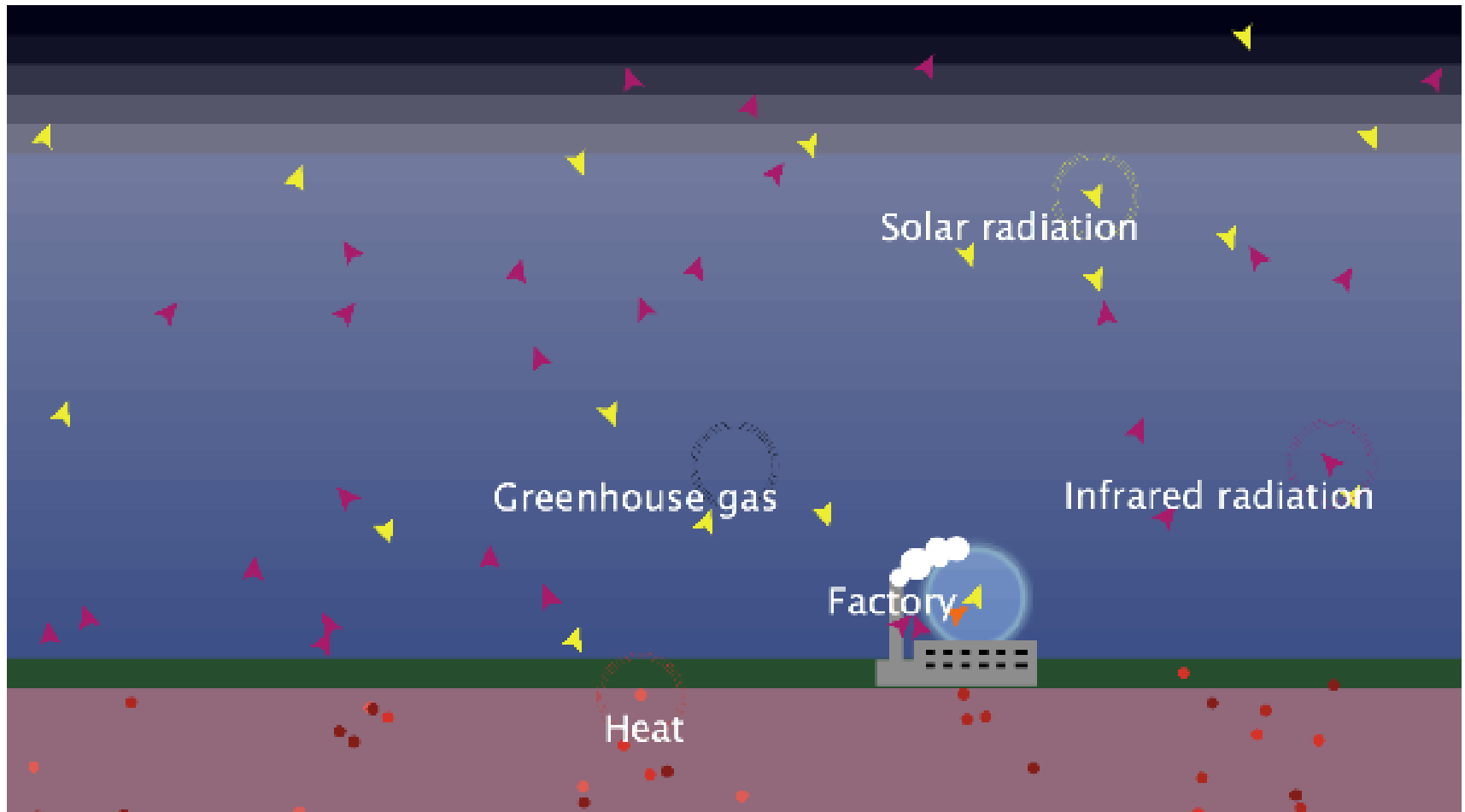
What do you observe?

- What should be improved [this is beta version of user interface]?
- What can students learn?
- What surprised you?
- What seems scientifically misleading?
- See Slides 8-16 for exploration hints

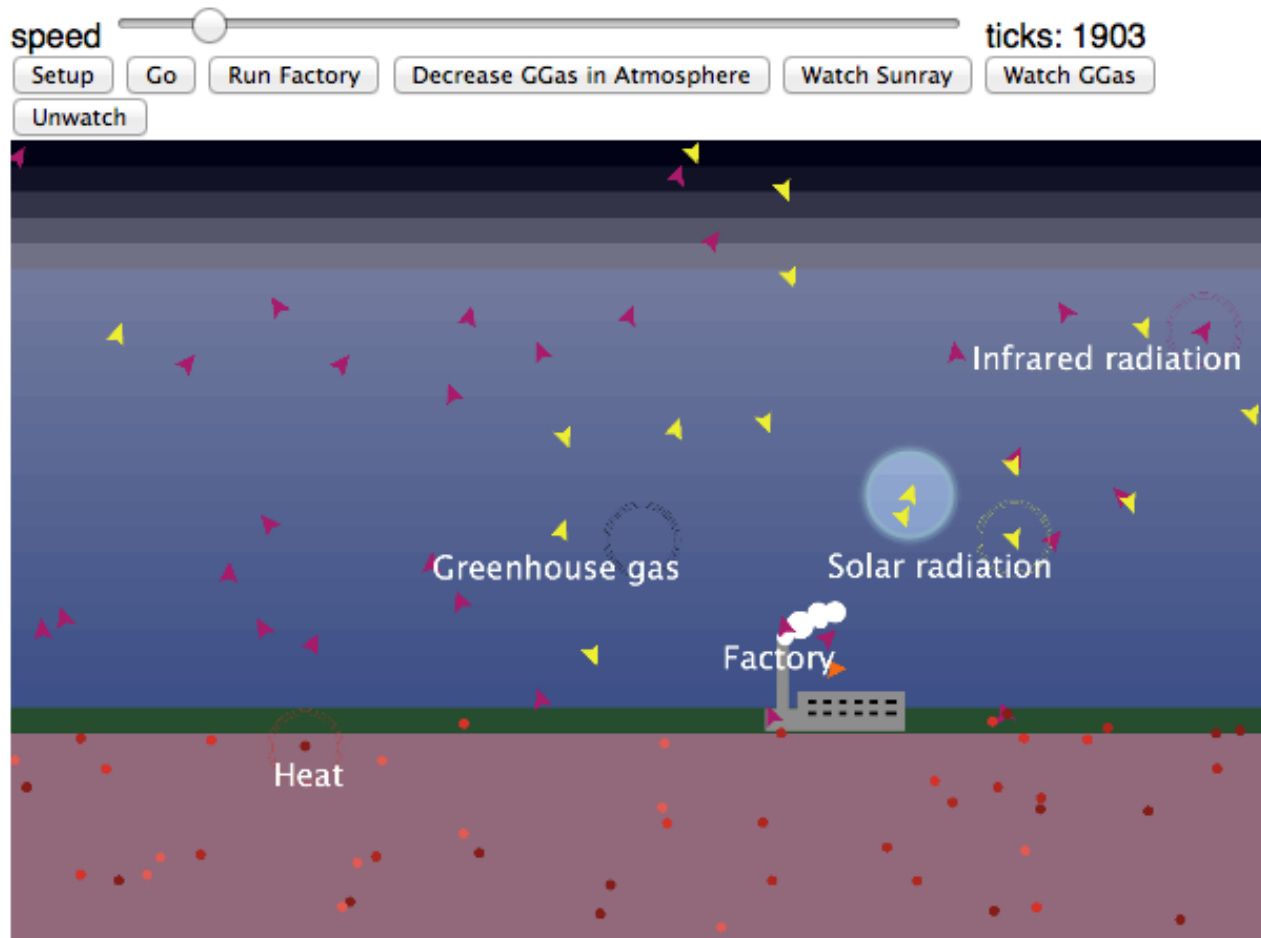
Watch a Sunray



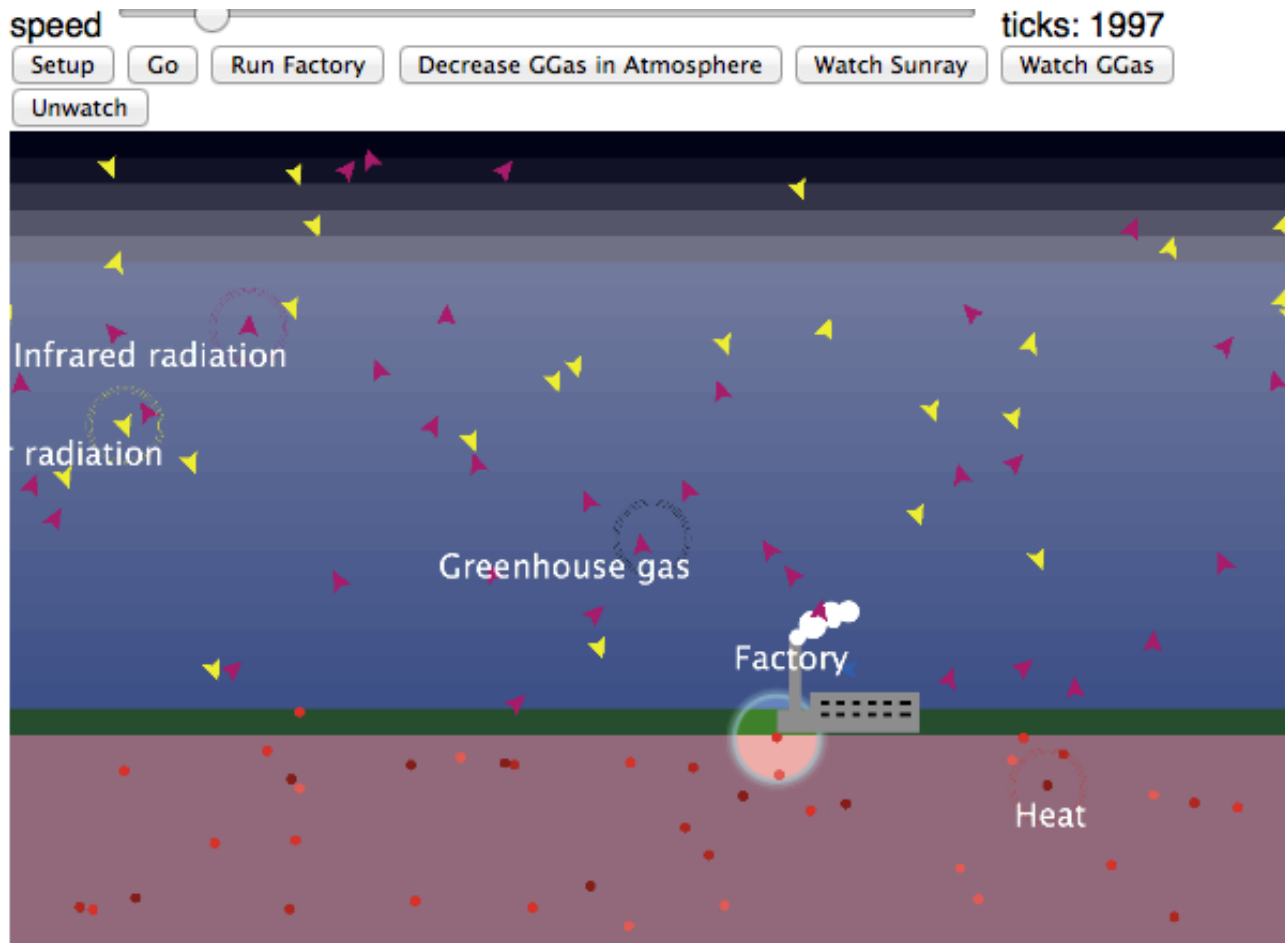
Watch a Sunray Reflect



Watch a Sunray

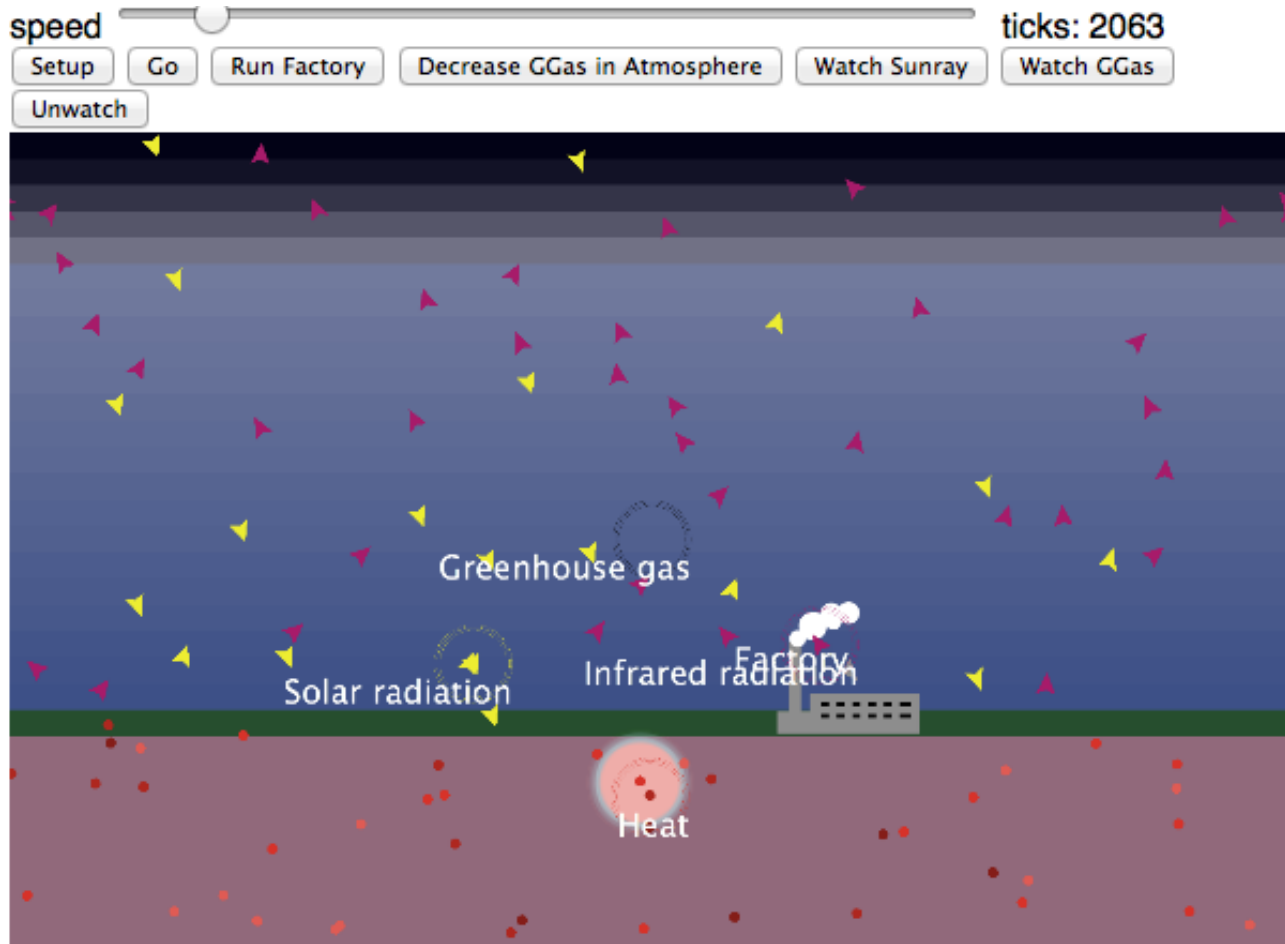


Watch a Sunray Transform into Heat

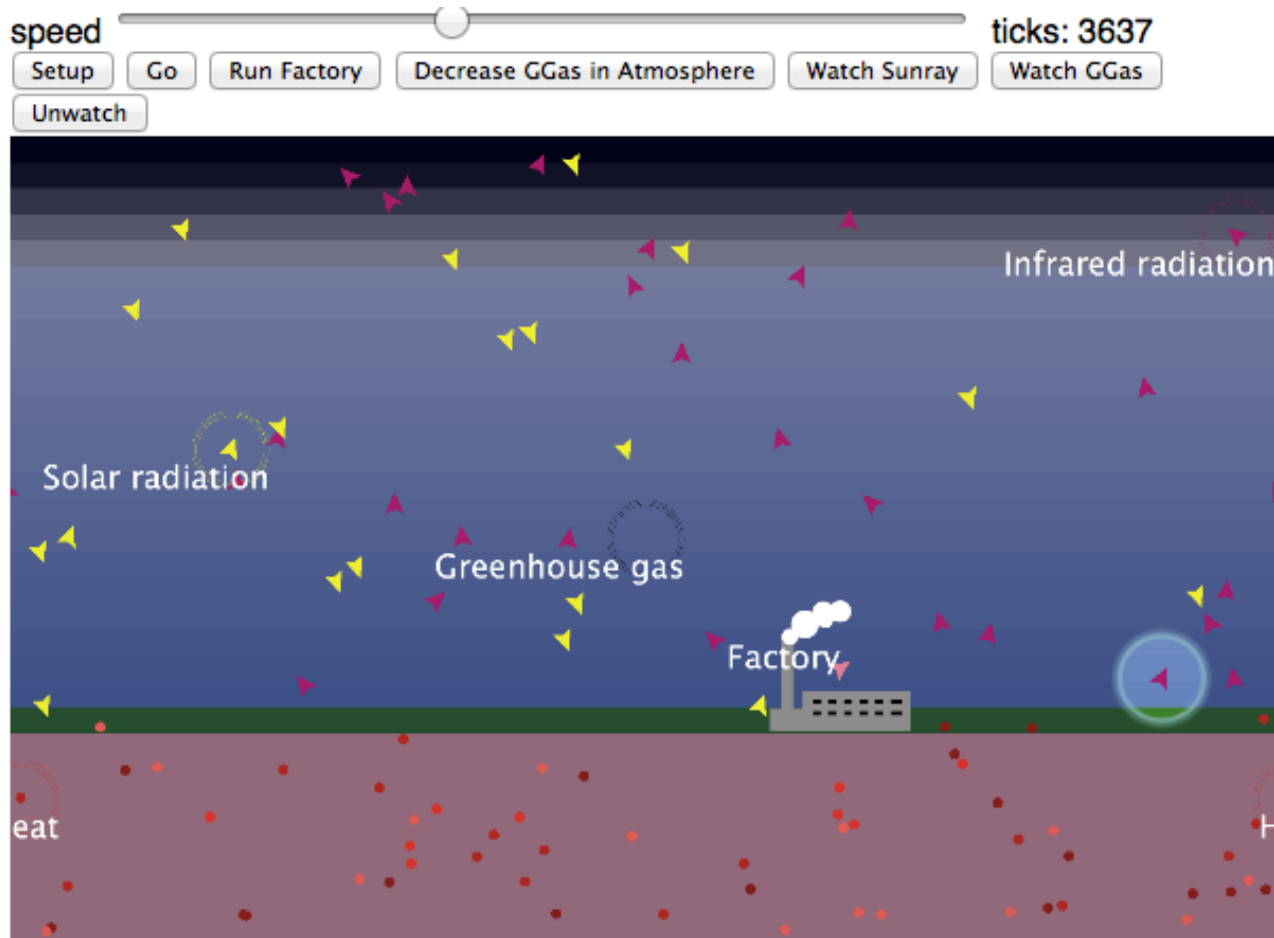


http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html

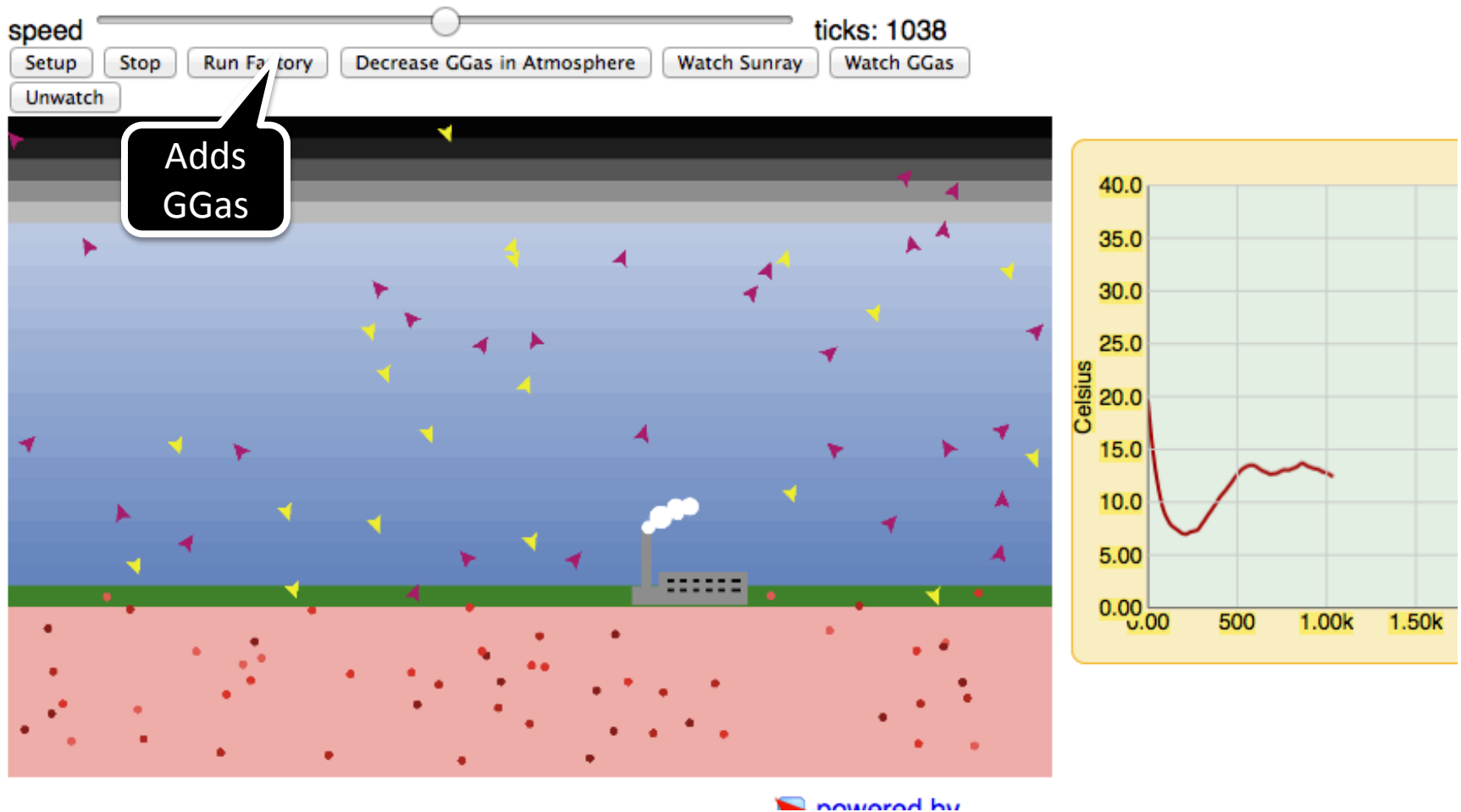
Watch Heat Below the Surface of the Earth



Watch Heat Transform into IR

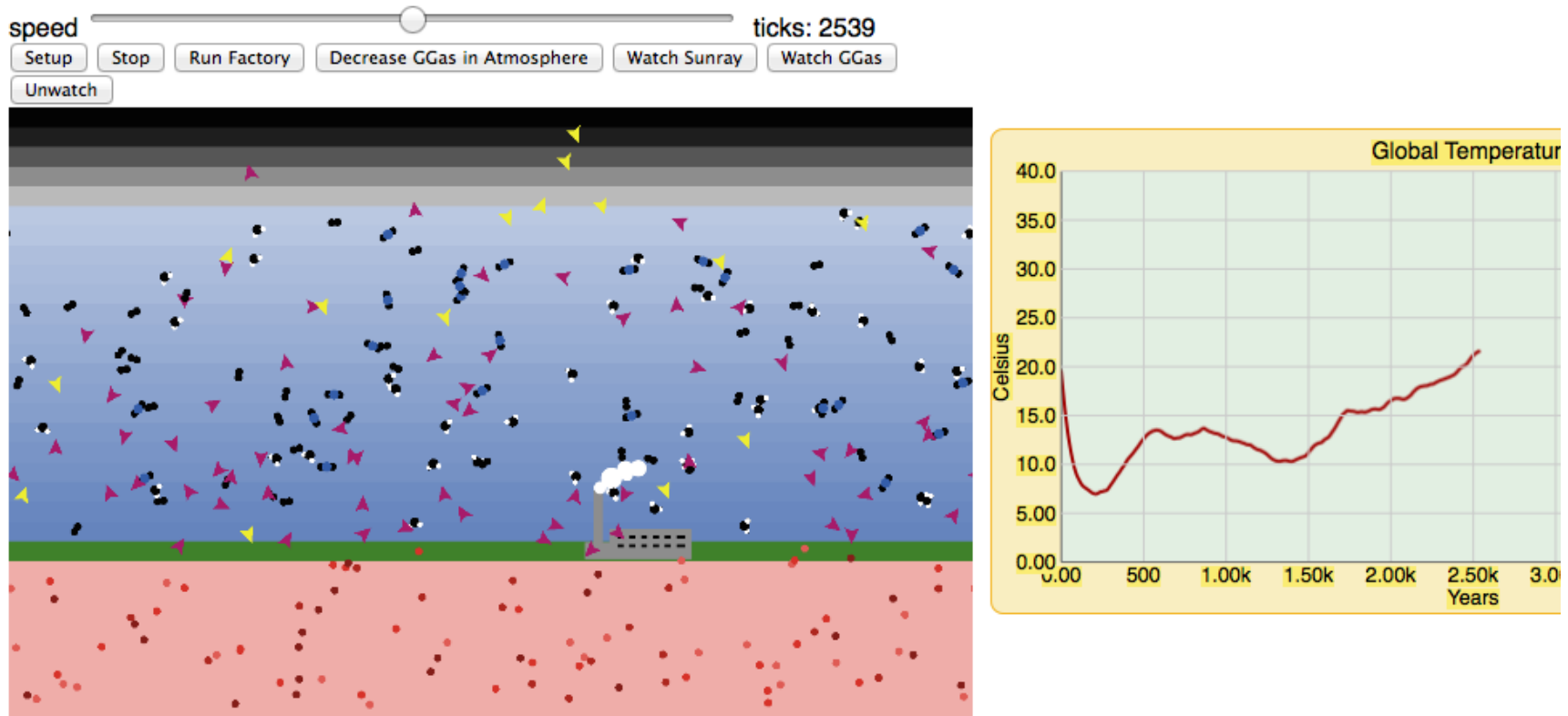


Explore Increasing and Decreasing Greenhouse Gases



powered by

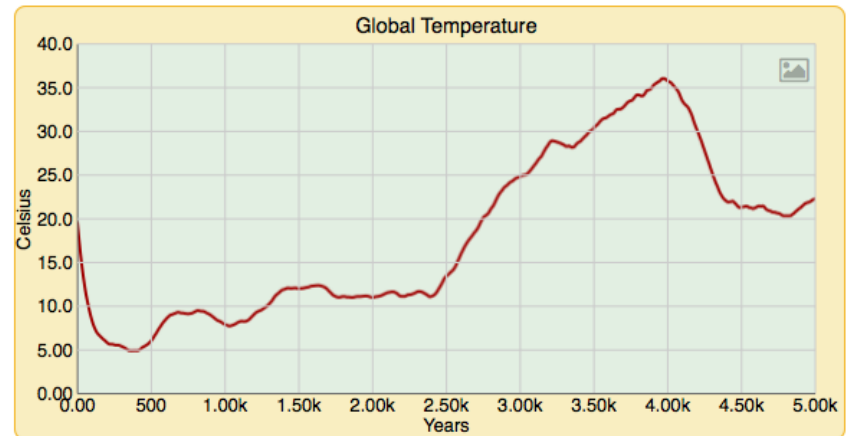
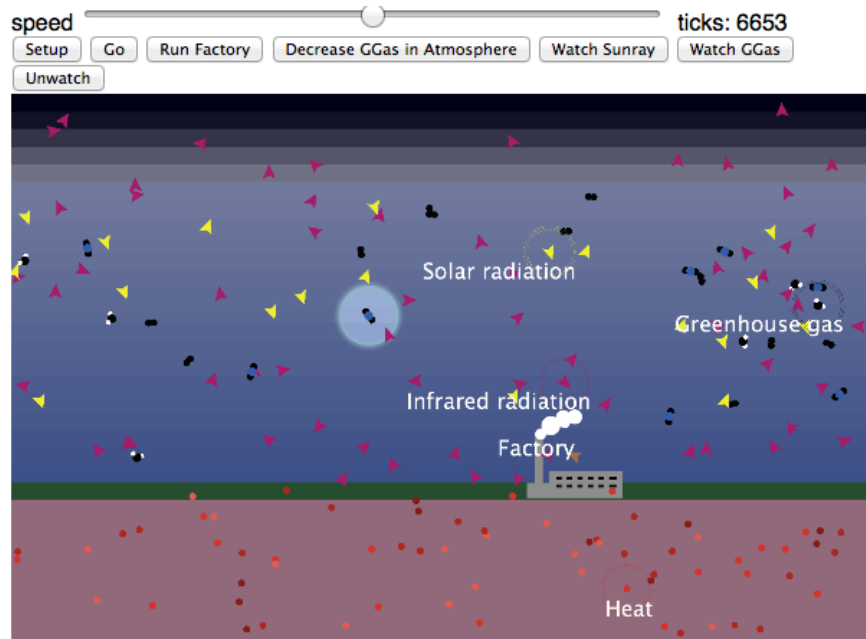
Run Factory at 2.5K Years



http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html

Run Factory to 4K, then Decrease GGas

- Watch a GGas



http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html

Report Back Ideas

- Raise your hand and describe your thoughts.
- Contribute your thoughts to Chat
- Comment on others' contributions using Chat

Why use visualizations to add new ideas?

- Illustrate ideas that are too small (atoms), vast (solar system), lengthy (climate change, plate movement) or fast (airbag deployment) to observe directly.
- Communicate in both images and words
- With **appropriate guidance**, can promote student autonomy in investigating variables or conditions.
- **Research supports using visualizations:**
 - Ainsworth & Loizou (2003)
 - Höffler and Leutner (2007)
 - Ryoo & Linn (2012)

Web-based Inquiry Science Environment

WISE v4 Full Screen Ideas (0) Add Idea My Work Flagged Home / Sign Out

What makes a good cancer medicine?:
Of [EB]
[EB]
ser!

Inquiry Map

- What Is Cancer? +
- The Phases of Cell Division +
- Trade offs, side effects +
- Investigating Plant A -
- 4.1 How does Plant A affect mi
- 4.2
- 4.3
- Pl

Invest

Invest

Your f

MAKE SOME OBSERVATIONS

This cell was treated with *Typhonium flagelliforme*. Press P to see how it affects mitosis.

Record your observations in your Idea Basket. Try to note

Hints

1. 1 of 1
2.
3.

To keep your basket organized, type "Plant 1" as a tag for each new observation you make from this animation.

Reflection Note: Would you recommend Plant A?

Tall Wide Basic Large help

QUESTION

What are your recommendations for this plant as a possible medicine? Give reasons for your recommendations.

RESPONSE

This is your first revision.

SAVE CHANGES SAVE & CLOSE

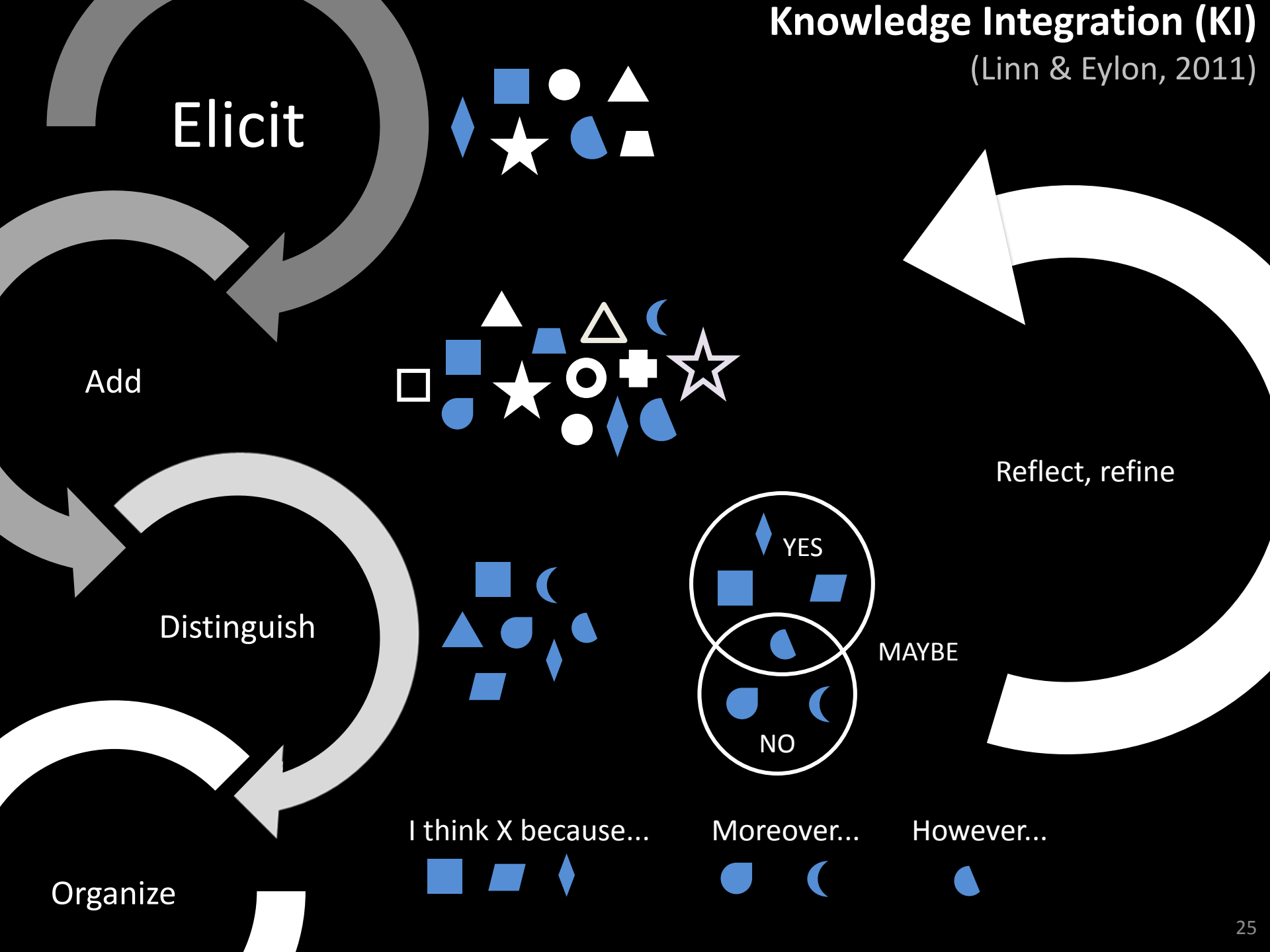
NORMAL CELL

WISE Evidence

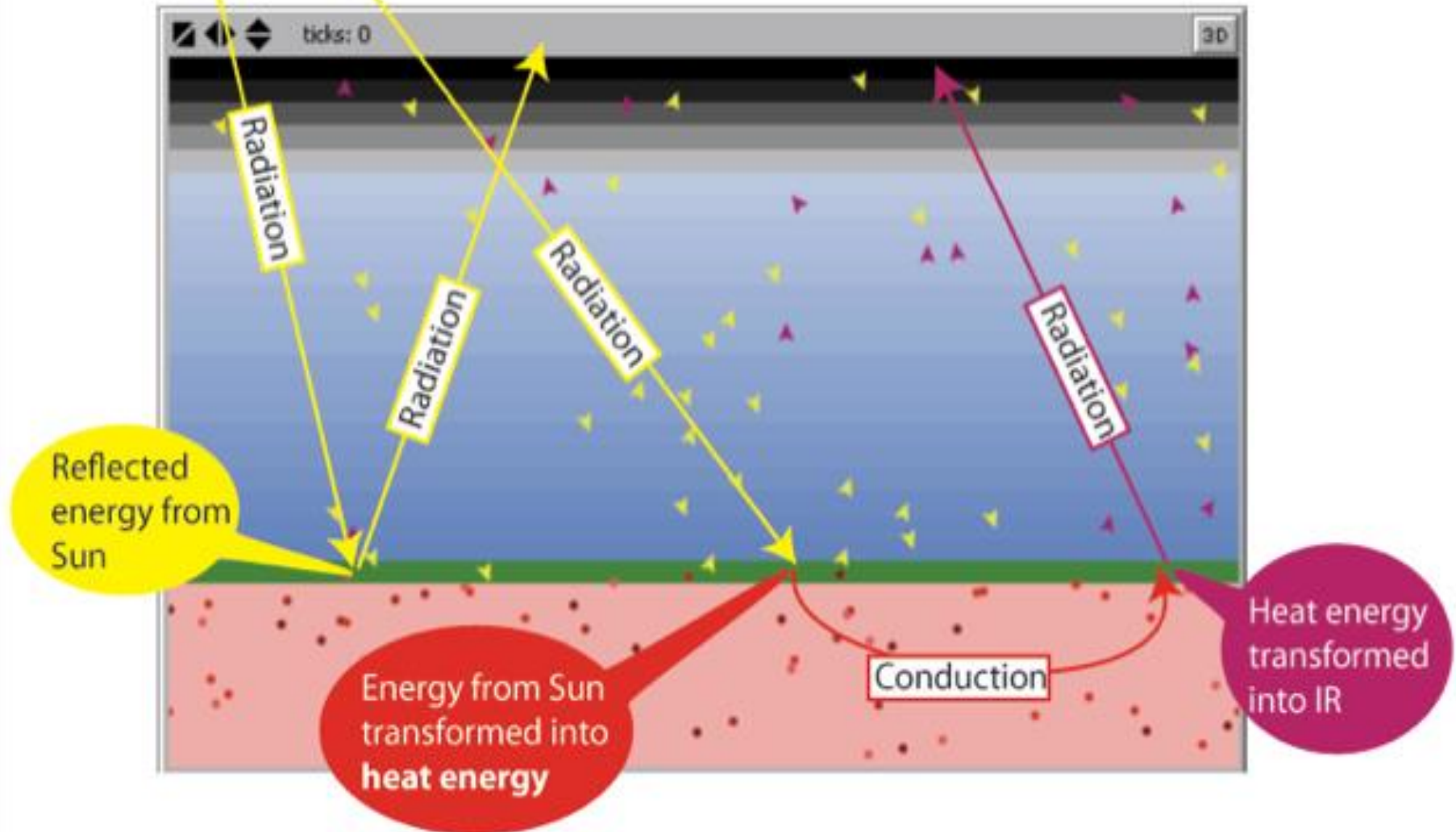
Back -1 Stop +1 Play

Knowledge Integration (KI)

(Linn & Eylon, 2011)










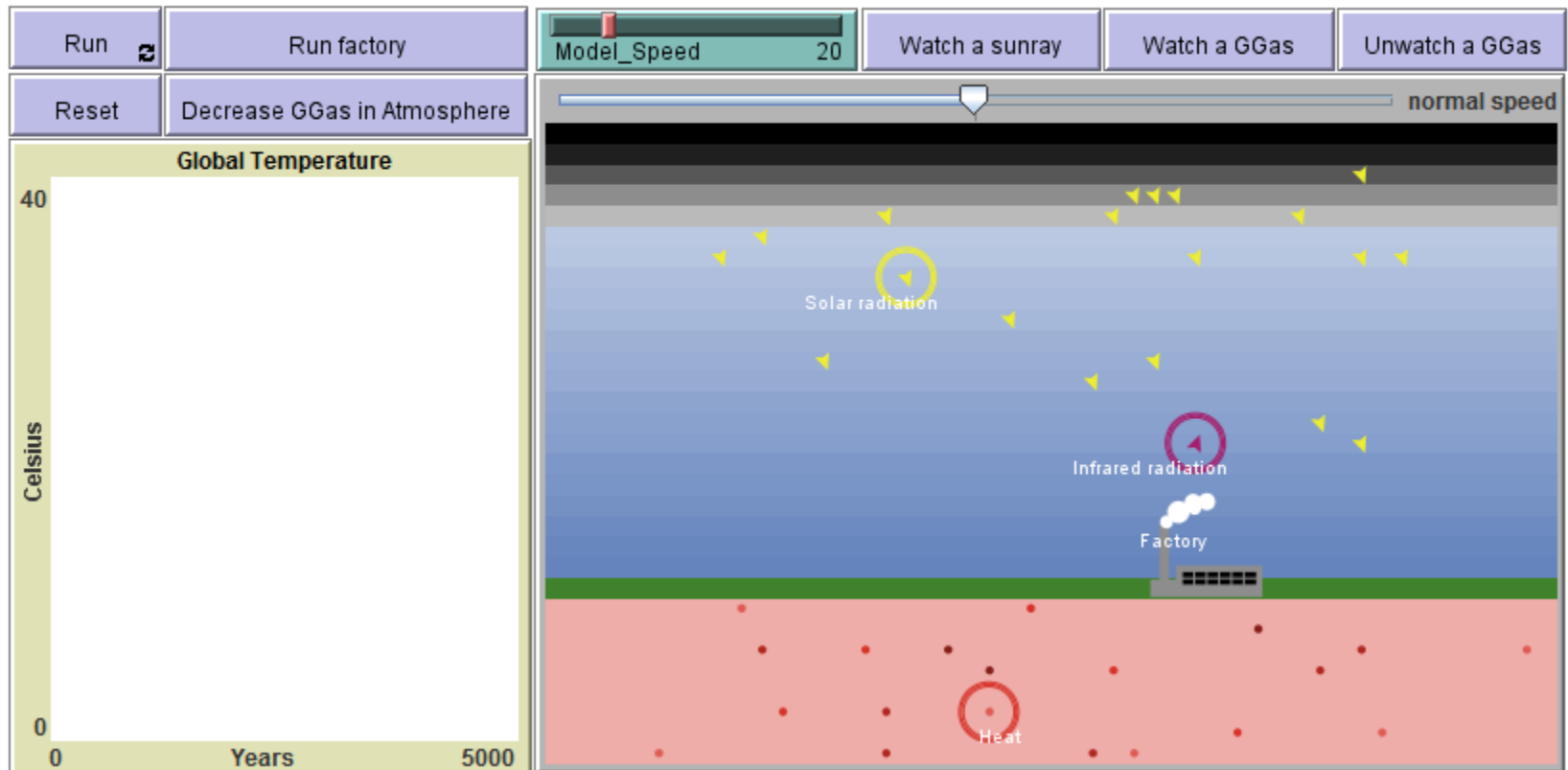
Adding ideas: Greenhouse Gas Visualization



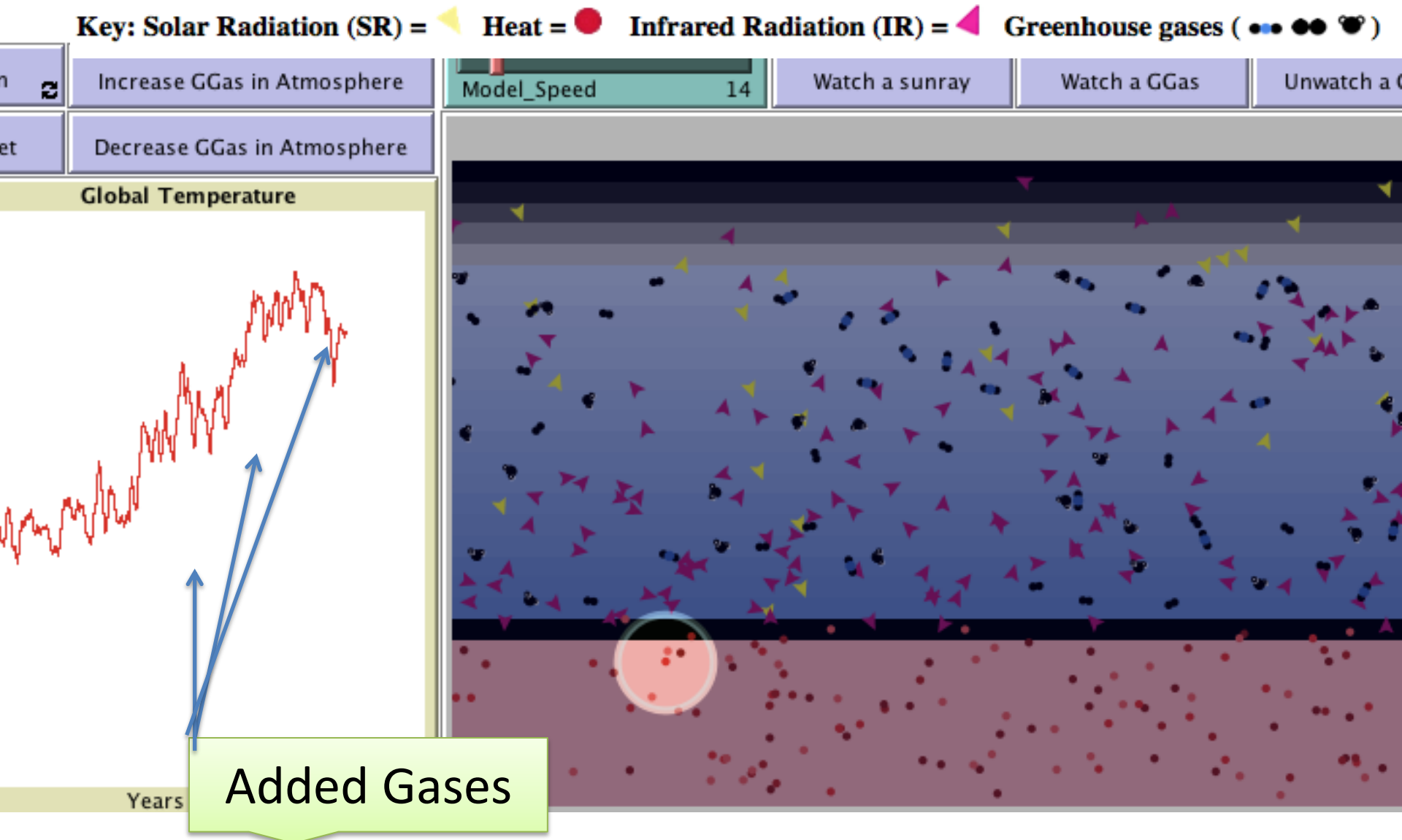
Students Explore the Visualization:

“Probably all the pollution in the air could (make it warmer)”

Solar Radiation (SR) =  Heat =  Infrared Radiation (IR) =  Greenhouse gases (   )



Students Add Greenhouse Gases



Essay Questions Can Ask Students to Distinguish Ideas

Burning Coal: Sasha & Chris

1. Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?

- ☒ A warmer climate
- ☐ A cooler climate
- ☐ Lower relative humidity
- ☐ More ozone in the atmosphere

Sasha & Chris Explain their Response

QUESTION

Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?

In the space below explain your answer to the question on the previous step. After you receive feedback you may change your answer on the next step.

Burning coal would produce carbon dioxide which become greenhouse gases, which would break parts of the ozone layer

Is this your best work?

The image shows a screenshot of a quiz application. At the top, a blue header bar contains the word "QUESTION" in white. Below this, a question is displayed: "Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?". A red dialog box is overlaid on the screen, containing the text: "You have one chance to get guidance so this should be your best work. Are you ready?". At the bottom of the dialog box are two buttons: "OK" and "Cancel". In the background, a yellow banner reads "After you receive feedback you may". Below the dialog box, the start of an answer is visible: "Burning coal would produce carbon dioxide which become greenhouse gases, which would break parts of the ozone layer."

QUESTION

Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?

You have one chance to get guidance so this should be your best work. Are you ready?

OK Cancel

After you receive feedback you may

YOUR P

Burning coal would produce carbon dioxide which become greenhouse gases, which would break parts of the ozone layer.









Knowledge Integration Guidance

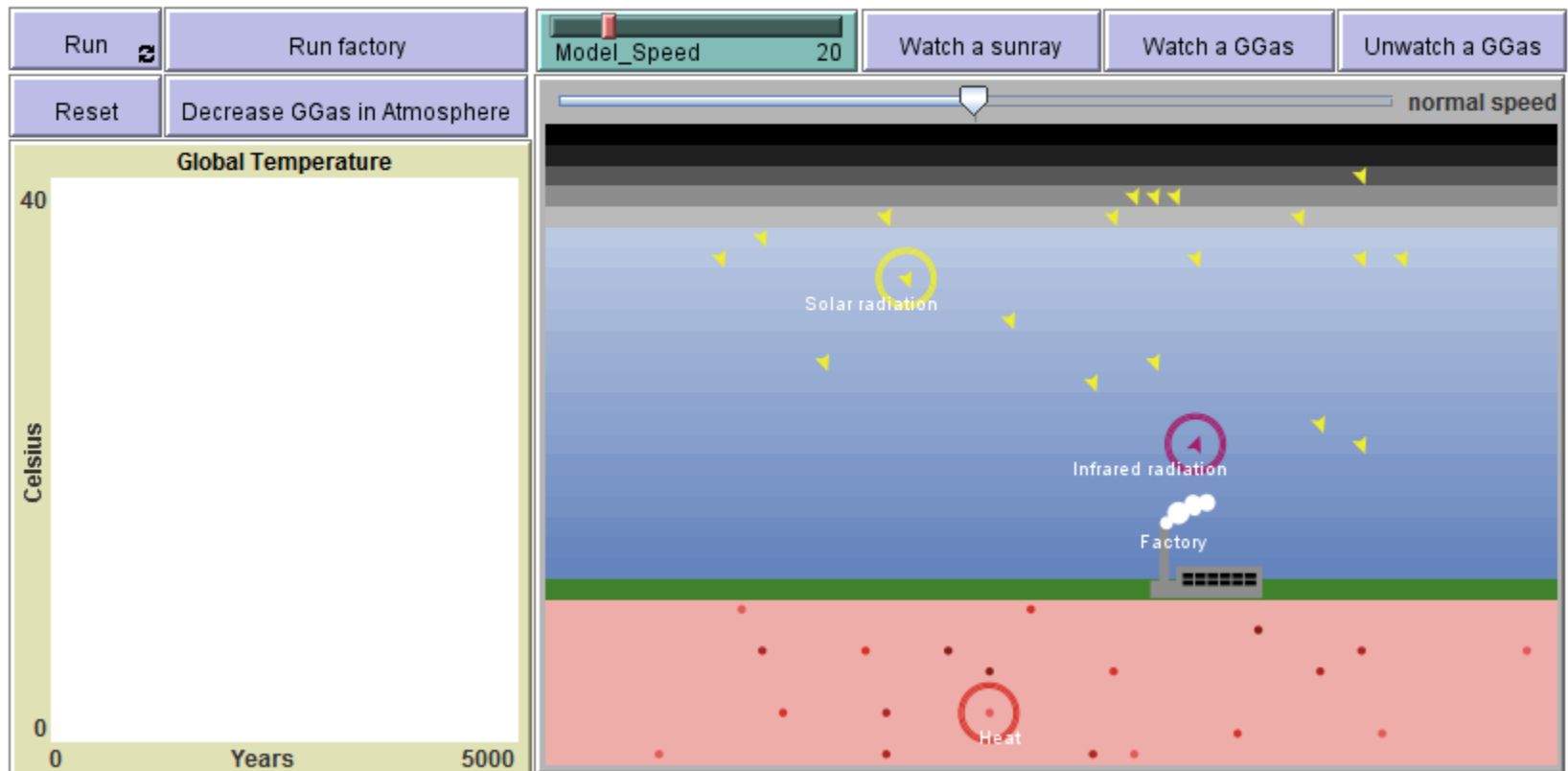
Your answer needs more ideas.

To improve your response [return to step 4.3](#) to find out how increased carbon dioxide in the atmosphere affects the global temperature.

Using the ETS c-rater technology WISE analyses natural language responses and generates personalized guidance based on student explanations (Liu et al, 2013).

Sasha & Chris revisit Step 4.3

Solar Radiation (SR) =  Heat =  Infrared Radiation (IR) =  Greenhouse gases (    )



Sasha & Chris Revise their Response

Burning coal has increased the amount of carbon dioxide in the atmosphere. Carbon dioxide can increase the temperature of the climate

Erin & Sam Explain their Response

QUESTION

Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?

In the space below explain your answer to the question on the previous step. After you receive feedback you may change your answer on the next step.

It could warm up the earth because more carbon dioxide would make the earth warmer.








Guidance for Erin & Sam

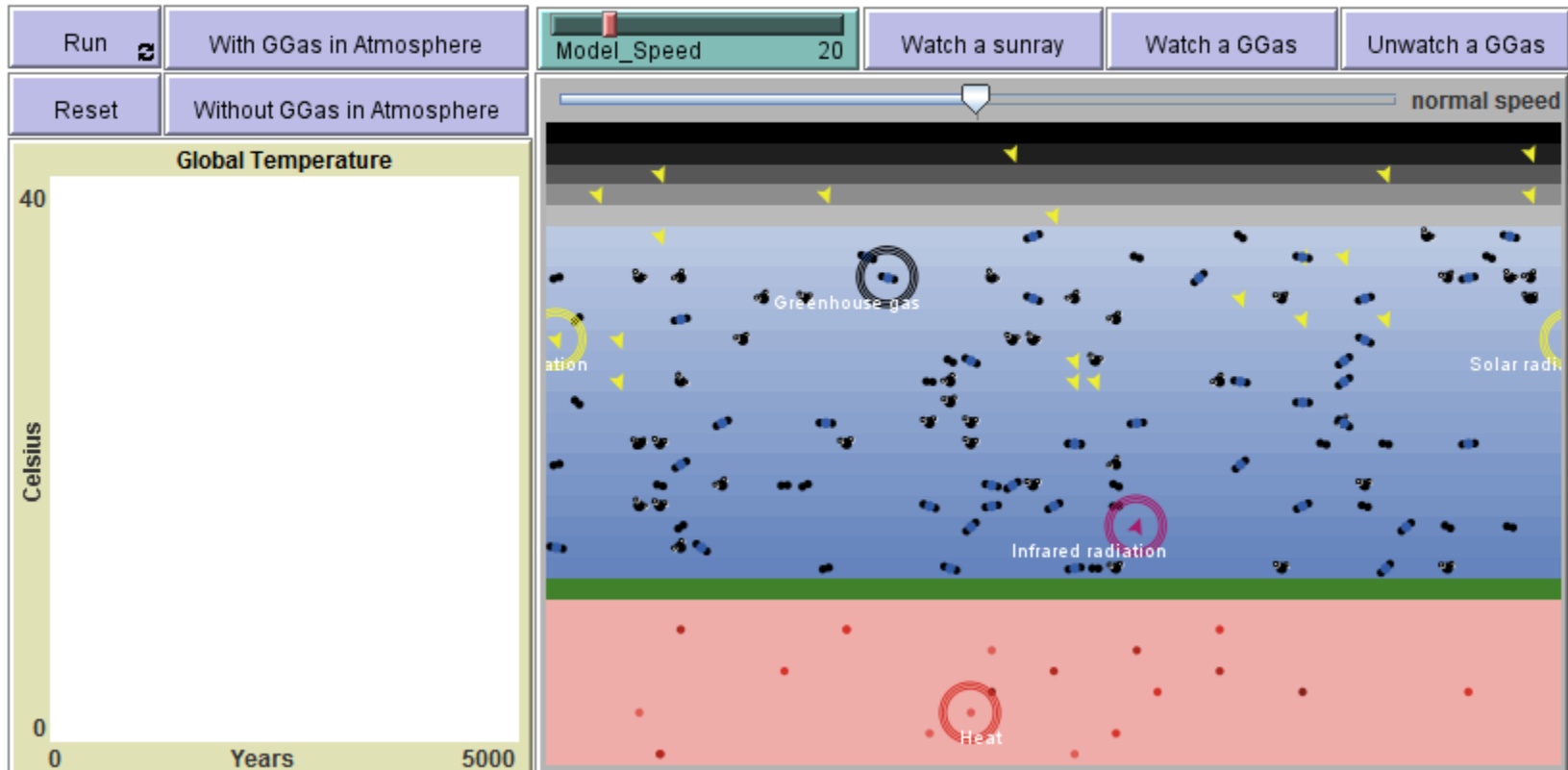
Good progress, but your answer can be improved.

To improve your response [return to step 3.3](#) to find out how carbon dioxide in the atmosphere affects the global temperature by interacting with energy released by the surface of the Earth.

Guidance generated by ETS c-rater technology.

Erin & Sam Revisit Step 3.3

Solar Radiation (SR) =  Heat =  Infrared Radiation (IR) =  Greenhouse gases (   )



Erin & Sam Revise their Response

QUESTION

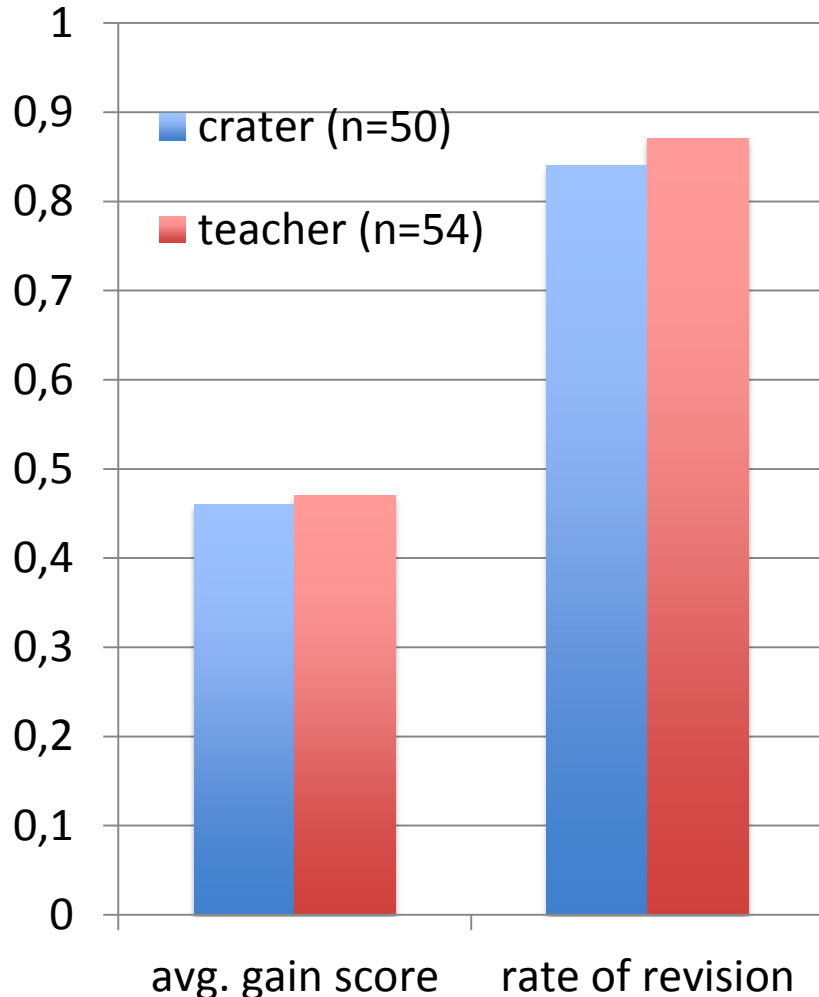
Burning coal to produce electricity has increased the amount of carbon dioxide in the atmosphere. What possible effect could the increased amount of carbon dioxide have on our planet?

Carbon dioxide is a greenhouse gas and green house gases make the earth warmer. They make the earth warmer because they keep the infrared radiation in the atmosphere, which heats up the earth.

How Does Knowledge Integration Guidance Help Distinguish Ideas?

- Knowledge Integration Guidance Does Not
 - Give the correct answer
- Knowledge Integration Guidance Does
 - **Acknowledge** progress: “Good Progress” “Need Ideas”
 - **Identify** a place to improve: “Find out how carbon dioxide in the atmosphere affects the global temperature”
 - **Suggest** a way to get information: “Return to step X.X.”
 - **Ask** for a new explanation: “Write an improved explanation here”

Instructor and Automated Guidance Equally Effective

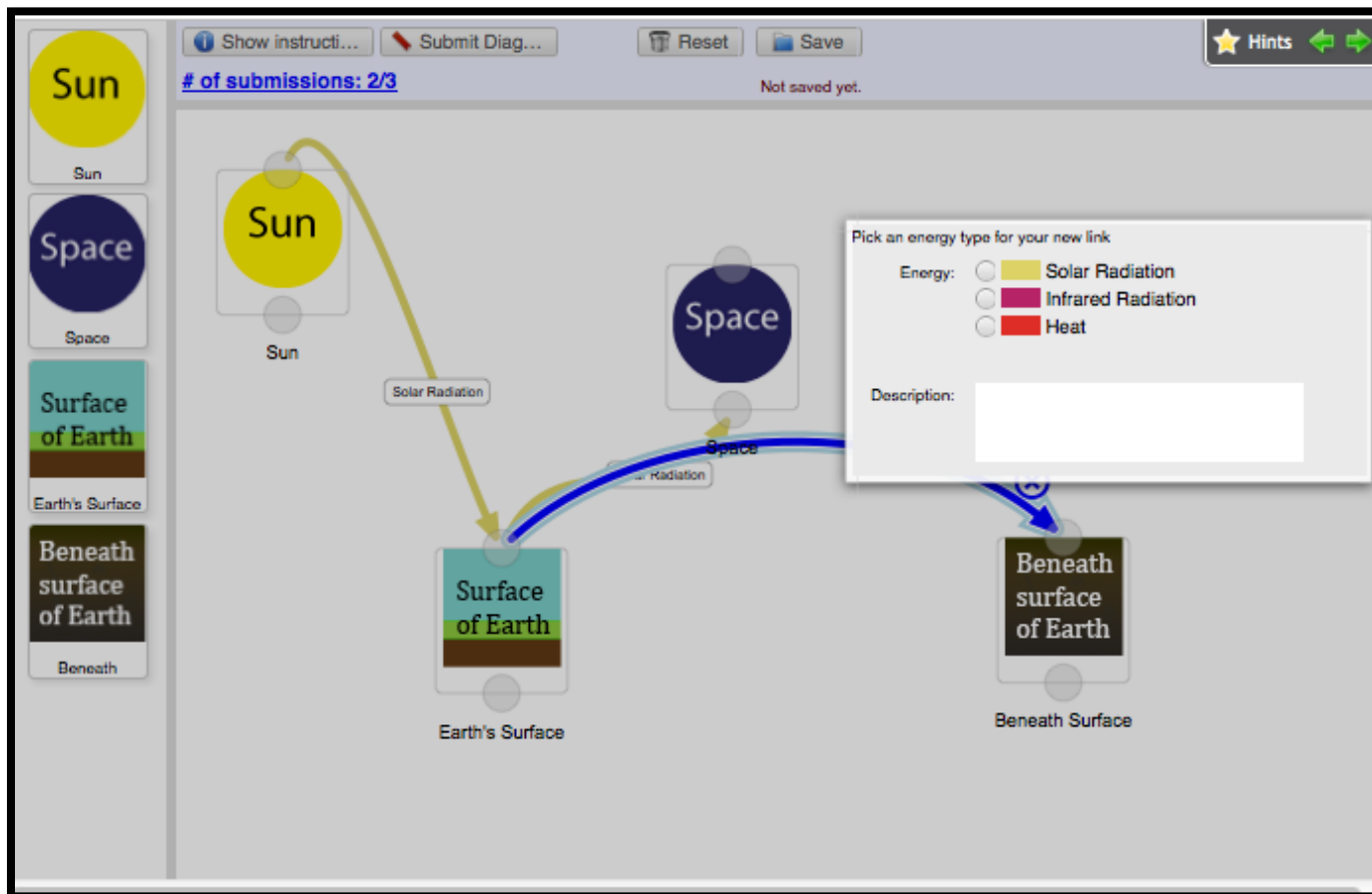


“the comments the computer made were helpful because **we were able to see what we needed to fix about our story and that we needed to add more details to it about the process of photosynthesis.**”

Student Comment

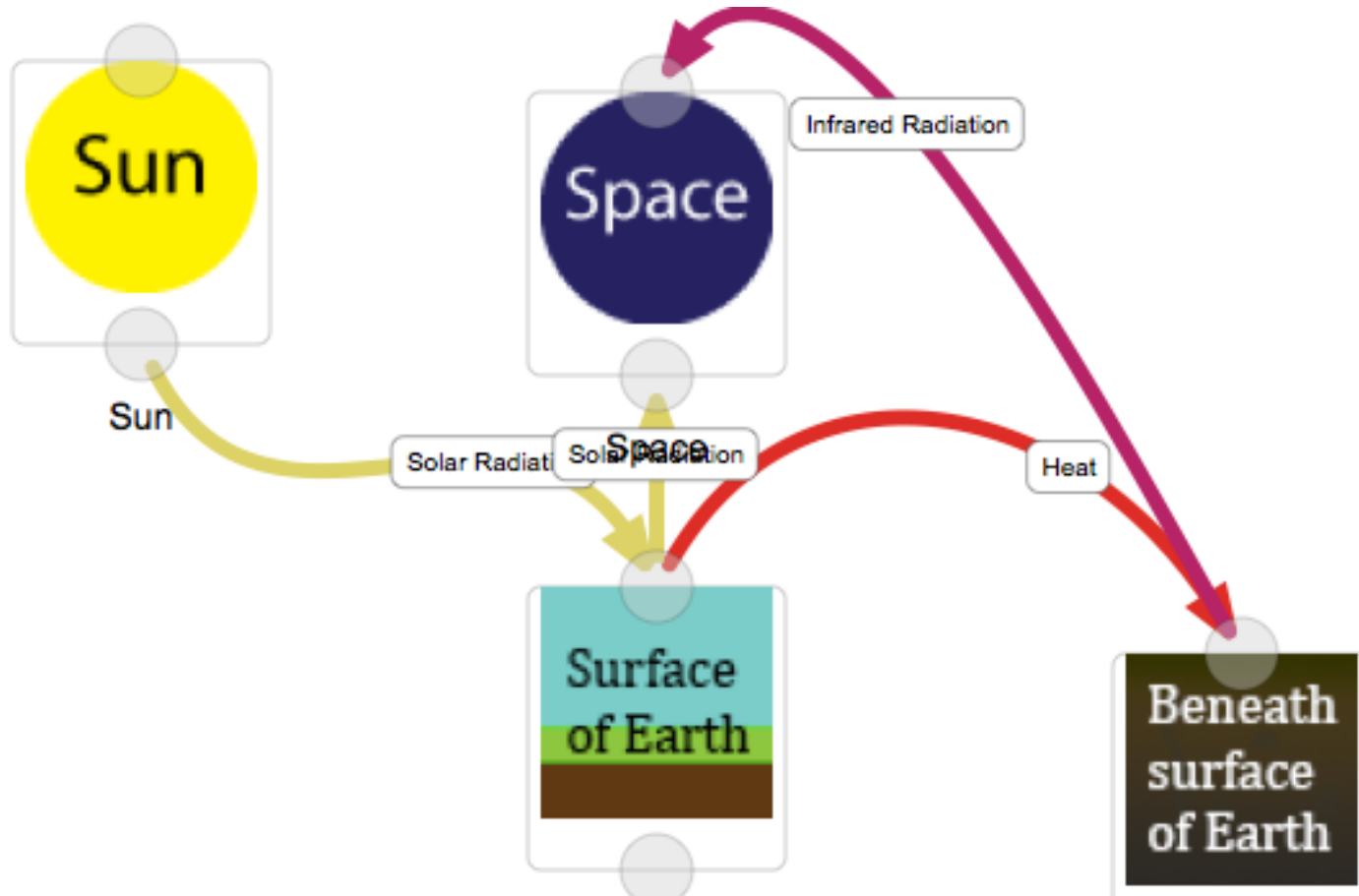
Distinguishing Ideas: MySystem

Connect the pictures to show how Energy moves between the Sun, the Earth, and Space.



My System Initial Design

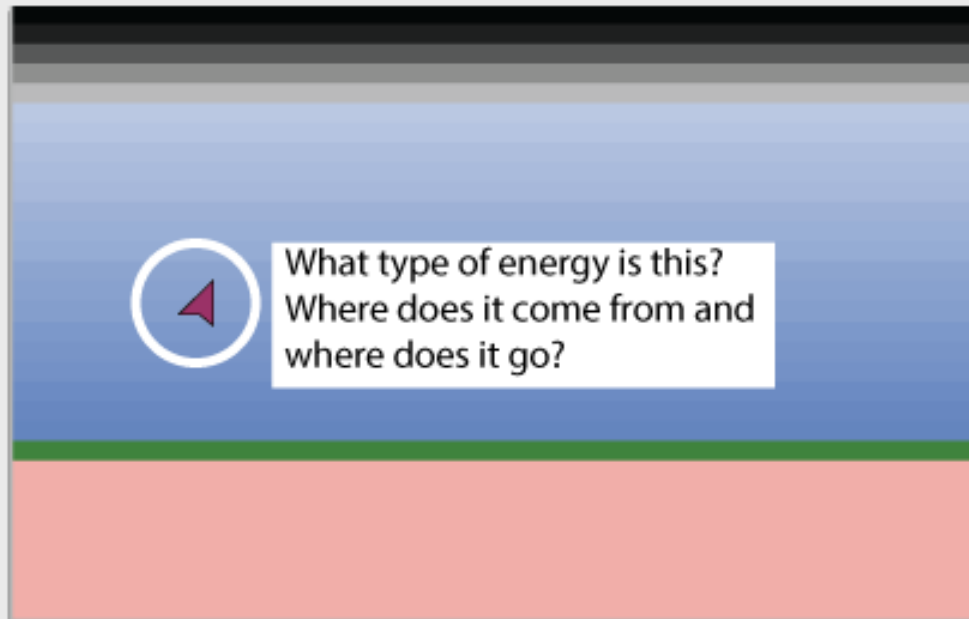
Connect the pictures to show how Energy moves between the Sun, the Earth, and Space.



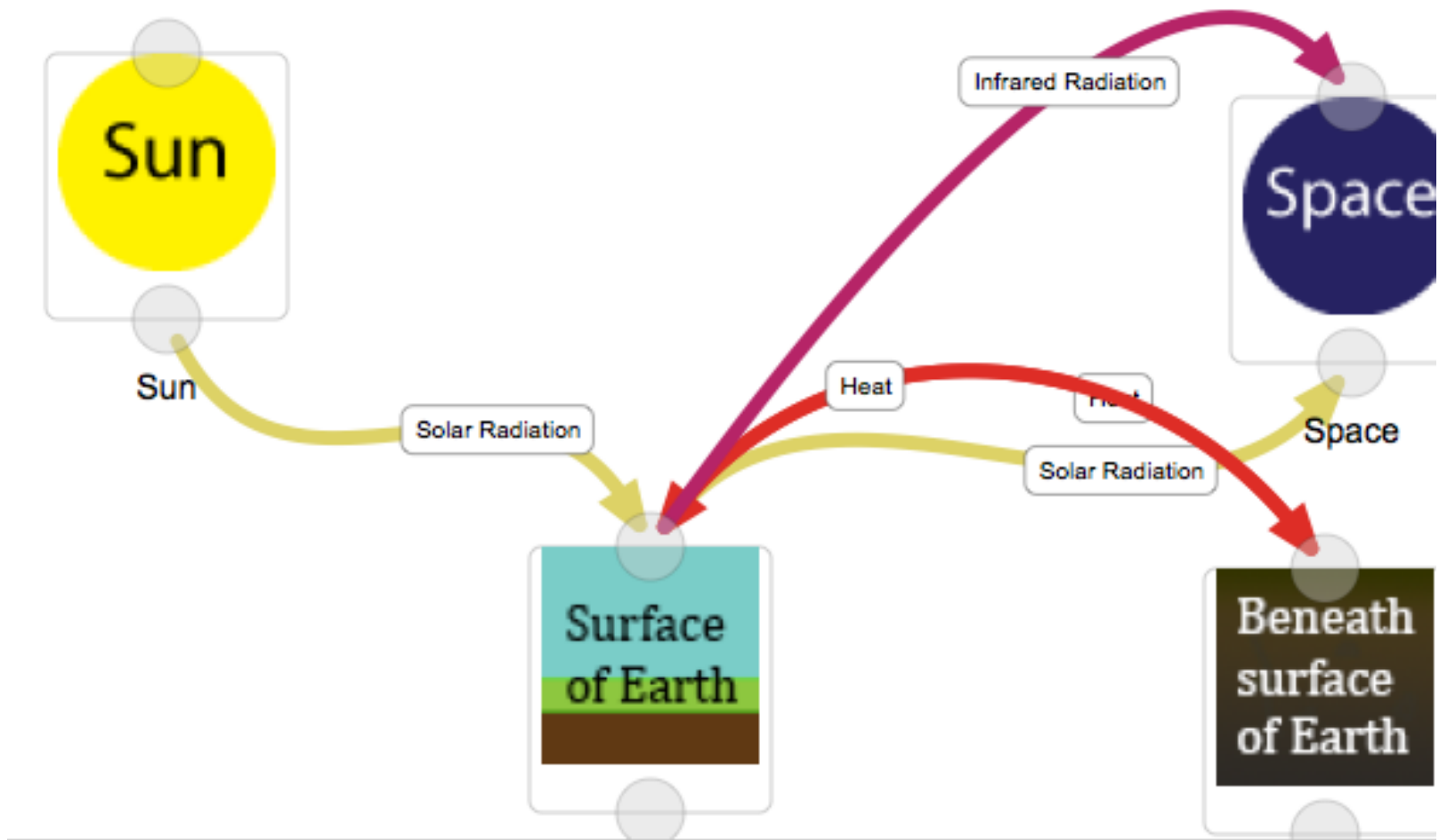
Get Knowledge Integration Guidance

of submissions: 1/3

You're getting there. Now make sure your diagram answers the questions below. Click on Step 2.8 at the left menu for help.



Revise My System Concept Map



Get My System Guidance

of submissions: 2/3

Great Job!

Advantages of diagrams?

- MySystem requires weighing competing alternatives—similar to essays
- MySystem reduces use of written expression
 - Allows language learners to illustrate their thinking.
- Research supports distinguishing ideas using guidance on drawings for:
 - MySystem, Ryoo & Linn (2014)
 - Concept maps, Segedy Kinnebrew, & Biwas (2013)
 - Chemical Reactions, Rafferty, et al (2013)

Why Distinguish Ideas in Embedded Assessments?

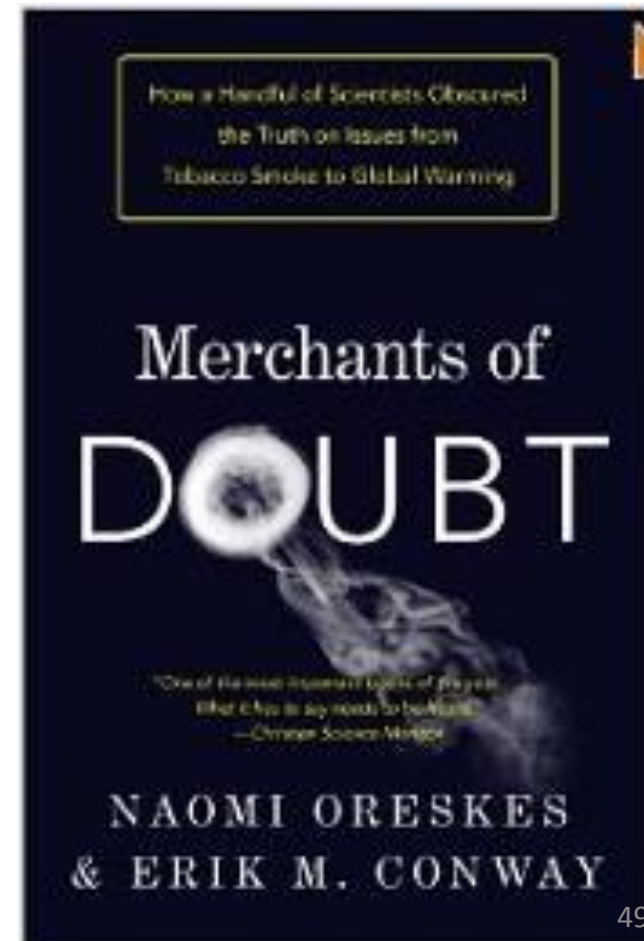
- When students write essays they have to come up with their own analysis
- MySystem uses images rather than words
- Essays and My System can be scored and help instructors plan next lessons
- Research shows essays & drawings help students learn:
 - By rewriting essays (Roediger & Karpicke, 2006)
 - By explaining their ideas (Chi et al., 1989)
 - By generating instead of selecting answers in multiple choice questions (Lee, Liu. Linn, 2011)

Reflection Questions

- Reflecting can promote lifelong learning:
 - Which is better for the climate: eating meat or being a vegetarian?
- Reflecting can draw on many science topics to promote cumulative learning:
 - Write a letter to a policy maker explaining how pollution from cars contributes to climate change and ask for action.

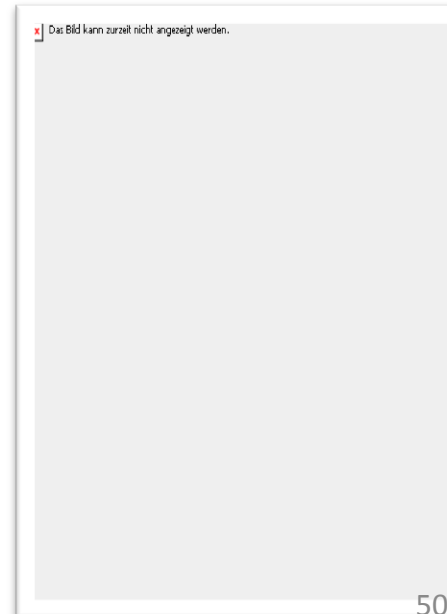
Why promote reflecting on ideas?

- To consolidate understanding, students need to reflect and integrate ideas
- Reflection prepares students to interpret new, persuasive messages in the future
- Research supports value of reflection:
 - Chi et al. (2000).
 - Bransford, Brown, & Cocking (1999)
 - Collins, A. & Brown, J. S. (1988)

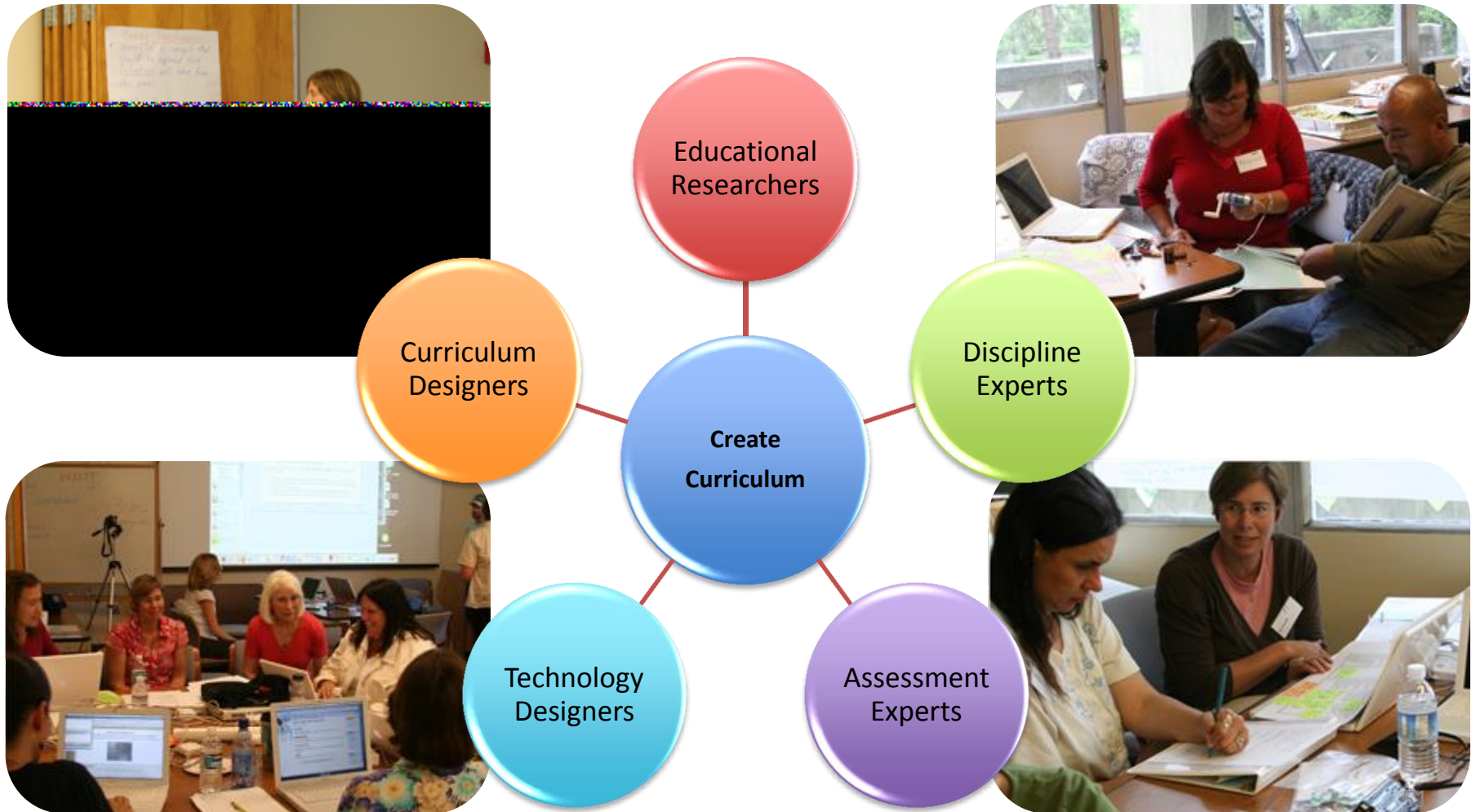


Conclusions: Take Advantage of Research-based Design Principles

- Knowledge Integration (Linn & Eylon)
 - Elicit, Add, Distinguish, Reflect Pattern
 - Elicit/Predict is excellent first step
 - Adding ideas is often main focus of instruction
 - Visualization valuable
 - Distinguishing ideas is VERY DIFFICULT
 - Reflections long history of success
 - One minute lecture summary
- Timing and sequence is important
 - Structure learning



Form Partnerships for Design



Iterative Design of Curricula to Promote Knowledge Integration

- Refine visualizations
 - Remove extraneous information
 - Cue important aspects
- Guide student interactions with visualizations using inquiry activities and automated guidance
- Design assessments that measure goals of instruction and also serve as learning opportunities.
- Use evidence from student work to revise course activities



Start Now at: WISE.berkeley.edu

Welcome to the new wise.berkeley.edu! • Looking for the old WISE? Visit wise2.berkeley.edu.

WISE v4

web-based inquiry science environment

Username: Password:

[Sign In](#) [Forgot Username](#)

Welcome! New to WISE? Sign up for free [Create WISE](#)

Free & Open Source

WISE is a free, open-source tool for science education. It is built on modern open-source technologies and is completely free. Emerging from education research funding, and built on modern open-source technologies, WISE is an active, on-going learning and research tool used by an international community of teachers, researchers, and software developers.

What's New?

WISE included in STEMworks Database Aug 17, 2012

WISE has been chosen as an example program that "deepen(s) young people's learning in science, technology, engineering and ..."

[f](#) [t](#)

WISE Projects

[Browse WISE Curricula](#)

WISE Features

- Learning Environment +
- Teacher Tools +
- Getting Started +
- Check Compatibility +

Genetics: Simple Inheritance

Grades 6-8 | 4-5 hours | English

Students will learn about cystic fibrosis, a trait that is controlled by a single gene. Modes of inheritance including dominant and recessive alleles.

The WISE Advantage

WISE In Action

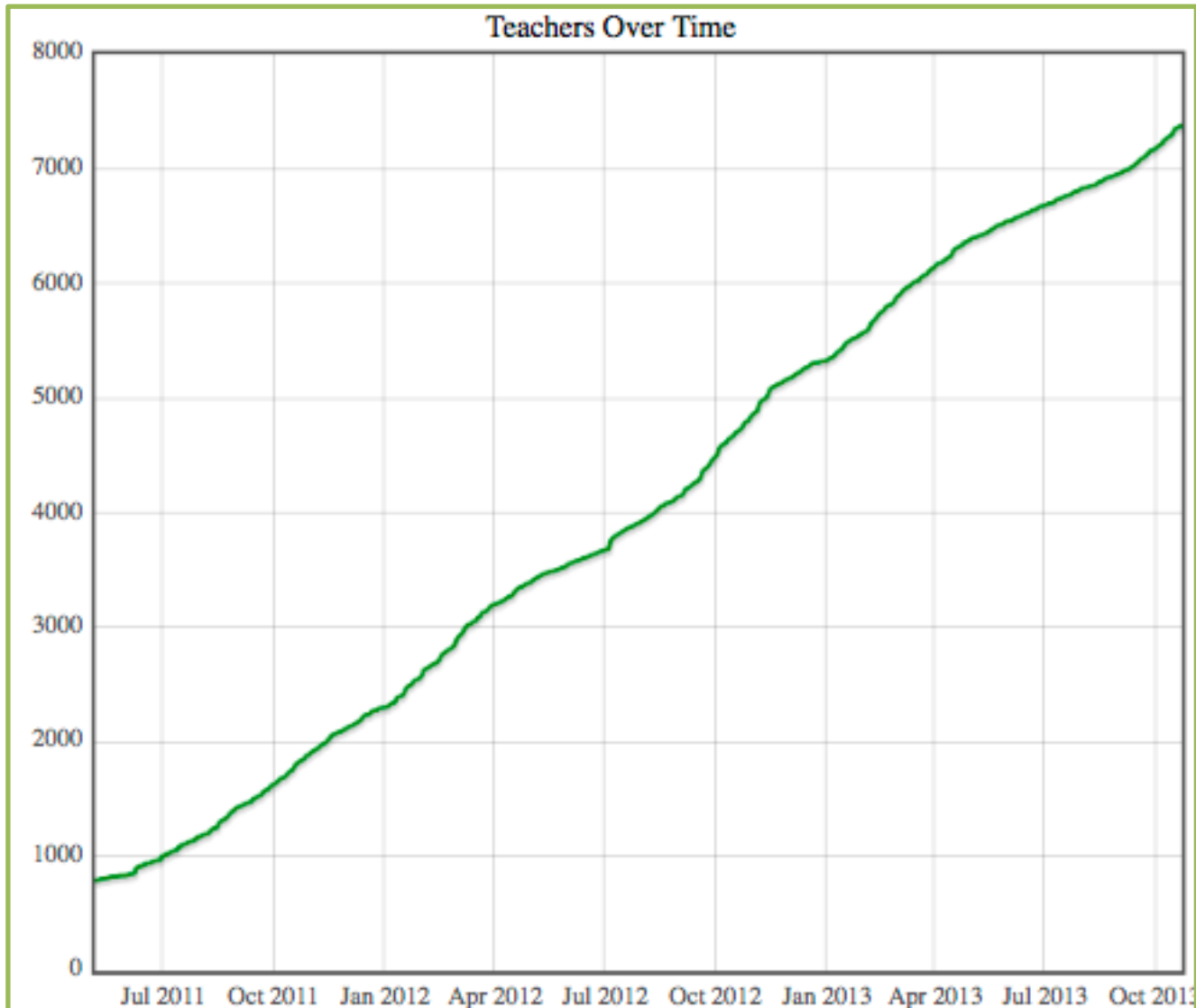
Research Technology

Free & Open Source

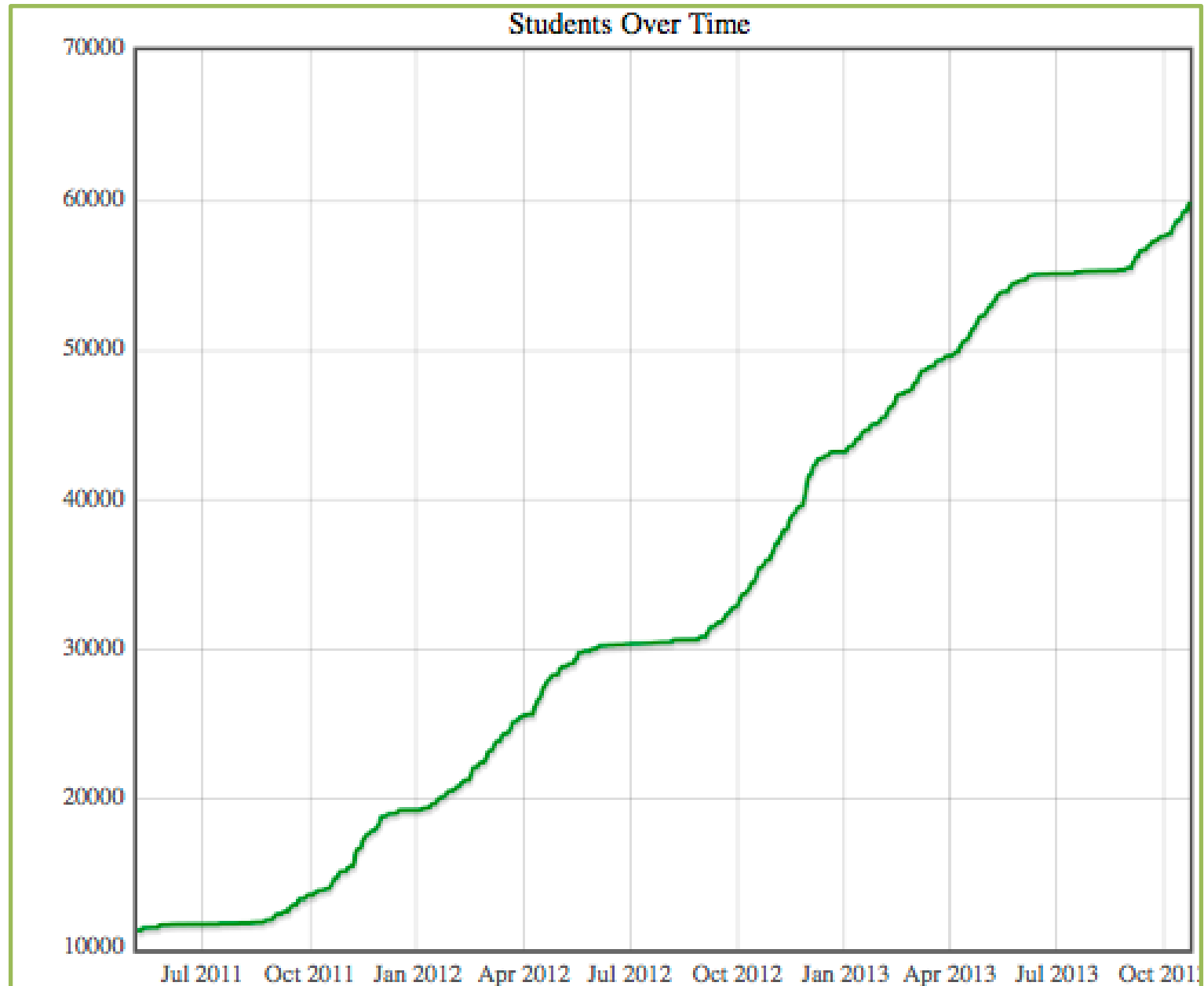
Inquiry Projects for 4th-12th grades

Tools for Teachers to Monitor Progress and Assign Grades

Over 7000 Teachers Using Latest WISE Since Inception July, 2011



Over 60,000 Students Since July, 2011



WISE4 Instances Outside of Berkeley

Institution	Grade/Subject	Notes
University of Virginia	High School/Engineering	Students design structurally-sound community buildings using WISE and 3D Modeling/Printing Software.
University of Seattle	High School/Genome Science	WISE is used to support research on how high school students construct arguments using database evidence.
National Taiwan Normal University	Middle School/Biology, Earth&Life Sciences	WISE interface and several WISE library projects were translated into Chinese.
University of Sydney	Environmental Science	They will be integrating WISE with NetLogo models as well as the Unity3D "Omosa" virtual world for learning science inquiry and predator – prey ecosystems they have developed

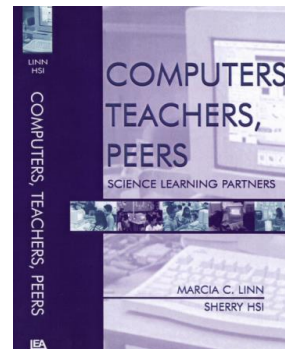
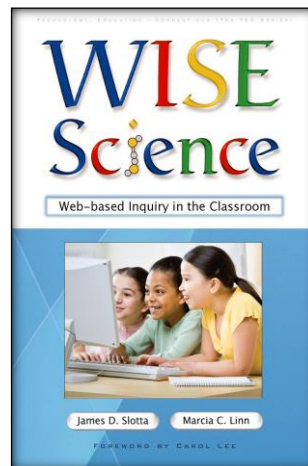
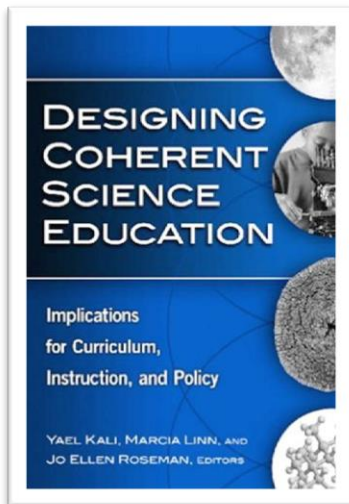
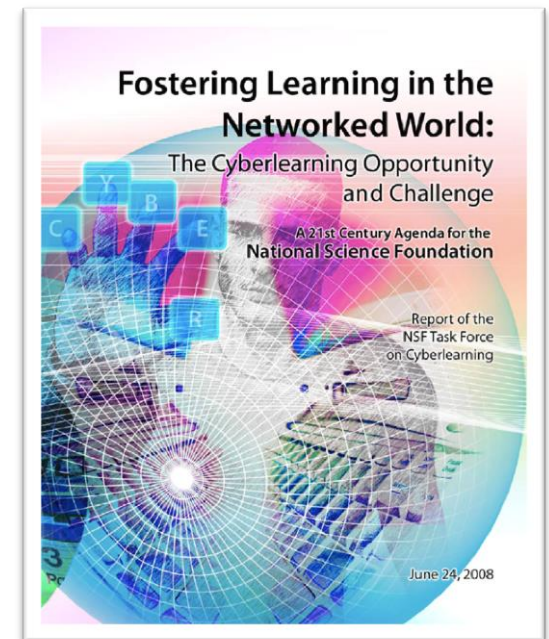
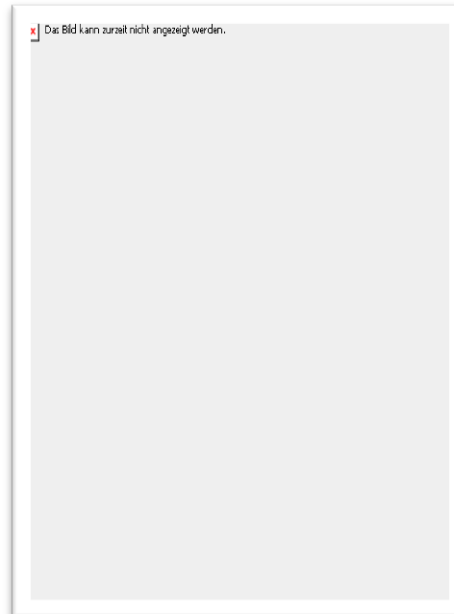
WISE4 Instances Outside of Berkeley

Institution	Grade/Subject	Notes
Concord Consortium, Boston, MA	Middle&High School Science	WISE is used to test integration with 2D and 3D visualizations they build using javascript, flash and java applets.
University of Toronto	Middle&High School Science	WISE is used to test integration with their in-house real-time technology and teacher tools.
Vanderbilt University	High School Physics	Physics-based game engine built using Flash is integrated with WISE. Research analyzes students' science learning processes in digital games with a particular focus on conceptual change, representations, and argumentation in these environments.
University of Tokyo	Middle&High School Science	Translation of WISE into Japanese.

WISE is Free and Available



WISE.Berkeley.edu



mclinn@berkeley.edu