Inquiry Learning

Marcia C. Linn
University of California, Berkeley
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Network of Academic Programs in the Learning Sciences (NAPLeS)
Marcia Linn Background

• **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

[Logos for TELS, WISE, NSF, Berkeley, and Visual]
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?

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

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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 versus Observe: Linn & Songer (1983)
What happens to solar radiation?

After you look at the picture, scroll down to see a model of what happens to solar radiation.

- Incoming energy from Sun
- Reflected energy from Sun
- Energy from Sun transformed into heat energy
- Radiation
- Conduction
- Heat energy transformed into IR
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](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

[Image]

http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html
Watch a Sunray Reflect

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

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

http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html
Watch Heat Transform into IR

http://galapagos.telscenter.org/models/Project_Id_9979_Step_4.3_GCC_Factory_Greenhouse_Effect_annot_with_graph.html
Explore Increasing and Decreasing Greenhouse Gases

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

- Inquiry Map
- Hints
- Embedded Assessments
- WISE Evidence
Knowledge Integration (KI)
(Linn & Eylon, 2011)

Elicit

Add

Distinguish

Organize

Reflect, refine

I think X because...

Moreover...

However...

Moreover...

MAYBE

YES

NO

MAYBE

YES

NO

MAYBE

YES

NO

MAYBE
Adding ideas: Greenhouse Gas Visualization
Students Explore the Visualization: “Probably all the pollution in the air could (make it warmer)”
Students Add Greenhouse Gases

Added 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
Burning coal would produce carbon dioxide which become greenhouse gases, which would break parts of the ozone layer.
Is this your best work?

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?
Knowledge Integration Guidance

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
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

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

<table>
<thead>
<tr>
<th>Solar Radiation (SR)</th>
<th>Heat</th>
<th>Infrared Radiation (IR)</th>
<th>Greenhouse gases</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>With GGas in Atmosphere</th>
<th>Reset</th>
<th>Without GGas in Atmosphere</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Global Temperature</th>
<th>Model_Speed</th>
<th>Watch a sunray</th>
<th>Watch a GGas</th>
<th>Unwatch a GGas</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Celsius</th>
<th>Years</th>
<th>5000</th>
</tr>
</thead>
</table>

- 40

- 0

- 0

- 5000
Carbon dioxide is a greenhouse gas and greenhouse 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.”

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.

What type of energy is this? Where does it come from and where does it go?
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)
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)
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

Create Curriculum

Educational Researchers

Discipline Experts

Assessment Experts

Technology Designers

Curriculum Designers
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

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

<table>
<thead>
<tr>
<th>Institution</th>
<th>Grade/Subject</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Virginia</td>
<td>High School/Engineering</td>
<td>Students design structurally-sound community buildings using WISE and 3D Modeling/Printing Software.</td>
</tr>
<tr>
<td>University of Seattle</td>
<td>High School/Genome Science</td>
<td>WISE is used to support research on how high school students construct arguments using database evidence.</td>
</tr>
<tr>
<td>National Taiwan Normal University</td>
<td>Middle School/Biology, Earth&amp;Life Sciences</td>
<td>WISE interface and several WISE library projects were translated into Chinese.</td>
</tr>
<tr>
<td>University of Sydney</td>
<td>Environmental Science</td>
<td>They will be integrating WISE with NetLogo models as well as the Unity3D &quot;Omosa&quot; virtual world for learning science inquiry and predator – prey ecosystems they have developed</td>
</tr>
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<td>Concord Consortium, Boston, MA</td>
<td>Middle&amp;High School Science</td>
<td>WISE is used to test integration with 2D and 3D visualizations they build using javascript, flash and java applets.</td>
</tr>
<tr>
<td>University of Toronto</td>
<td>Middle&amp;High School Science</td>
<td>WISE is used to test integration with their in-house real-time technology and teacher tools.</td>
</tr>
<tr>
<td>Vanderbilt University</td>
<td>High School Physics</td>
<td>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.</td>
</tr>
<tr>
<td>University of Tokyo</td>
<td>Middle&amp;High School Science</td>
<td>Translation of WISE into Japanese.</td>
</tr>
</tbody>
</table>
WISE is Free and Available

WISE.Berkeley.edu

mclinn@berkeley.edu