Preparing Students for Independent Inquiry Learning

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LEARNING THROUGH INQUIRY IN HIGHER EDUCATION: CURRENT RESEARCH AND FUTURE TRENDS (INHERE)
MUNICH, GERMANY
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Thank You To WISE Project

Libby Gerard, Jonathan Lim-Breitbart, Emily Harrison, Jennifer King Chen, Adi Kidron, Geoffrey Kwan, Jacqueline Madhok, Camillia Matuk, Beth McBride, Kevin McElhaney, Kihyun Ryoo, Jim Slotta, Charissa Tansomboon, Hiroki Terashima, Jonathan Vitale, Eliane Weise, the Linn Research Group

Lab-centric Computer Science

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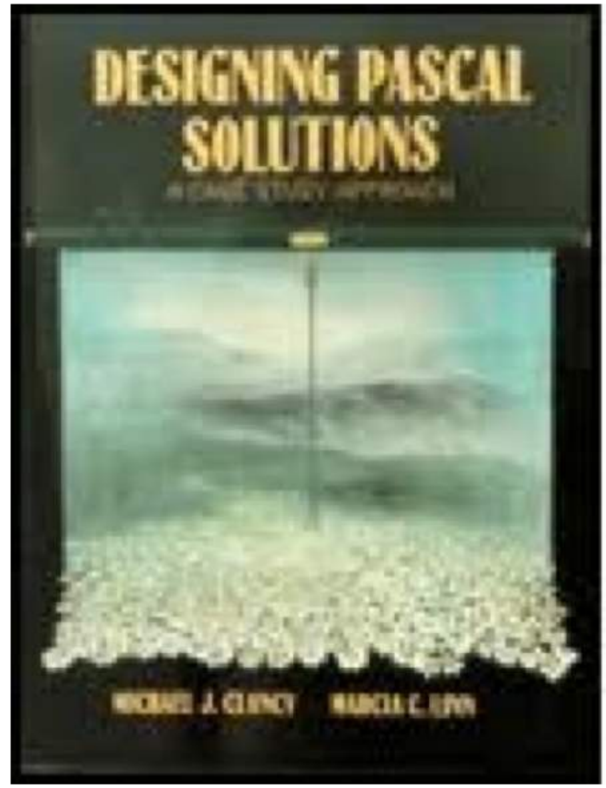
- Flipped classroom in the 90s
  - No lectures! Berkeley questioned contribution of the instructor: Mike Clancy
- Linn, M. C. & Clancy, M. J. (1992) The case for case studies, *Communications of the ACM 35* (3), 121-132.
- "Online curricula for monitored, closed-lab first-year CS courses", NSF grant DUE-0443121), 2005.



Linn, M. C. (1995). Designing computer learning environments for engineering and computer science: The Scaffolded Knowledge Integration framework. *Journal of Science Education and Technology*, *4* (2), 103-126.

National Research Council Report, 2017

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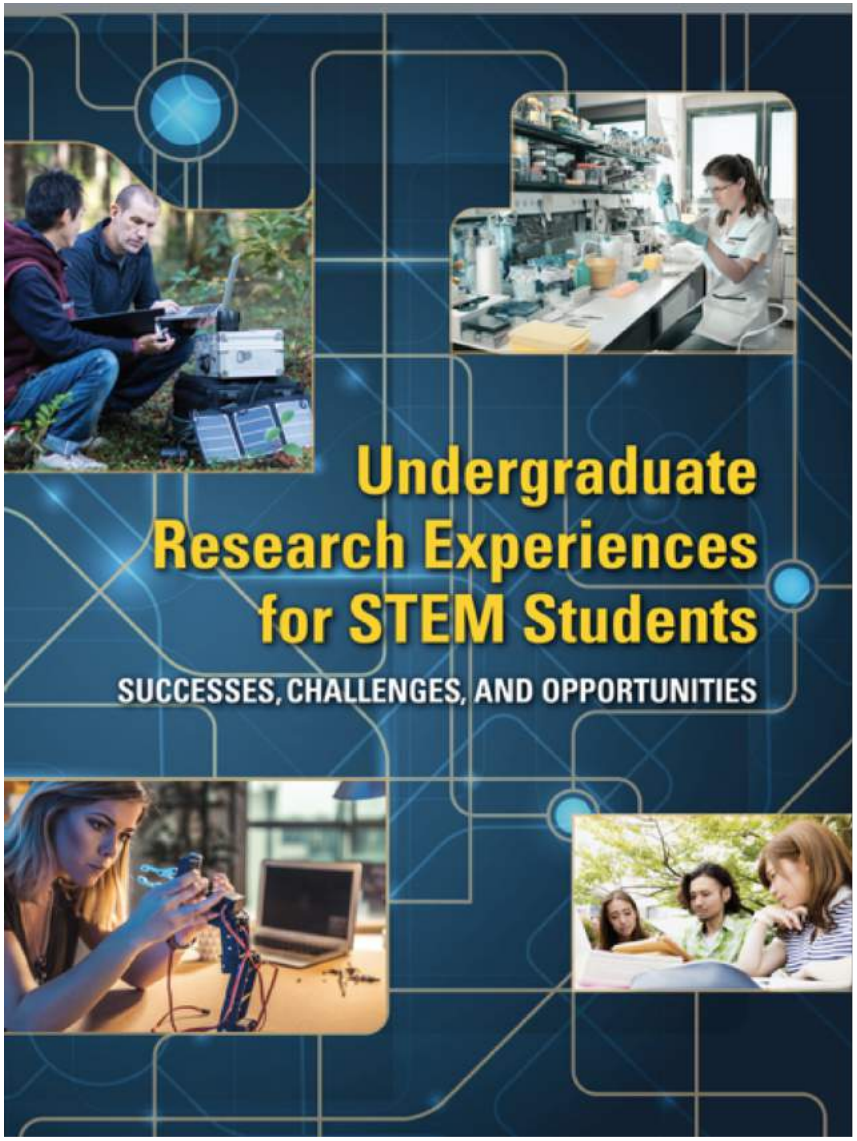

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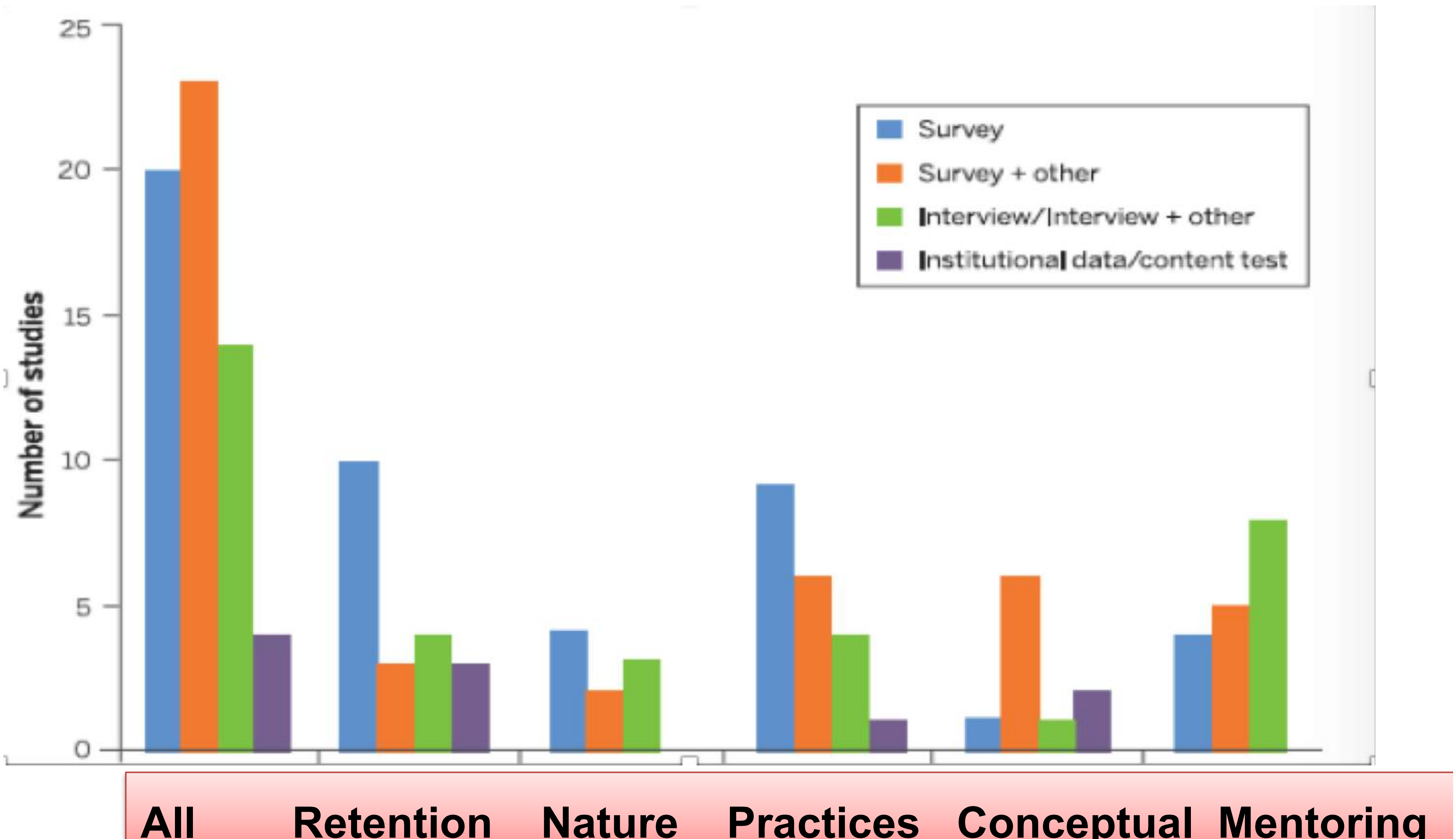
Evidence For Undergraduate Research Impact is Largely Self-Report



CURES Short and UREs Long

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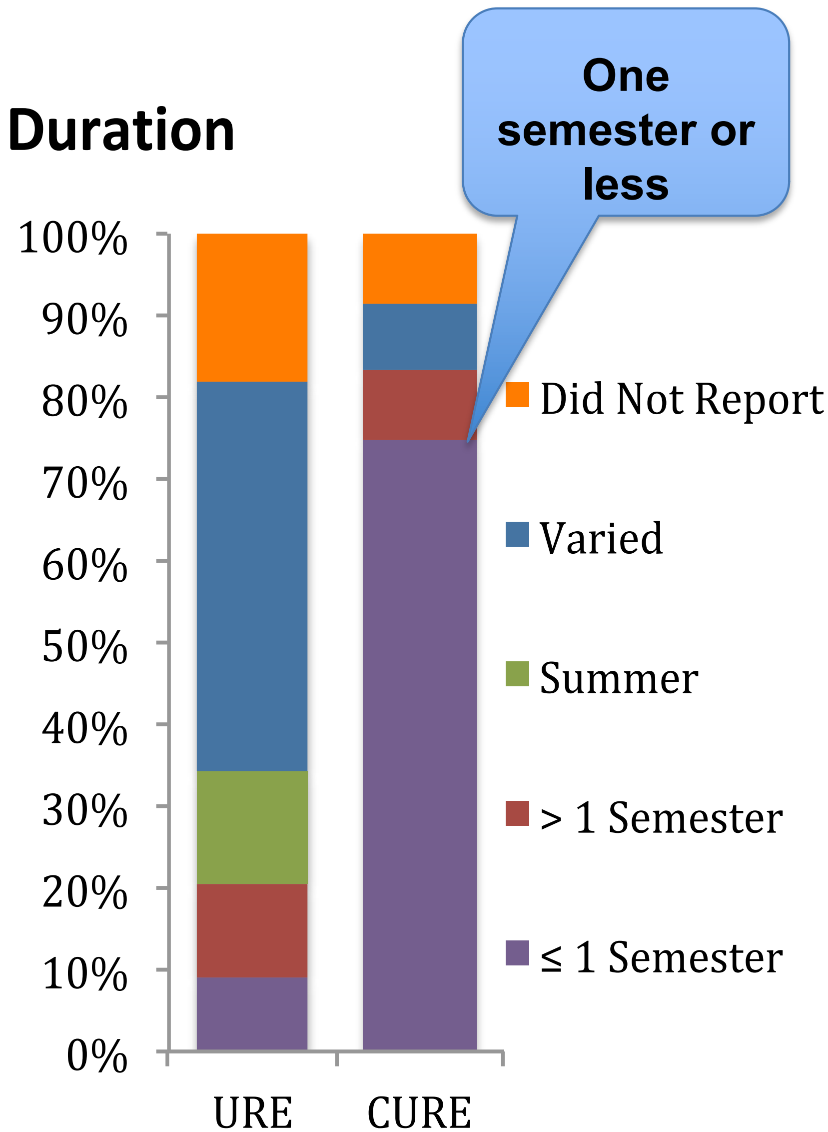

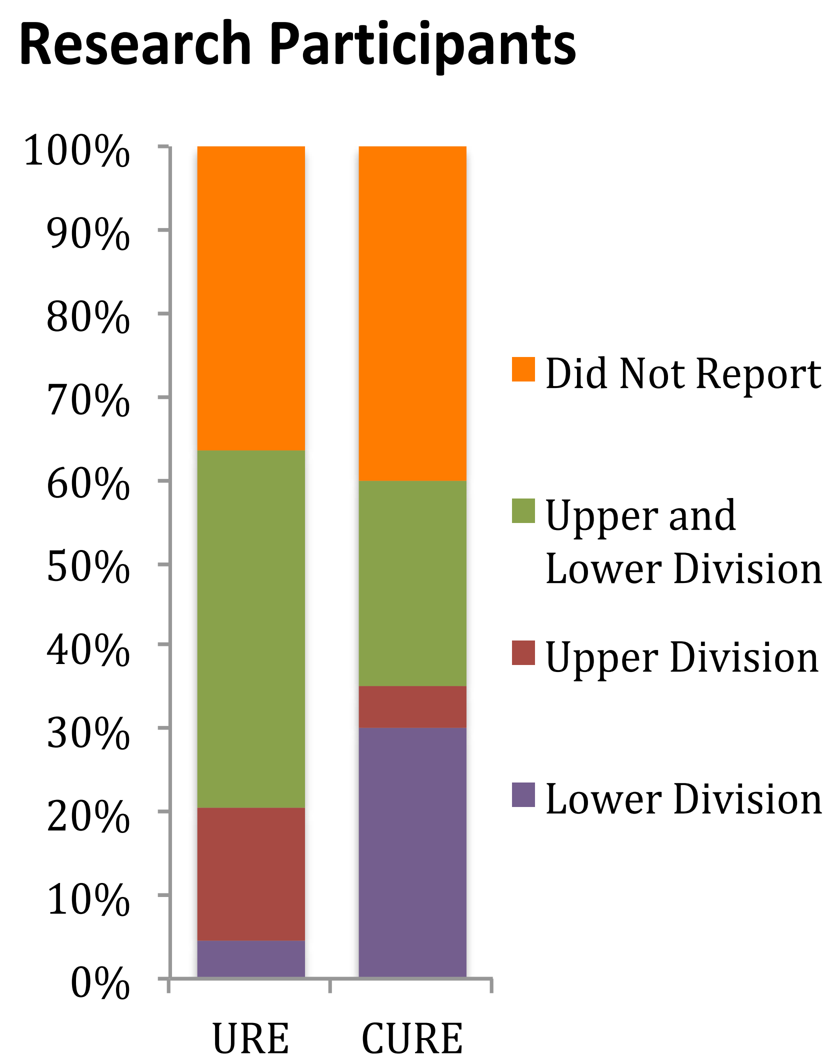

Linn, M.C., Palmer, E., Baranger, A., Gerard, E. & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, 347, 627.

Report Conclusions

Taking the entire body of evidence into account, …the published peer-reviewed literature to date suggests that participation in a URE is beneficial for students.

Basically, participation is not harmful!!

Studies focused on students from historically underrepresented groups indicate that participation in UREs improves their persistence in STEM and helps to validate their disciplinary identity (e.g., Estrada et al. http://thesciencestudy.csusm.edu/index.php?id=39)

Self reported engagement in "Hands-on research activities with laboratory equipment in class" buffered high achieving African American and Latino undergraduates against an increase in performance-avoidance goals over time. (Hernandez et al. J Educ Psychol. 2013 Feb 01; 105(1).)

Little is currently known about mechanisms for how UREs work and which aspects of UREs are most powerful.

Theoretical Perspective:

Design Instruction and Assessment to Promote Knowledge Integration

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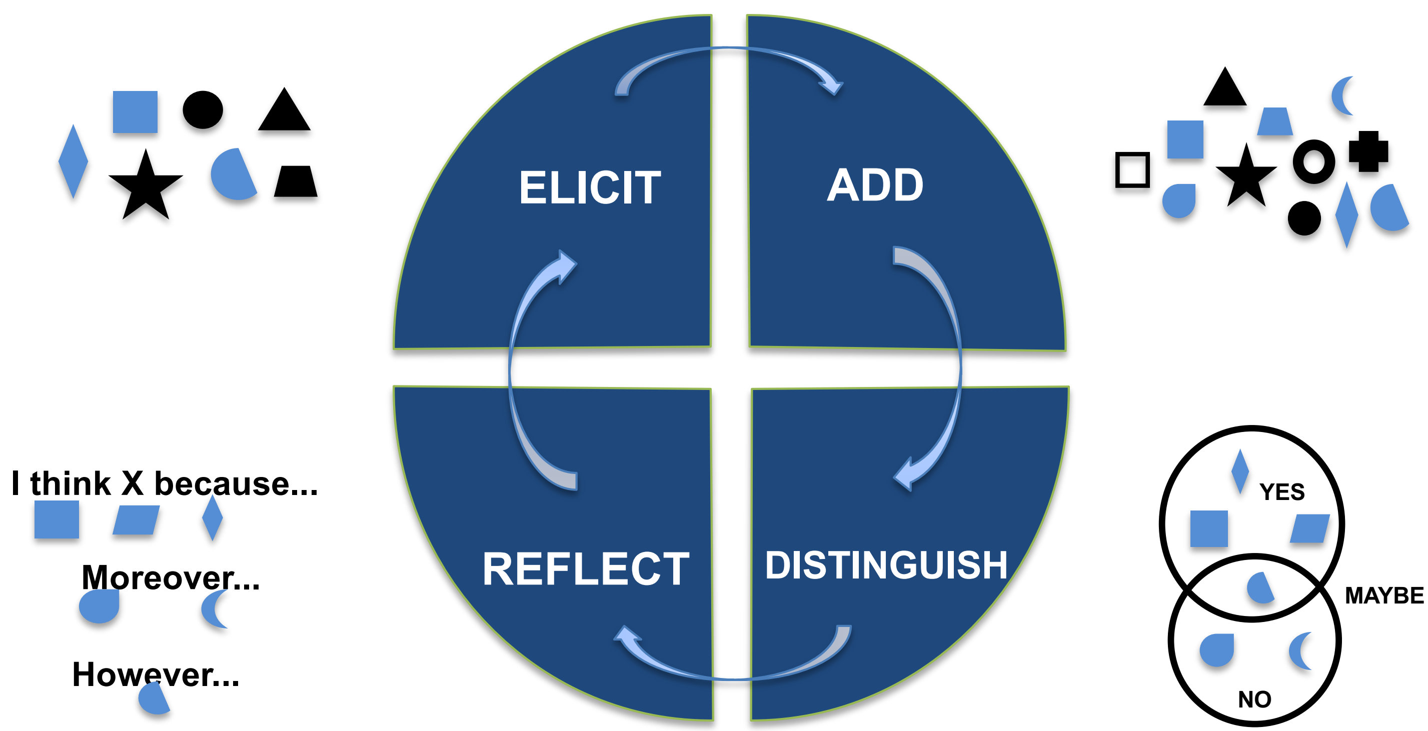

STEM Courses vs. UREs

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Courses impart **fragmented and flawed ideas**

"You first must do, or accomplish, thing A followed by thing B which leads into thing C and ta- da you're done with that list of goals" Stone, 2015

URE's surprise students

"I honestly expected it to be like my organic chemistry lab that I just finished last year [...] I'm used to 'here is the procedure, now get to it,' I thought that was what the experience would be like" Cartrette, et al. 2012, pg. 1084

Collaborators at Berkeley

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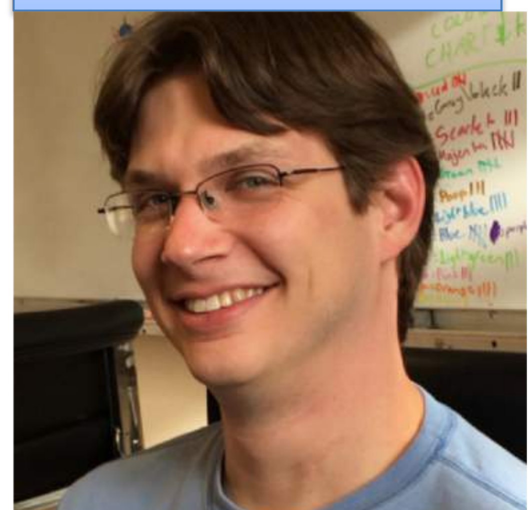
Anne Baranger

Elissa Stone

Erin Palmer



Max Helix

Sloan Foundation
Barbara White Fund
NSF IUSE
NSF Research Experience for Teachers
NSF GRFP

Study Students and Faculty [Preliminary]

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Can Students Answer Inquiry Questions About Posters Reporting Their Research?

- CURE Students
- URE Students
- URE Faculty

Interviews of students and faculty.

Student interviews conducted during a poster presentation.

Poster Presentation Assessment

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- Allow student to present without interruption
- Then prompt to elaborate on topics including:
    - Significance for science & society
    - Choice of experimental design
    - Knowledge of relevant literature
    - Confidence in conclusions
    - Next steps
- Score with Knowledge Integration Rubric:

  0: Absent; 1: Unrelated; 2: Isolated; 3: Partial Link; 4: Basic Link; 5: Complex Link

Faculty Validate These Goals

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- *“I think this is exactly the overall goal”*
- *“Yeah, this is what I ask them to do. The experience is tailored towards: Here's an experimental question, let's design an experiment to answer that question, what did we get, what does that mean, should we redesign the experiment, did we answer the question, if so, what do we do next?”*
- *“All of these look important, ideally we try to get them doing all of this.”*
- *“This pretty much summarizes what I view to be our contribution to their experience.”*
- Only two (mildly) negative comments in 21 interviews

Summary of Poster and Interview Findings

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Preliminary data suggests

- Progression towards complex links with more research experience.
  - Scientific importance
  - Experimental design, comparisons to alternatives
  - Content knowledge
- CURE students compared to URE have greater:
  - Insights into relevant literature
  - Confidence in design and error analysis
- URE students have GAPS in understanding of
  - Previous work and the literature
  - Societal importance
  - Limitations of experimental design and results
  - Next steps

Summary for Students

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Impacts of Undergraduate Research Experiences (UREs):

- Research experience valuable for
  - Scientific importance
  - Experimental design
  - Content knowledge
- Course valuable for appreciating
  - Previous work and the literature
  - Societal importance
  - Limitations of experimental design and results
- URE students show lack of understanding of limitations

Summary for Faculty

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- Faculty validate the goals of UREs
- Faculty expect undergraduates to learn independently or by observation
- Faculty expect mentors to know how to mentor, think mentoring is common sense
- Faculty unsure about mentor training,

Learning Sciences Connections

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Learning Sciences Connections and Implications

- The knowledge integration framework informs design, (Linn & Eylon, 2011)
  - Elicit. Students determine, refine question
  - Add. Effective faculty point to possible resources, do not provide ‘right answer’?
  - Distinguish. Students supported to test and refine their ideas in lab
  - Reflect. In poster presentation

Intentional Knowledge Integration: Example of Human Impacts on Climate Change

- What causes climate change?
- How might a 12 to 14 year old respond to this question?
- Talk to someone sitting near you.
- Discuss what you think middle school students might say.

Elicited Student Ideas

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

"Littering, it is bad to litter"

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

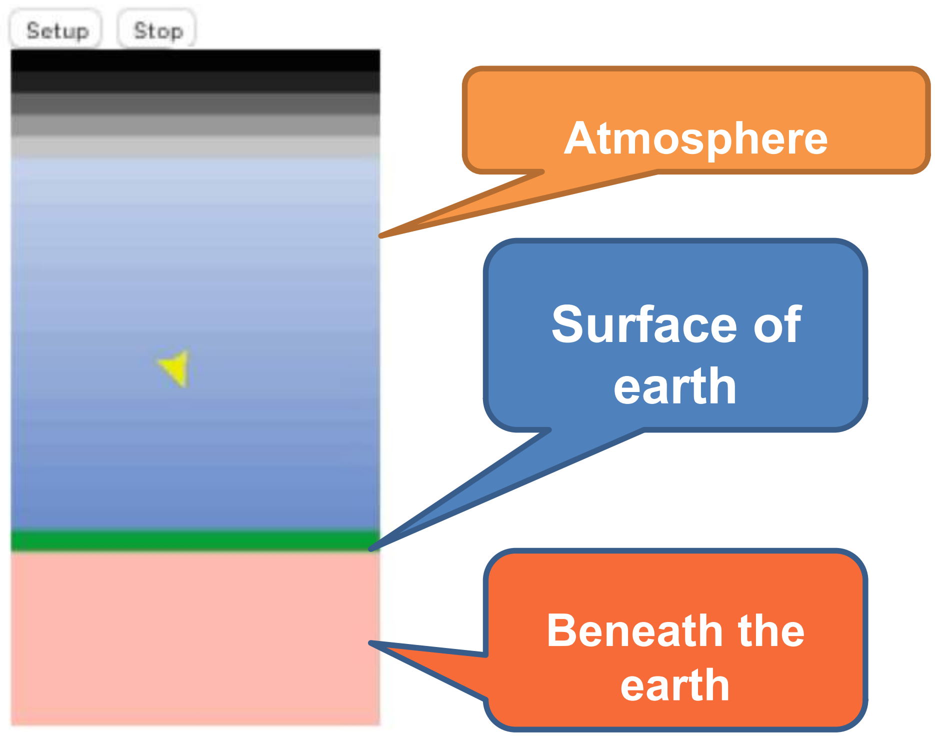
"My dad got a car, I saw…there was kind of smoke coming out of the car and it was really hot. Every car that I see pass by I see that coming out."

"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."

Adding Ideas: What happens when solar radiation hits the earth?

Solar Radiation

Heat



What happens to solar radiation after it hits the earth?

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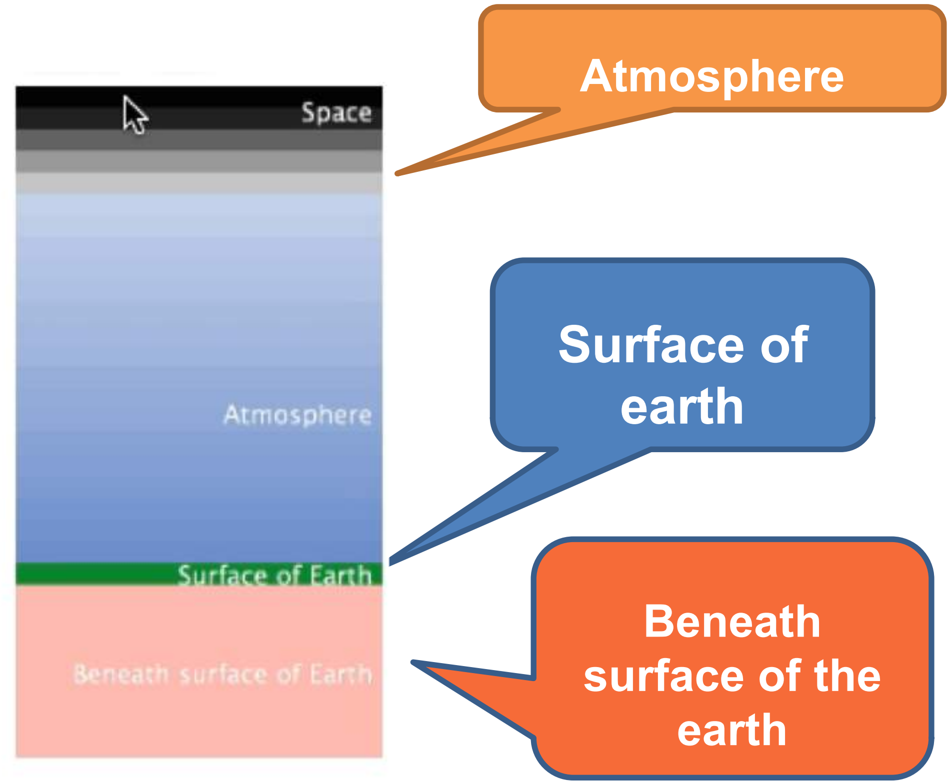
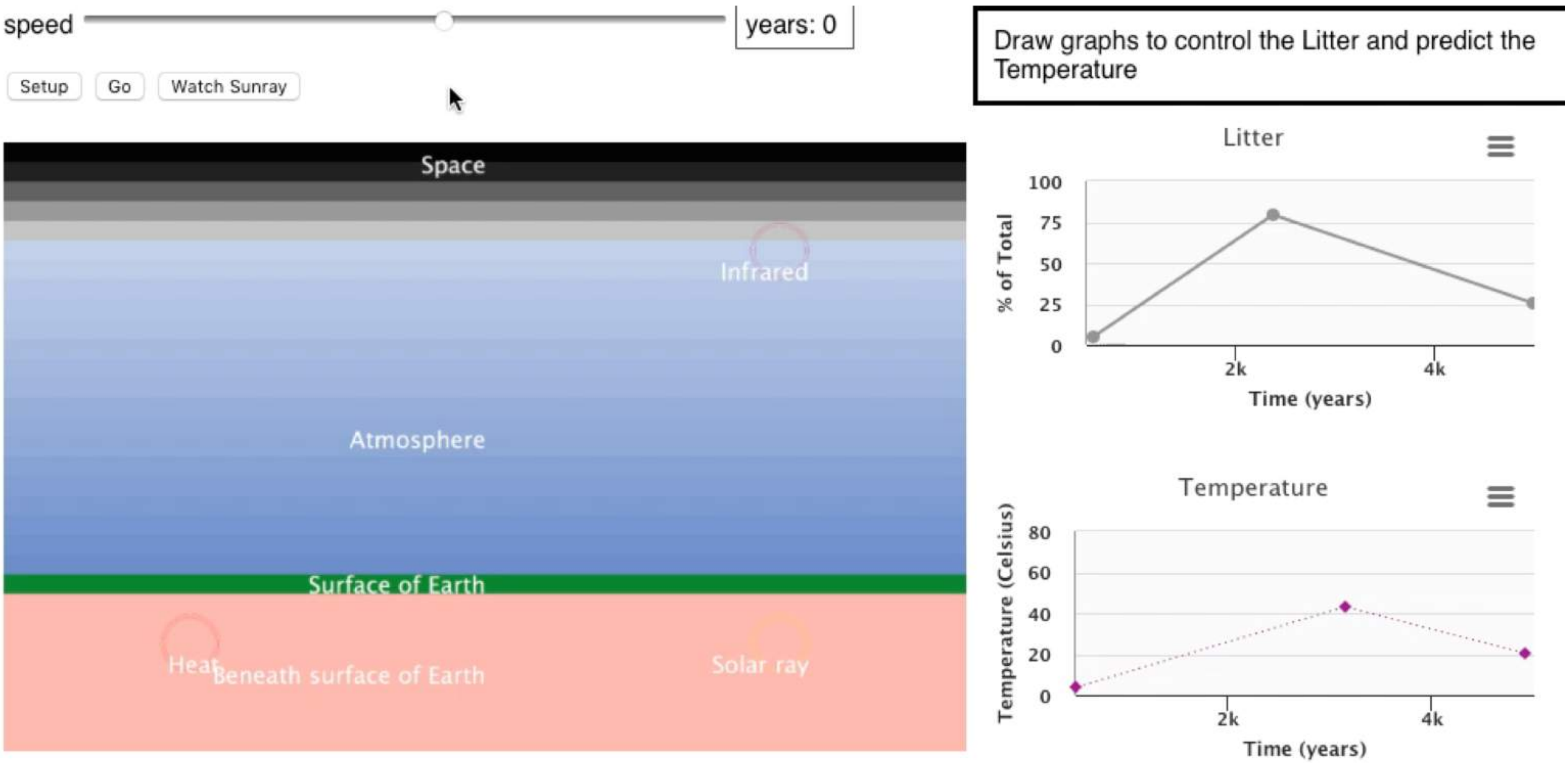
Solar Radiation

Infrared Radiation

Heat



Human Impacts: Litter



Human Impacts: CO2

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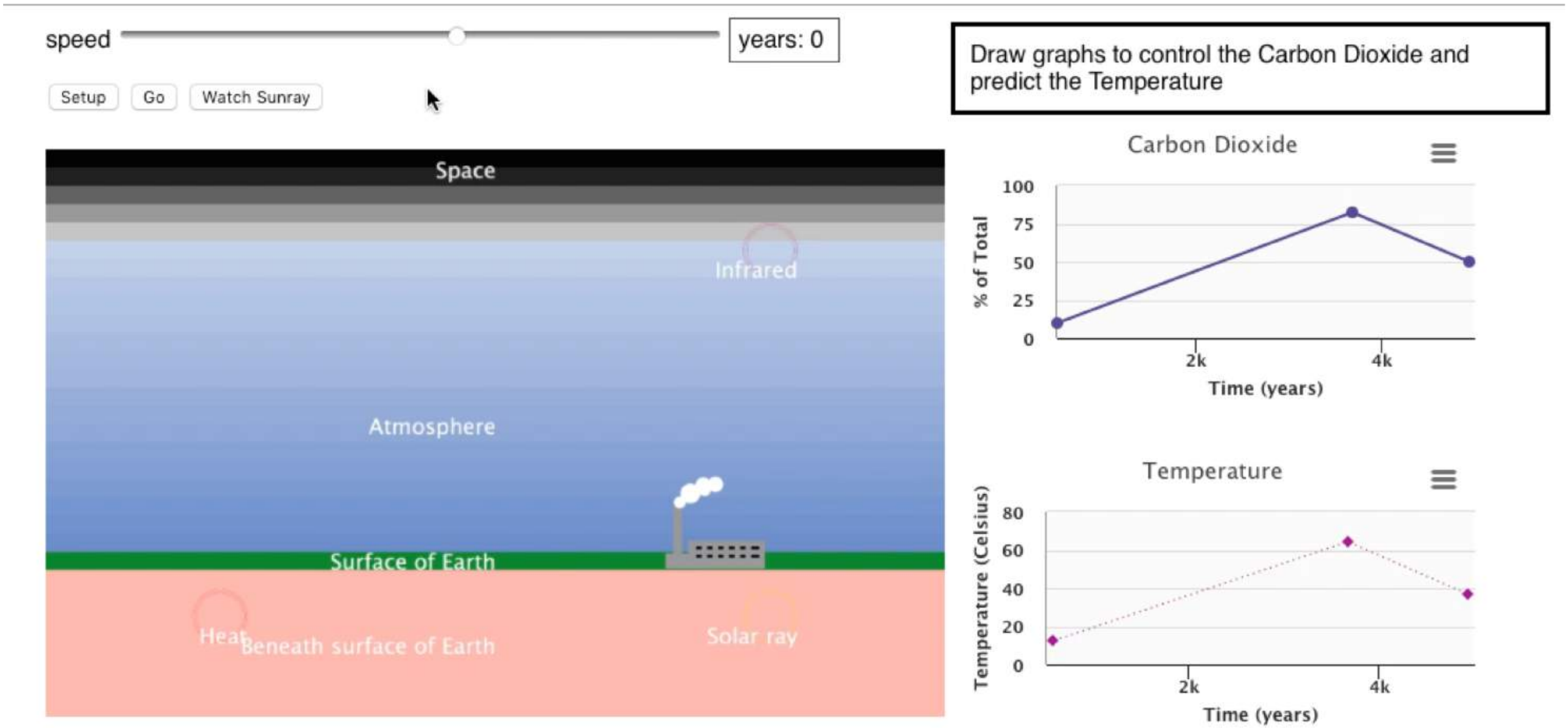
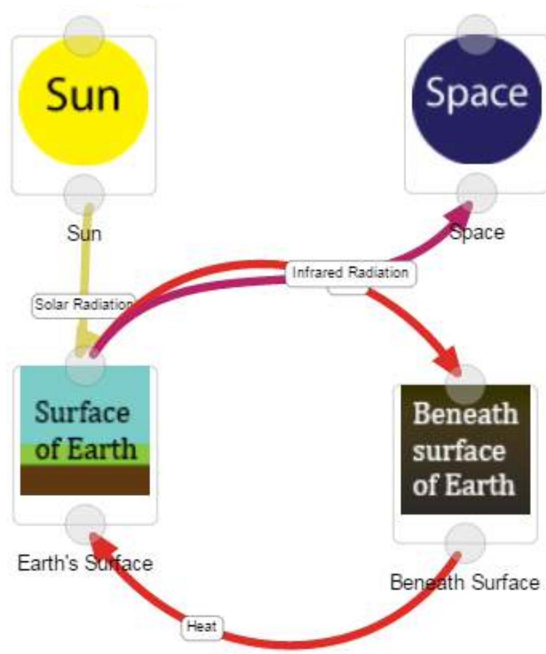
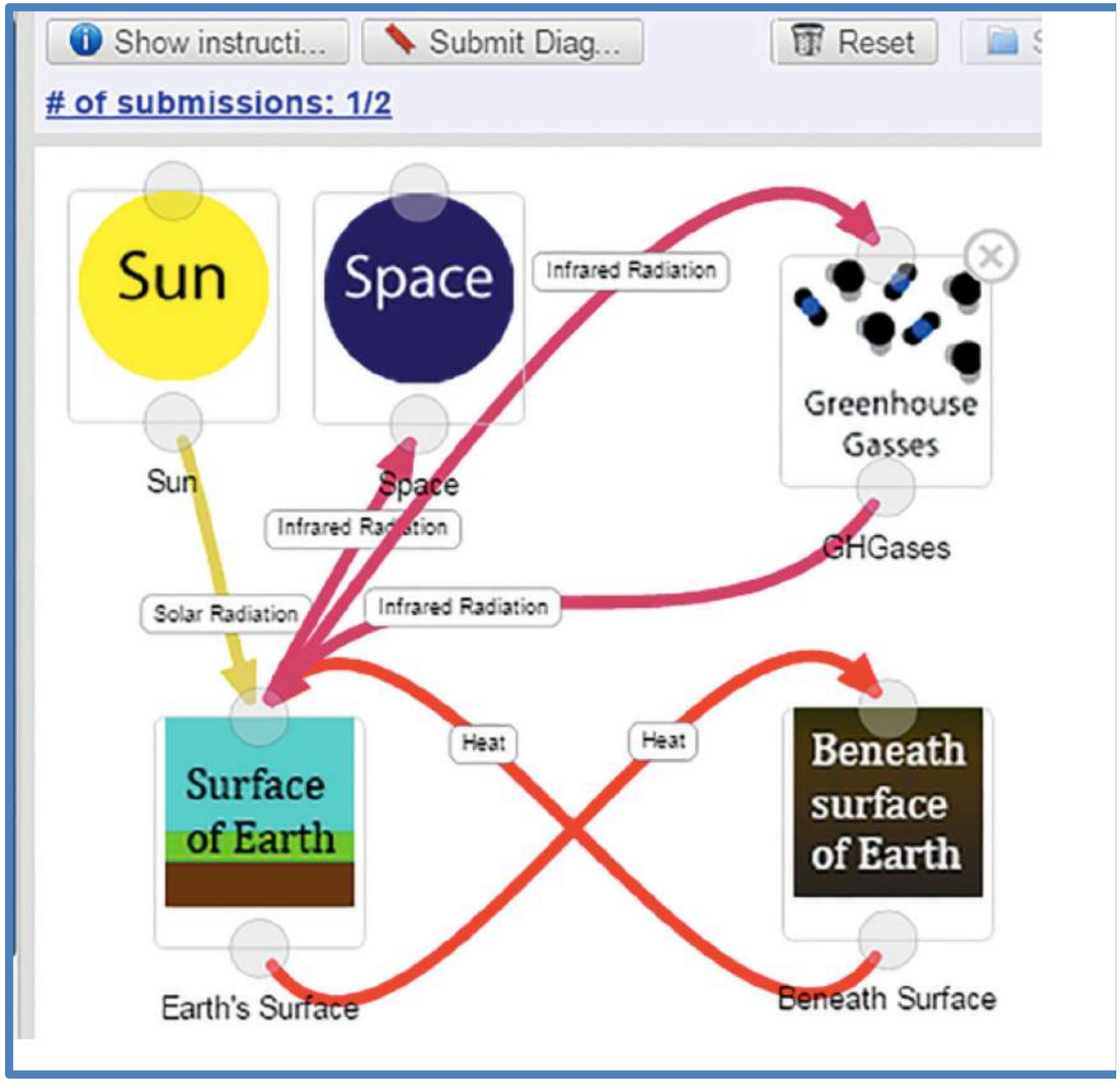


Creating a MySystem Diagram

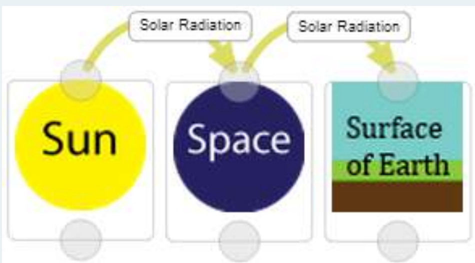


MySystem

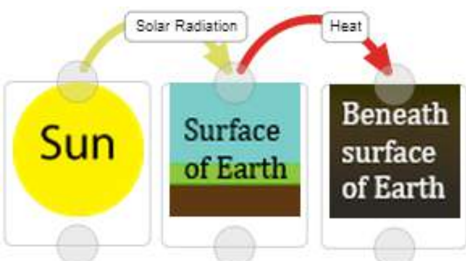
Students represent their ideas



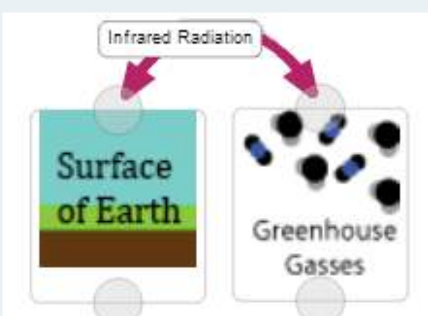
MySystem: Illustrates How Model Works



Energy comes from the sun. As the energy goes through space, it's called electromagnetic waves.



When the energy reaches the Earth it either gets absorbed or reflected. If the energy gets absorbed, it turns into heat energy which then goes back to the surface of the earth.



The infrared is trapped by greenhouse gasses or GGases and turned into heat, keeping the Earth warm. Too many GGases can be harmful, though.

Knowledge Integration vs. Specific Guidance

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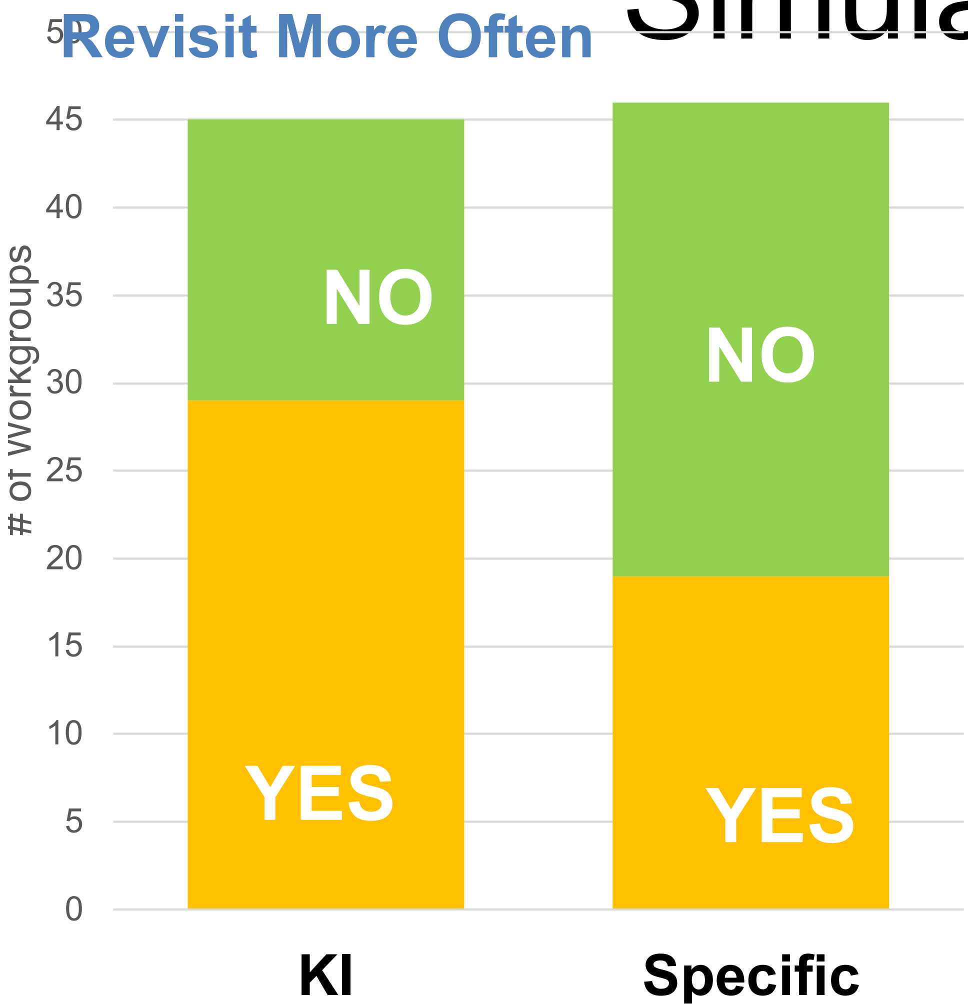
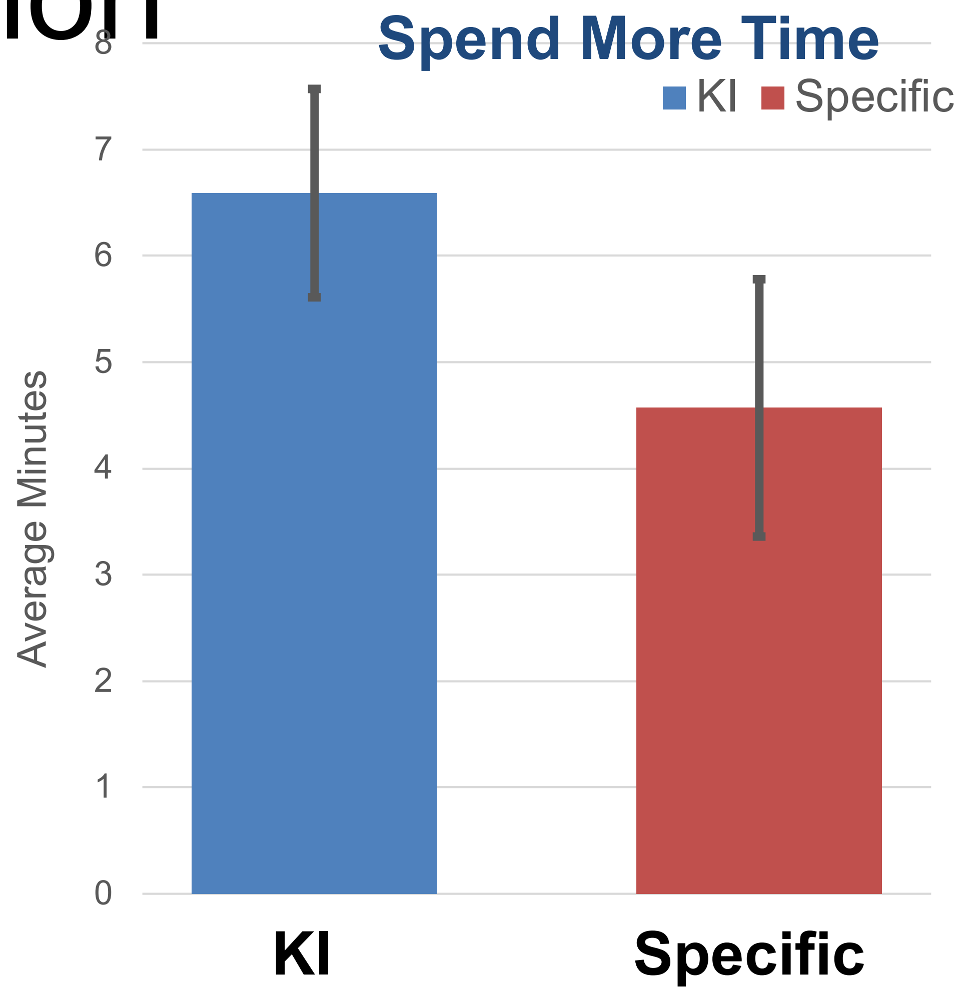
KI Guidance: **Ask students to reconsider evidence and revise their diagram**	**Specific Guidance:** **Tell students how and what to improve in their diagram**
Good progress, but your answer can be improved. To improve your response return to Step 3.3 to **find out how carbon dioxide in the atmosphere affects the global temperature by interacting with energy** released by the	Good progress, but your answer can be improved. To improve your response recall from Step 3.3 **that carbon dioxide in the atmosphere increases the global temperature by trapping infrared radiation** released by

Knowledge Integration: Students Interact More With the Simulation

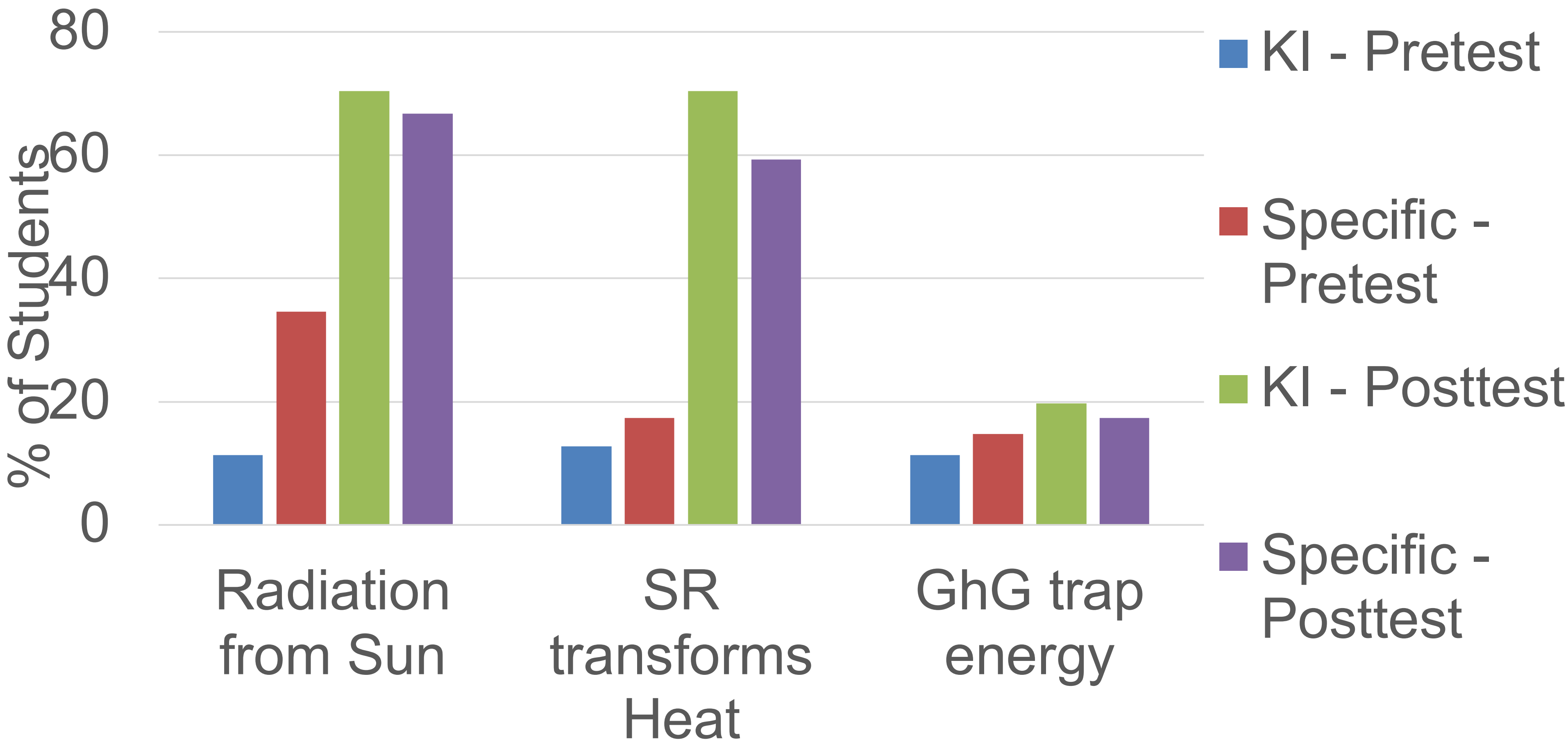


$\chi^2(1) = 4.0, p < .05$



$t(55) = 1.3, p > .1$

Knowledge Integration Students Use More Normative Ideas to Justify their Responses



Reflection. Explain how the Earth is warmed by energy: Consider where energy comes from, how it moves, and how it transforms

KI Rubric Level 1: I don't know; off task

2: Irrelevant or incorrect

3: Partial link Greenhouse gases make the climate warmer

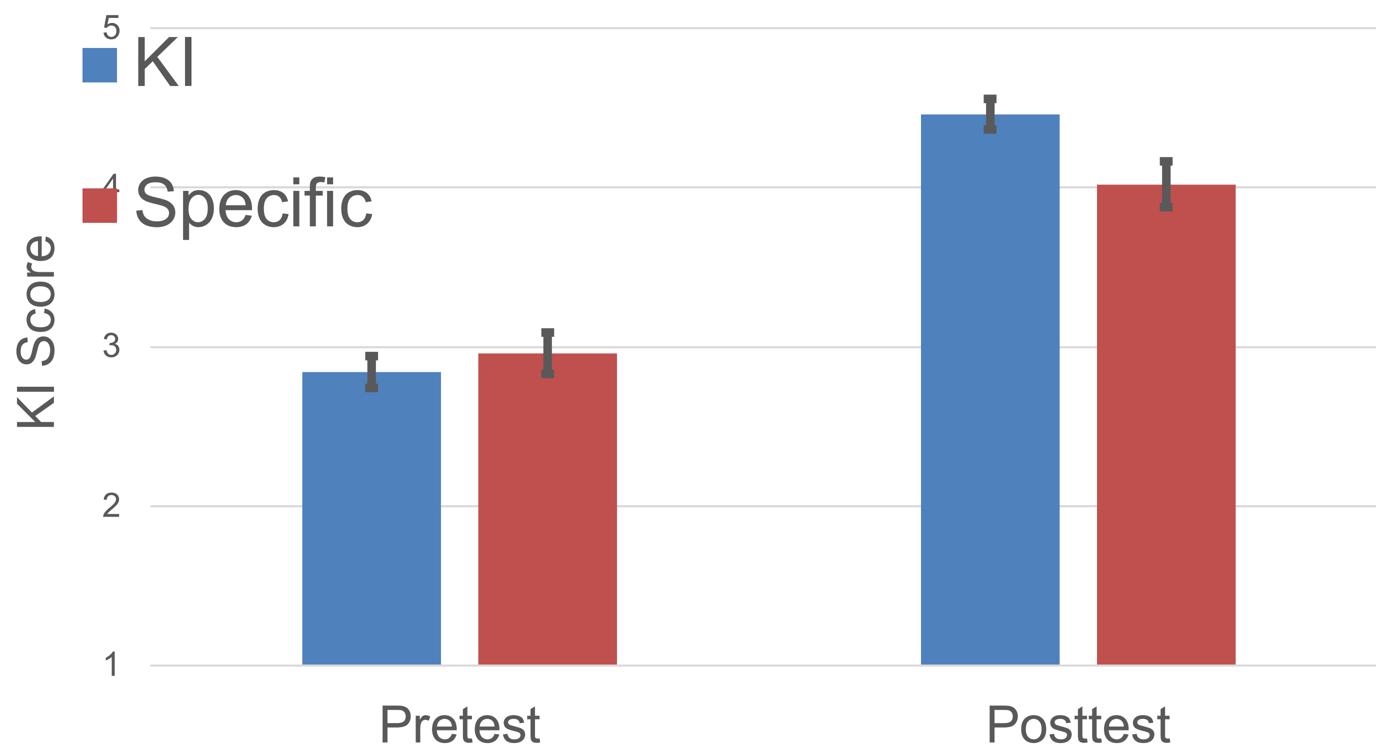
4, 5: One point for each unique, valid link

When the energy reaches the Earth it either gets absorbed or reflected. If the energy gets absorbed, it turns into heat energy (2 links)

The infrared is trapped by greenhouse gasses and turned into heat, keeping the Earth warm (1 link)

Knowledge Integration Significantly Outperform Specific from Pretest to Posttest

Desirable Difficulty: Specific improves performance during learning but knowledge integration leads to long term retention



Regression on posttest score (controlling for pretest)
KI Condition: B = 0.5, SE = 0.2, β = 0.2, t = 2.4, p <.05

MySystem and Essays

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English Language Learners (ELLs) perform equally to native speakers on MySystem.

Both groups make equal gains on Energy Stories

ELLs have lower scores that native speakers on Energy Stories.

Conclusions

Learning Sciences Connections and Implications

- Precollege, undergraduates, and graduate student mentors need scaffolding to succeed (Furtak et al)
- *Poster Interview* distinguishes between course and URE; captures the advantages of multiple semesters of research
  - Needs further analysis

Implications

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- Pilot results suggest that a course is more effective than a URE for a one semester program
- Combinations of undergraduate experiences have multiple benefits
- Faculty have limited confidence in mentor professional development

Research Approaches

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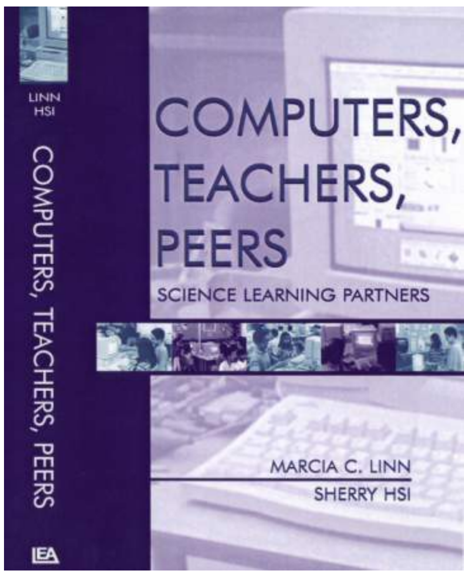
Selection Bias. Students selected for undergraduate research experiences have already had success: High GPAs, aspire for academic degree.

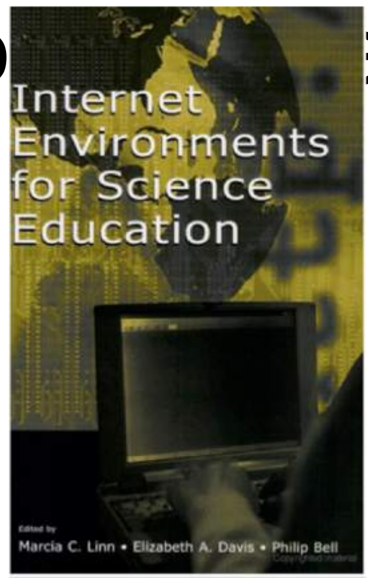
Matching Controls. Propensity Score Matching is best option. Not perfect.

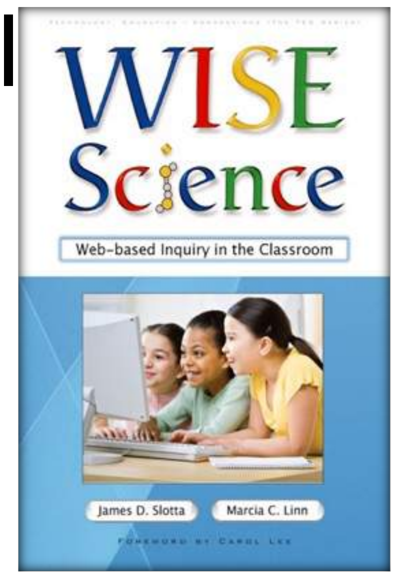
Design Research. Compare alternatives to see which works best.

Pedagogical Framework

- Knowledge integration informs design of instruction, assessment, and mentoring

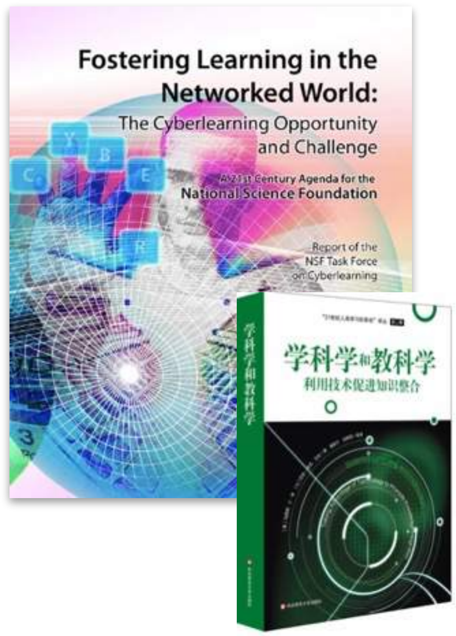






2000 **2004** **2009** **2011 [2015]**

WISE is Free and Customizable



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