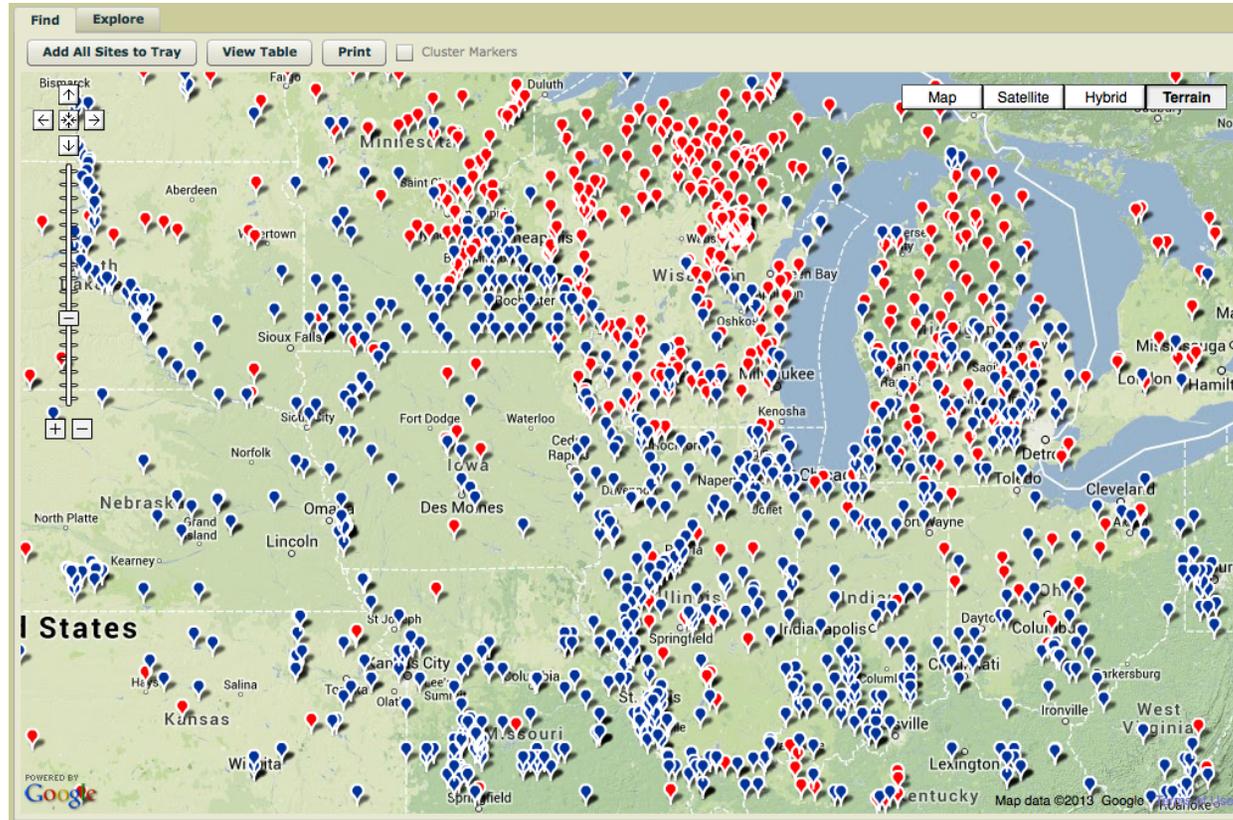


Best Practices in Teaching with Data: Lessons from Research on Learning

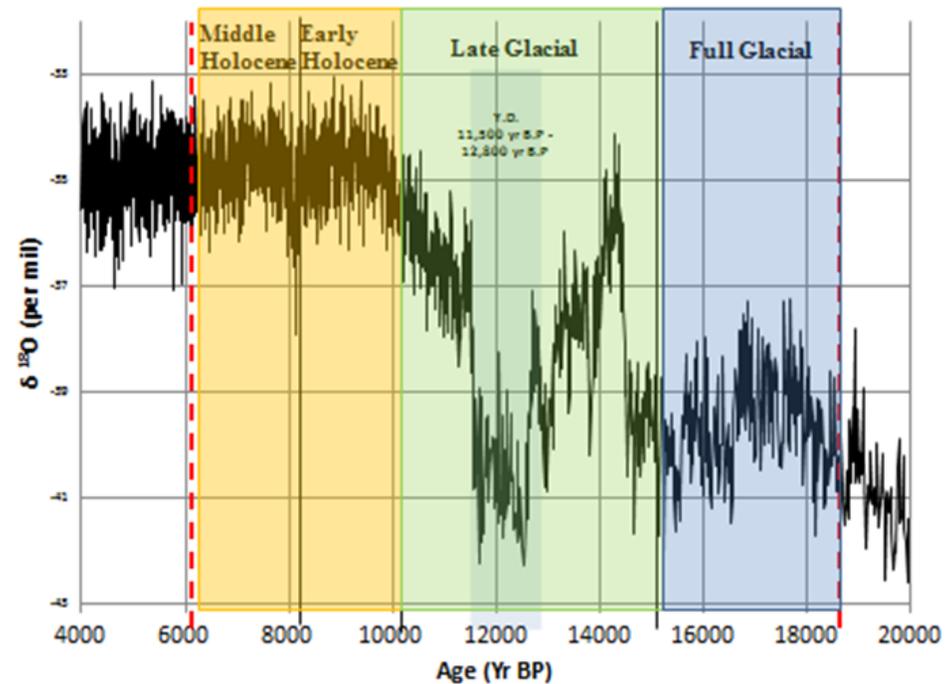


Carol Ormand, SERC, Carleton College

2015 Workshop on Teaching with the Neotoma Database

What do we mean by 'Teaching with Data?'

Data = Output of scientific research



Modified from GRIP, 2003

Data Collection

Problem Sets

Labs

Undergraduate Research

Diagrams

Models

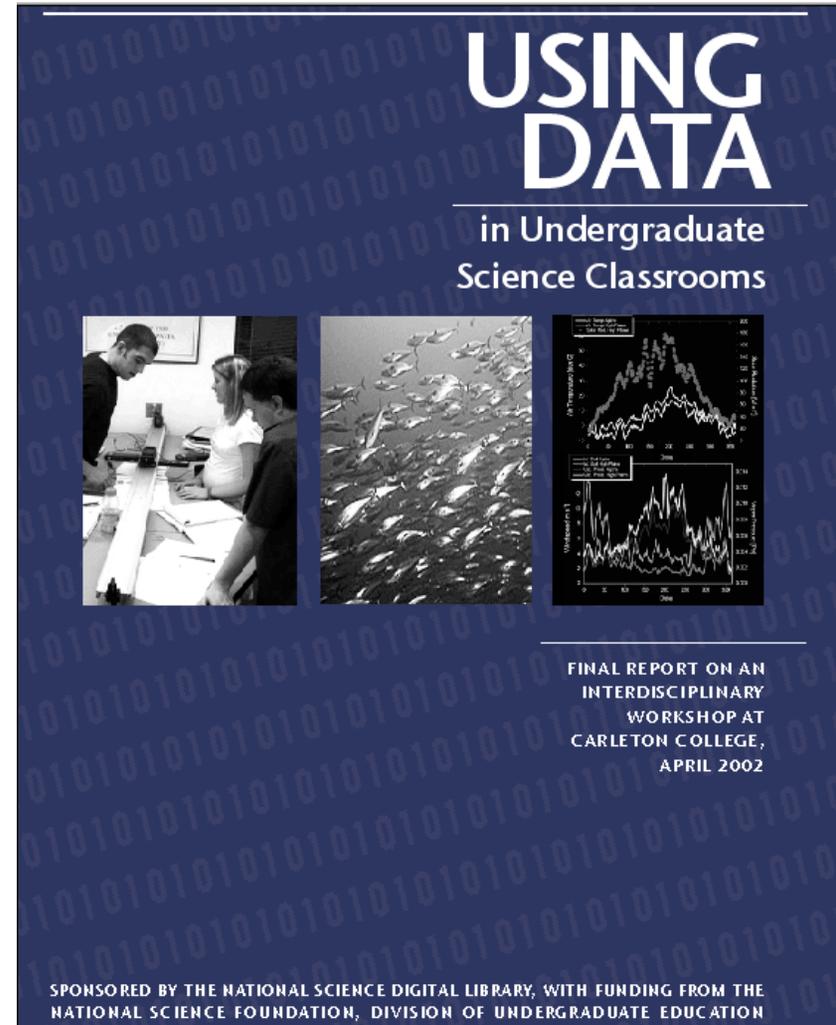
Visualizations

Service Learning

Why Teach with Data?

Faculty Say

- To prepare students to address real world complex problems
- To develop students' ability to use scientific methods
- To prepare students to critically evaluate the validity of data or evidence and of their consequent interpretations or conclusions
- To teach quantitative skills, technical methods, and scientific concepts
- To improve verbal, written, and graphical communication skills
- To train students in the values and ethics of working with data



**USING
DATA**

in Undergraduate
Science Classrooms

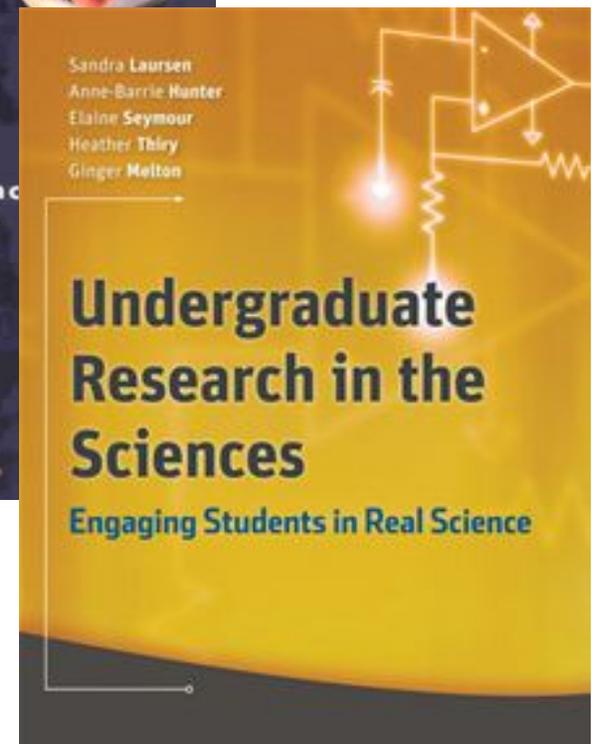
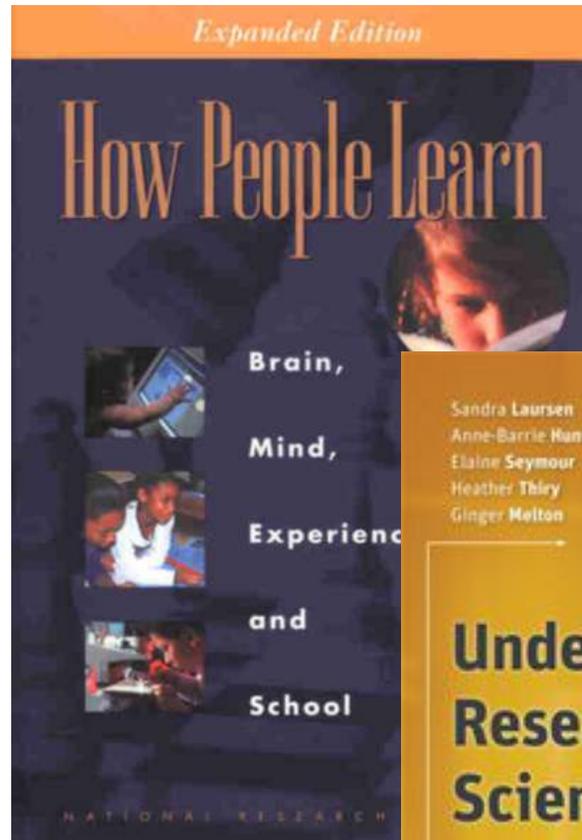
FINAL REPORT ON AN
INTERDISCIPLINARY
WORKSHOP AT
CARLETON COLLEGE,
APRIL 2002

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NATIONAL SCIENCE FOUNDATION, DIVISION OF UNDERGRADUATE EDUCATION

Why Teach with Data?

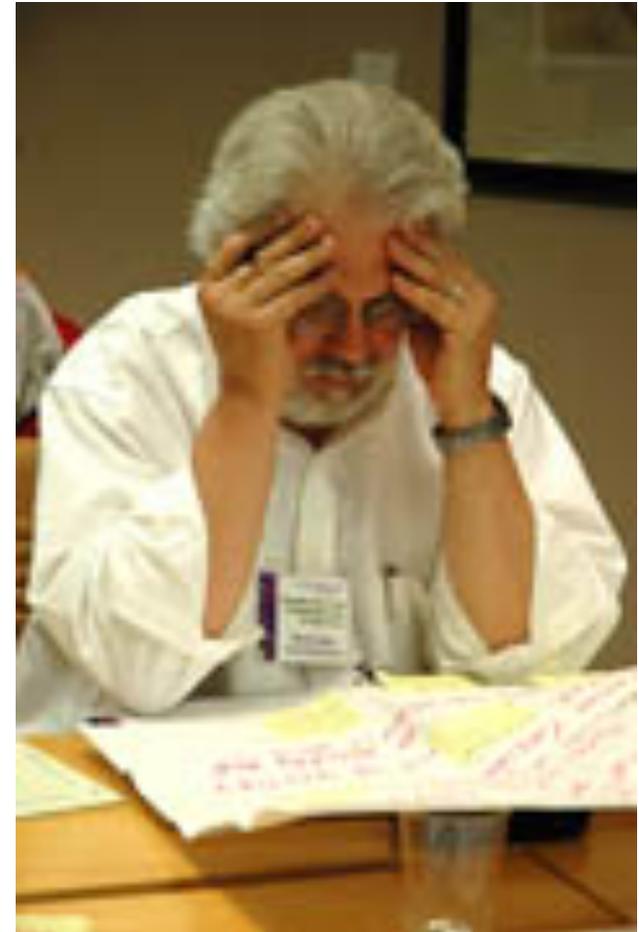
Researchers say

- Rich cases tie to prior knowledge
- Gaining sensitivity in preparation for future learning
- Authentic experience of science
- Adaptive scientific problem solving
- Confidence

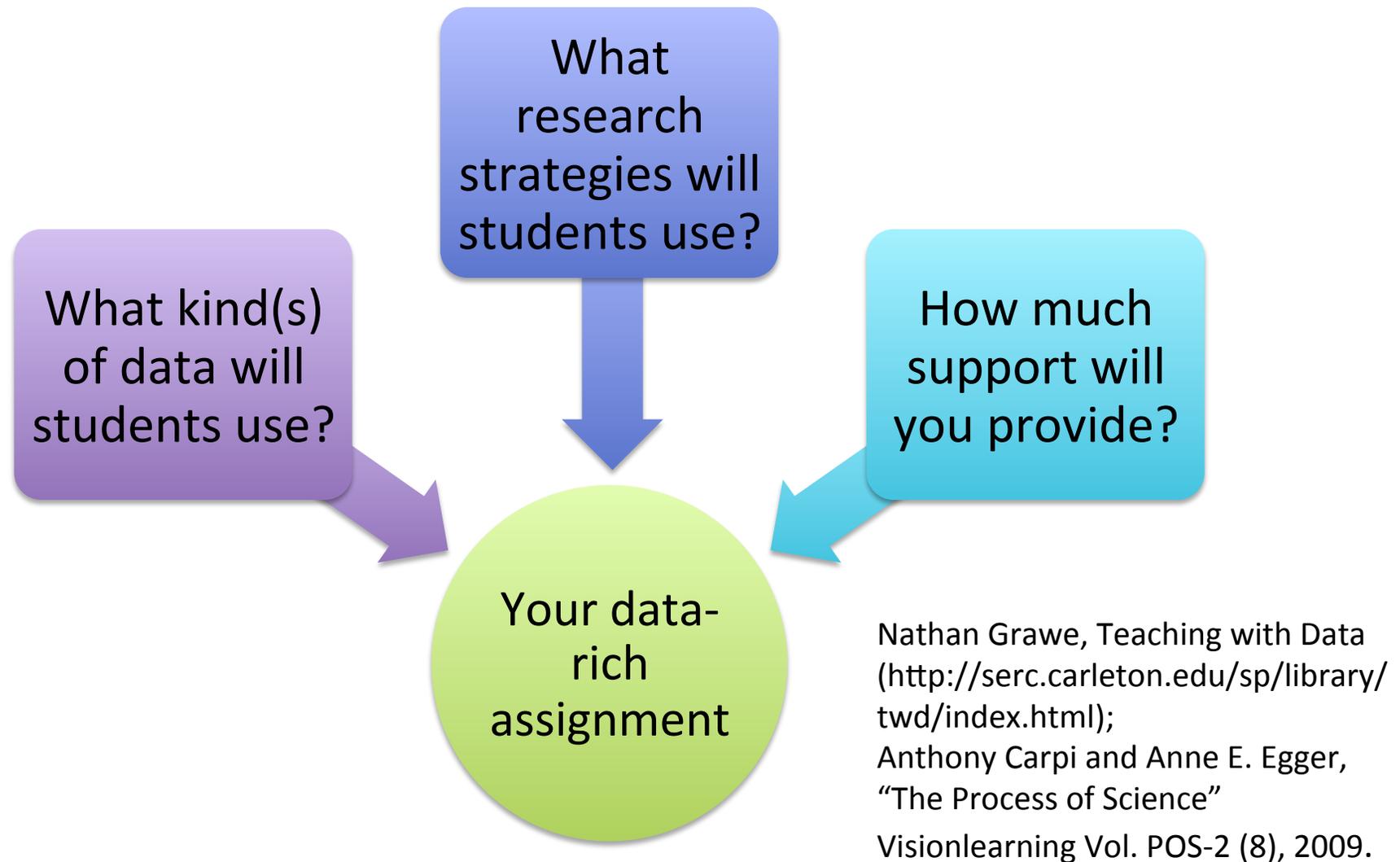


Why is Teaching with Data Hard?

- Matching level of student expertise to the data-rich problem
- Finding/developing data analysis tools that can be mastered
- Preparing data and designing the activity
- Assessment/grading
- Course content vs. data exploration time tradeoff



Best Practices for Teaching with Data



Designing your Data-Rich Assignment: Why Active Learning?



Active learning increases student performance in science, engineering, and mathematics

Scott Freeman^{a,1}, Sarah L. Eddy^a, Miles McDonough^a, Michelle K. Smith^b, Nnadozie Okoroafor^a, Hannah Jordt^a, and Mary Pat Wenderoth^a

^aDepartment of Biology, University of Washington, Seattle, WA 98195; and ^bSchool of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning ($n = 158$ studies), and that the odds ratio for failing was 1.95 under traditional lecturing ($n = 67$ studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (i) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (ii) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Freeman, Scott, Eddy, Sarah L., McDonough, Miles, Smith, Michelle K., Okoroafor, Nnadozie, Jordt, Hannah, and Wenderoth, Mary Pat (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*. (Meta-analysis of 225 studies of STEM learning.)

What Kind(s) of Data will Students Use?

- Processed data
 - Ex: Datasets uploaded to the Neotoma database with calibrated ^{14}C ages
- Published research data
 - Ex: You might give students some of your own published data to work with (probably processed, to some extent)
- Simulated data
 - Ex: Ages based on an age-depth model could be considered simulated data
- Student-generated data
 - Ex: If you take students with you to collect data at your field site and upload it to the Neotoma database, it would be student-generated data
- Data provided by civic partners

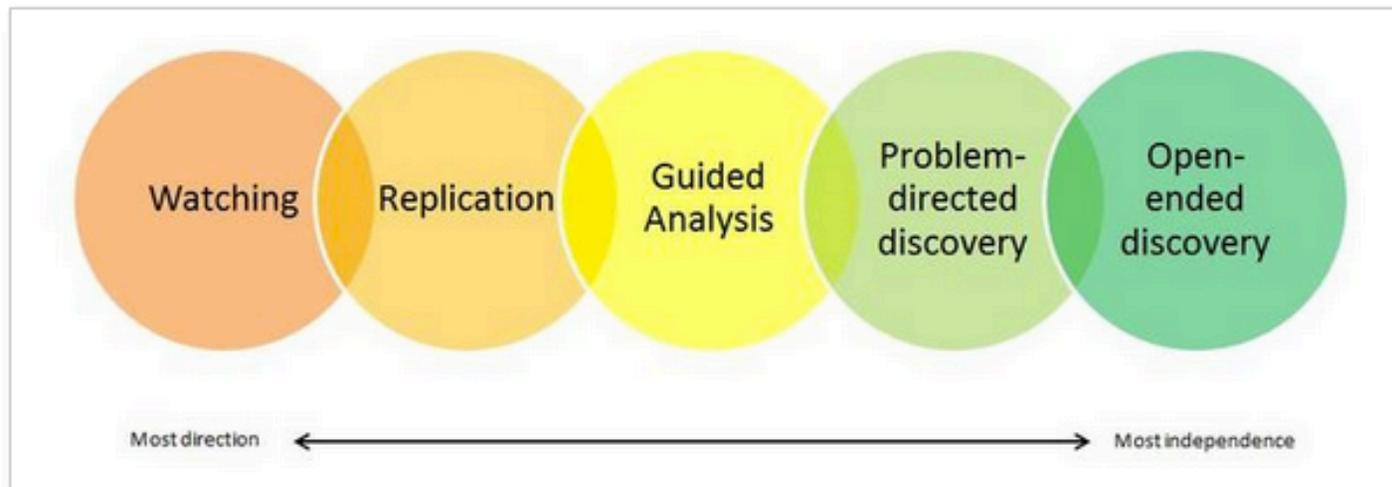
What Research Strategies Will Students Use?

- Experimentation
 - Ex: explore the effect of changing one variable
 - It's hard for me to think of how to do this in teaching with historical data (such as that in the Neotoma database)
- Description
 - Ex: Describe the distribution of spruce forests in North America 10,000 years ago
- Comparison
 - Ex: Compare the distribution of spruce forests in North America 10,000 years ago to now
- Modeling
 - Ex: compare the temperature distributions predicted by a climate model for a particular time period to the distribution of temperature-sensitive species for that same time

How Much Support Will You Provide?

The amount of scaffolding students will need can depend on:

- Students' prior experience working with data
- The complexity of the data and/or interface
- Time available for the activity
- Learning goals for the activity (what do you want students to be able to do after they complete the activity?)

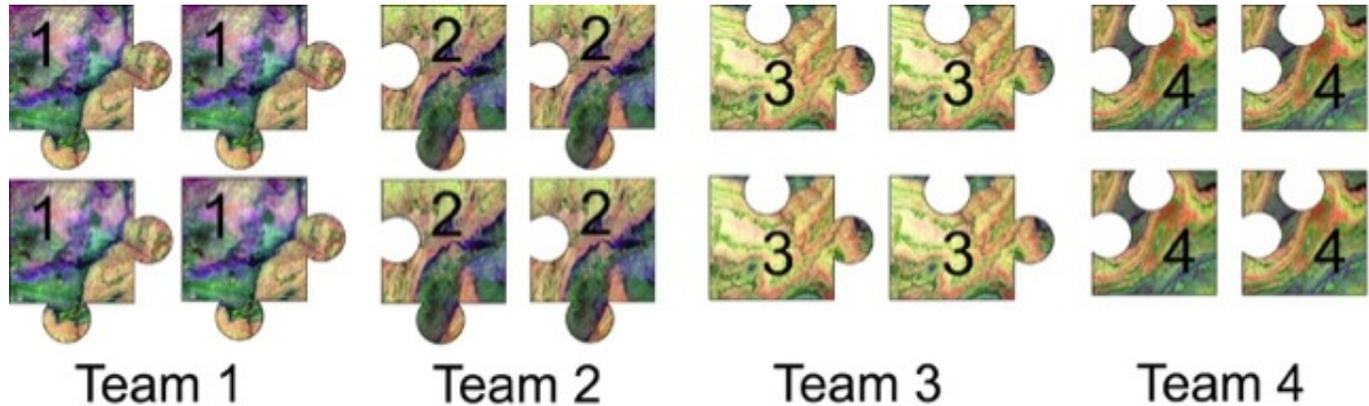


Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

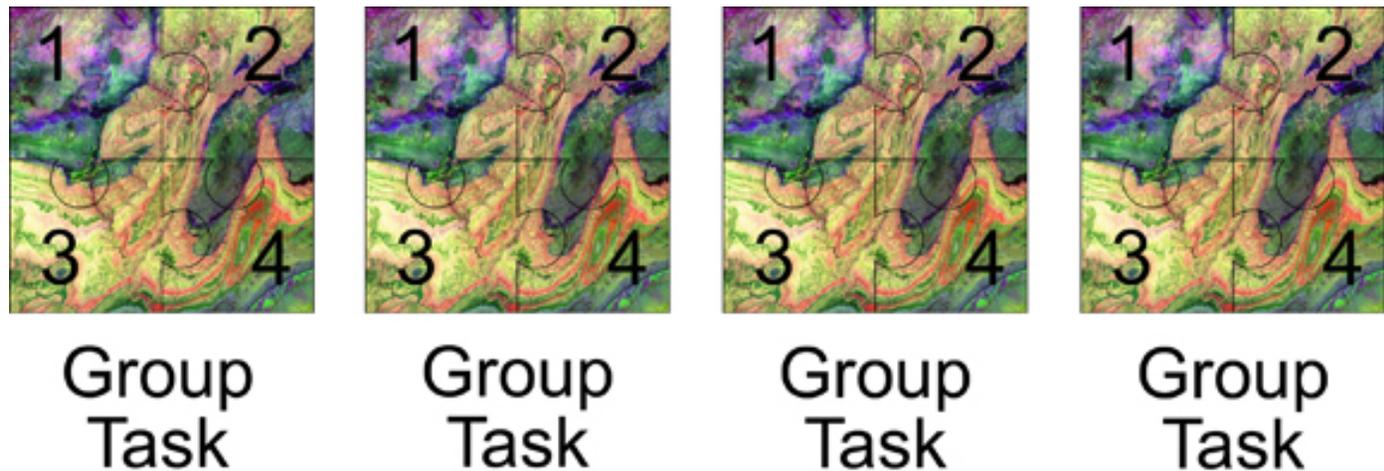
- Begin by articulating learning outcomes
 - If you don't know what you want them to learn, they won't learn it
- Structure the assignment to meet those goals
 - Give students the opportunity to practice whatever you want them to be able to do!
- When is team work beneficial?
 - When it replicates scientific inquiry
 - When you expect some students to struggle with some of the required skills
 - When you want students to be exposed to multiple data sets, but to explore just one in depth (consider using the jigsaw technique)

Designing a Data-Rich Assignment: the Jigsaw Method

Part I:



Part II:



Read all about it: <http://serc.carleton.edu/sp/library/jigsaws/index.html>

Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

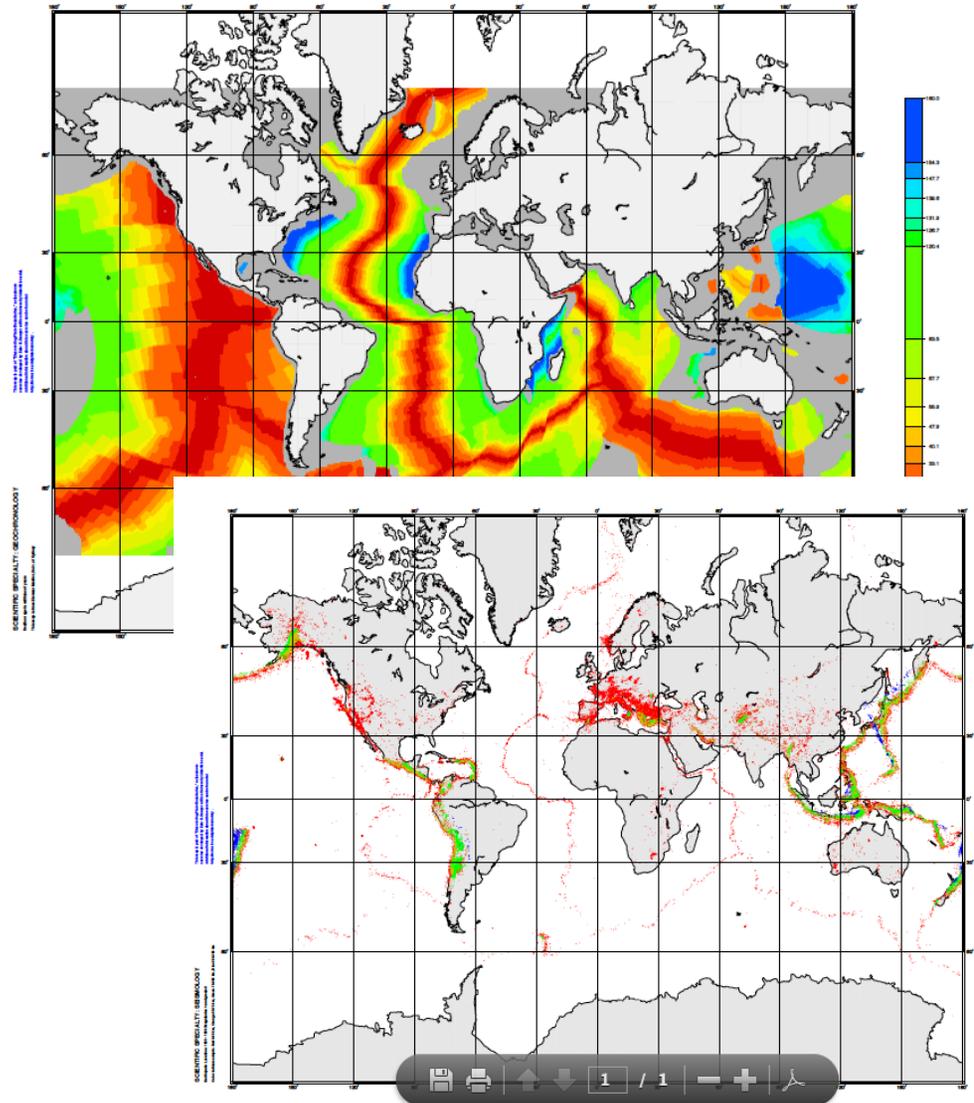
- Scaffold your assignment
 - Break it into sub-tasks
 - Require that students check in at the end of each part
- Provide instruction on methods/tools
 - How to access the Neotoma database
 - How to “get” the data (if that’s part of the assignment)
 - How to use Excel?
 - How to use R?

Designing your Data-Rich Assignment: Best Practices for Maximizing Learning

- Provide instruction on analysis and presentation
 - Be specific about how you expect them to analyze the data
 - Be specific about how you expect them to report their findings
 - You may have to show them “basic” things like how to format graphs and diagrams
- Model the behaviors you want students to adopt
 - And be explicit, as you do (“Here’s an example of what I expect you to do for this week’s lab assignment... ”)
- Develop a robust rubric for assessment
 - And consider handing it out with the assignment – so that students know from the start what you are expecting from them

Rediscovering Plate Tectonics: Dale Sawyer Plate Tectonics Jigsaw

- Constructing the argument for plate tectonics from key historical evidence
- What data would you use?
- How would you have students access the data?
- What support would you offer?
- How would you evaluate student learning?



Data-Rich Classroom Activities: Promoting Adoption

- Data set or tools can be transformative
- Organizing the data/materials is important, particularly if this work is burdensome
- Dissemination/adoption can be very fast if the activities are aligned with needs/wants
- Ready access to activities can support dissemination and use of strong ideas
- Ready-made activities can support teaching of new ideas (scientific or otherwise)

Data-Rich Classroom Activities: Examples on the SERC website

- GeoPRISMs
- Exploring Genomics Data
- InTeGrate
- GETSI
- (and far too many more to show today)
- ... and soon Neotoma...



The screenshot displays the SERC Site Guides website. The header includes the SERC logo and the text 'SERC Site Guides Helping Educators Find What They Need Within SERC Sites'. The main content area is titled 'Site Guide: Teaching with Current Research and Data'. A navigation menu on the left lists various categories such as 'How To Find', 'Teaching', and 'Career and Department'. The main content area features a 'General Collections' section with three entries: 'Teaching with Data', 'Teaching with Data Simulations', and 'Teaching with Data, Simulations, and Models'. Each entry includes a small thumbnail image and a brief description of the resource.

SERC Sites
Site Guides
Teach the Earth
Research
Webinars

SERC Site Guides

Helping Educators Find What They Need Within SERC Sites

SERC > Site Guides > Teaching with Current Research and Data

Site Guide: Teaching with Current Research and Data

Jump to: [Topical Teaching with Data Resources and Lab Activities](#) | [Geochemical and Geophysical Instrumentation, Analysis, and Facilities](#)

View All Site Guides
Search all of SERC

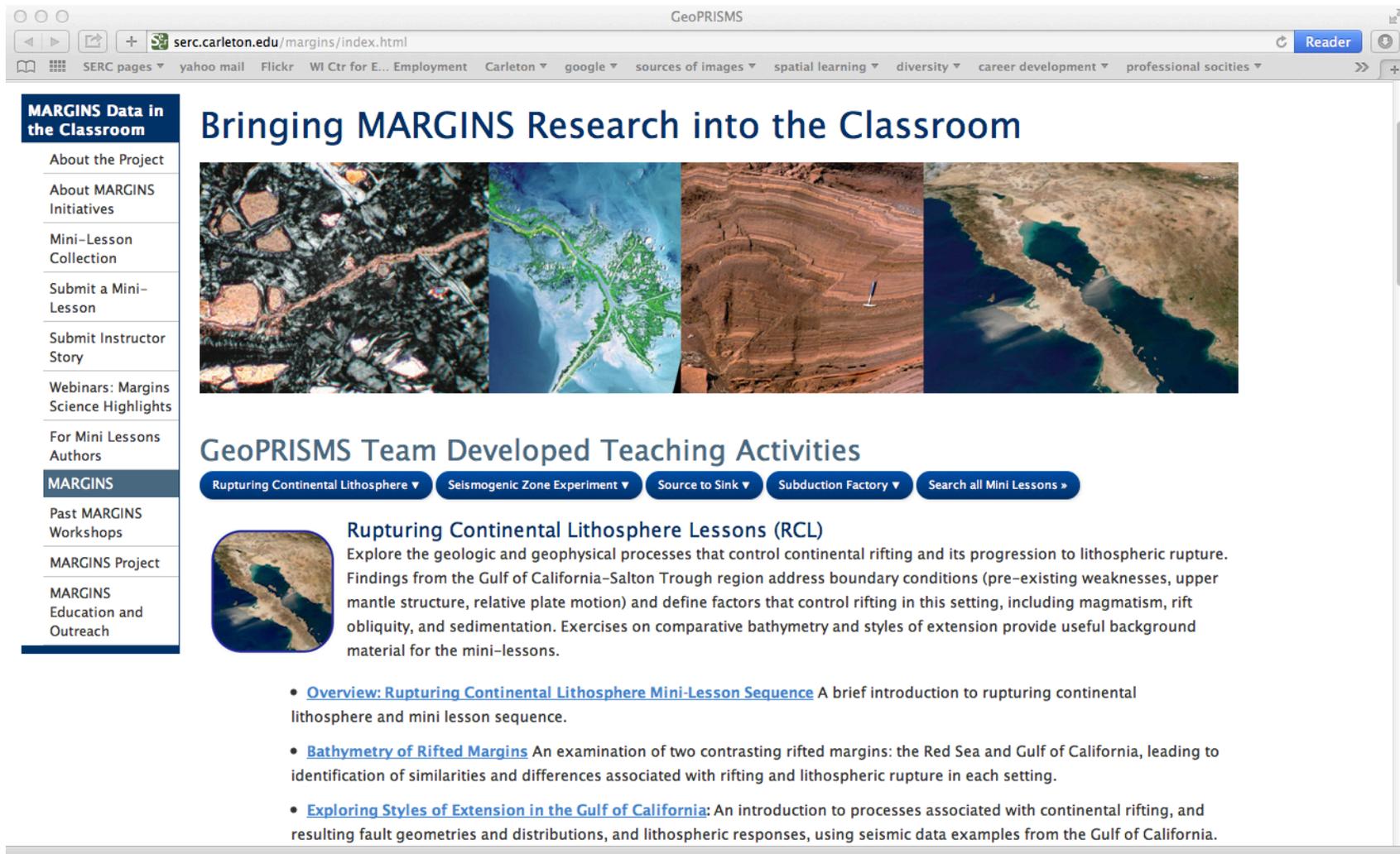
General Collections

Teaching with Data from *Pedagogy in Action* - This is the first page in a module about teaching with data in entry level geoscience classrooms. The module offers background information for teaching with data (what is it, why use it, and how does one use it) as well as a collection of activity examples one can use in their classroom.

Teaching with Data Simulations from *Pedagogy in Action* - Teaching with data simulations means giving students opportunities to simulate data in order to answer a particular research question or solve a statistical problem. This module explains how to use this technique along with with **example activities** and classroom tips.

Teaching with Data, Simulations, and Models from *On the Cutting Edge* - Today's geoscience education reaches beyond the traditional teaching tools such as rock samples and topographic maps. With the addition of computers in many geoscience classrooms and laboratories, faculty have unprecedented opportunity

Data-Rich Classroom Activities: GeoPRISMs



The screenshot shows a web browser window with the URL serc.carleton.edu/margins/index.html. The page title is "GeoPRISMs". The main heading is "Bringing MARGINS Research into the Classroom". Below this is a row of four images: a close-up of a rock outcrop, a satellite view of a rifted margin, a cross-section of a rifted margin, and a map of the Gulf of California-Salton Trough region. Below the images is the heading "GeoPRISMs Team Developed Teaching Activities" and a row of buttons for "Rupturing Continental Lithosphere", "Seismogenic Zone Experiment", "Source to Sink", "Subduction Factory", and "Search all Mini Lessons". The "Rupturing Continental Lithosphere" button is selected, leading to the "Rupturing Continental Lithosphere Lessons (RCL)" section. This section includes a small map of the Gulf of California-Salton Trough region and a description of the geologic and geophysical processes that control continental rifting and its progression to lithospheric rupture. Below the description is a list of three activities: "Overview: Rupturing Continental Lithosphere Mini-Lesson Sequence", "Bathymetry of Rifted Margins", and "Exploring Styles of Extension in the Gulf of California".

MARGINS Data in the Classroom

- About the Project
- About MARGINS Initiatives
- Mini-Lesson Collection
- Submit a Mini-Lesson
- Submit Instructor Story
- Webinars: Margins Science Highlights
- For Mini Lessons Authors

MARGINS

- Past MARGINS Workshops
- MARGINS Project
- MARGINS Education and Outreach

Bringing MARGINS Research into the Classroom



GeoPRISMs Team Developed Teaching Activities

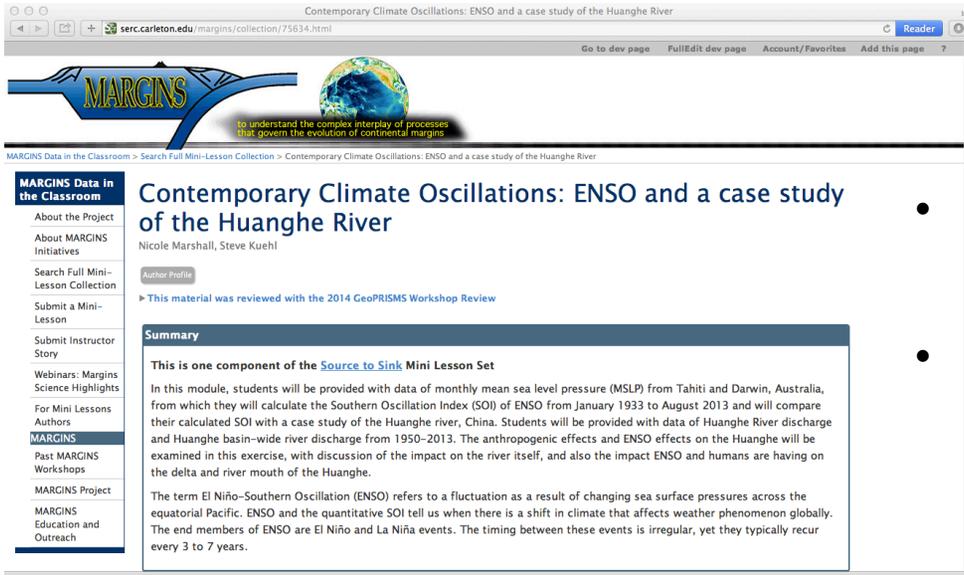
[Rupturing Continental Lithosphere](#) [Seismogenic Zone Experiment](#) [Source to Sink](#) [Subduction Factory](#) [Search all Mini Lessons](#)

Rupturing Continental Lithosphere Lessons (RCL)

Explore the geologic and geophysical processes that control continental rifting and its progression to lithospheric rupture. Findings from the Gulf of California-Salton Trough region address boundary conditions (pre-existing weaknesses, upper mantle structure, relative plate motion) and define factors that control rifting in this setting, including magmatism, rift obliquity, and sedimentation. Exercises on comparative bathymetry and styles of extension provide useful background material for the mini-lessons.

- [Overview: Rupturing Continental Lithosphere Mini-Lesson Sequence](#) A brief introduction to rupturing continental lithosphere and mini lesson sequence.
- [Bathymetry of Rifted Margins](#) An examination of two contrasting rifted margins: the Red Sea and Gulf of California, leading to identification of similarities and differences associated with rifting and lithospheric rupture in each setting.
- [Exploring Styles of Extension in the Gulf of California](#): An introduction to processes associated with continental rifting, and resulting fault geometries and distributions, and lithospheric responses, using seismic data examples from the Gulf of California.

Data-Rich Classroom Activities: Example from GeoPRISMs



Contemporary Climate Oscillations: ENSO and a case study of the Huanghe River

MARGINS Data in the Classroom > Search Full Mini-Lesson Collection > Contemporary Climate Oscillations: ENSO and a case study of the Huanghe River

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Contemporary Climate Oscillations: ENSO and a case study of the Huanghe River

Nicole Marshall, Steve Kuehl

Author Profile

► This material was reviewed with the 2014 GeoPRISMs Workshop Review

Summary

This is one component of the [Source to Sink](#) Mini Lesson Set

In this module, students will be provided with data of monthly mean sea level pressure (MSLP) from Tahiti and Darwin, Australia, from which they will calculate the Southern Oscillation Index (SOI) of ENSO from January 1933 to August 2013 and will compare their calculated SOI with a case study of the Huanghe river, China. Students will be provided with data of Huanghe River discharge and Huanghe basin-wide river discharge from 1950-2013. The anthropogenic effects and ENSO effects on the Huanghe will be examined in this exercise, with discussion of the impact on the river itself, and also the impact ENSO and humans are having on the delta and river mouth of the Huanghe.

The term El Niño-Southern Oscillation (ENSO) refers to a fluctuation as a result of changing sea surface pressures across the equatorial Pacific. ENSO and the quantitative SOI tell us when there is a shift in climate that affects weather phenomenon globally. The end members of ENSO are El Niño and La Niña events. The timing between these events is irregular, yet they typically recur every 3 to 7 years.

- **Part 1:** A lecture introducing ENSO and SOI. Brief discussion of the take-home assignment and groups are assembled.
- **Part 2:** The take-home group assignment where the students will take sea surface pressure measurements and convert them into SOI values. They will then make the SOI plot.
- **Part 3:** The Huanghe river is introduced in class. Students are sitting in the groups that worked on the SOI plot together. They can discuss answers to the in-class worksheet questions in this module.
- **Part 4:** Completion of module consists of a class discussion of their answers and any additional discussion of the Huanghe (other figures or conclusions from the Wang et al. (2006) study).

Data-Rich Classroom Activities: Exploring Genomics Data



[Exploring Genomics Data](#) > Overview of Chamaecrista Genomics Research

Overview of Chamaecrista Genomics Research

- Sequences
- Tools and Resources
- Timeline and Benchmarks
- Chamaecrista biology
- Candidate genes
- Gene expression
- Variation among ecotypes
- Functional genomics

Overview of Chamaecrista Genomics Research

Genomics research requires:

1. **A biological question**
2. **Sequences**
3. **Computational methods** to analyze the sequence data
4. **A critical researcher** to evaluate the results and connect the results to larger picture

The *Chamaecrista Explorer* is designed to help you develop genomics research questions and get you started analyzing genomics data by guiding you through different strategies. The web interface guides you through strategies for exploring genomics data and using it to understand biological questions about *Chamaecrista fasciculata*.

The Chamaecrista Explorer has been developed and evaluated with support from the National Science Foundation (DUE-0837375 and DEB-0746571.)

Using the *Chamaecrista* Genomics Explorer

Making sense of genomics data can be a bit daunting. The Explorer is designed to get you started analyzing genomics data by guiding you through five different strategies. You can start with any one of the strategies to ask and answer thoughtful questions. As you get more comfortable with the data, you'll find yourself combining several strategies to ask and answer more sophisticated questions. Approach the Explorer like you would a pick your own adventure type of book.

Research Problems in Lab

- 20 to 1 ratio – differentiated learning
- Complexity of tools can be limiting
- Supporting work out of class
- Evaluating progress

Places where sharing helped:

- *Faculty knowledge of subject*
- *Classroom management*

Data-Rich Classroom Activities: Exploring Genomics Data

“Using the *Chamaecrista* Genomics Explorer

“Making sense of genomics data can be a bit daunting. The Explorer is designed to get you started analyzing genomics data by guiding you through five different strategies. You can start with any one of the strategies to ask and answer thoughtful questions. As you get more comfortable with the data, you'll find yourself combining several strategies to ask and answer more sophisticated questions. Approach the Explorer like you would a pick your own adventure type of book.

“The strategies:

- *Chamaecrista* biology
- Candidate genes
- Gene expression
- Variation among genotypes
- Functional genomics”

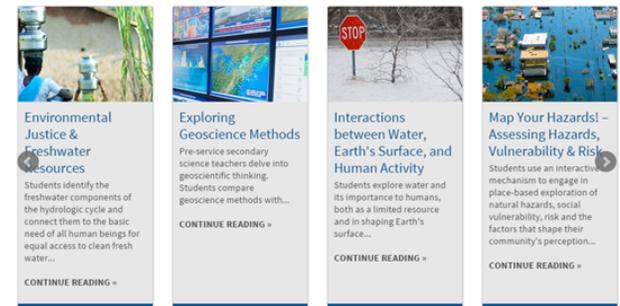


Data-Rich Classroom Activities: InTeGrate

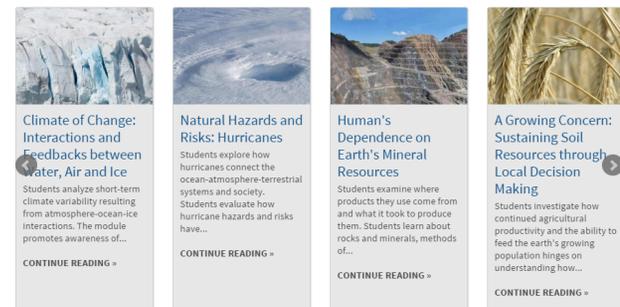


- Climate of Change
- Natural Hazards: Hurricanes
- Mineral Resources
- Soil Sustainability
- Living on Plate Boundaries
- Map your Hazards
- Environmental Justice and Freshwater Resources
- Geoscience Teaching Methods
- Water and Human Activity

InTeGrate Authored Modules and Courses



InTeGrate Authored Modules and Courses



Data-Rich Classroom Activities: InTeGrate

Climate of Change module:

- Forecasting climate variability and change
- Deciphering short-term climate variability
- Anomalous behavior
- Slow and steady?
- Systems@play
- Adapting to a changing world

Unit 2 Deciphering Short-Term Climate Variability

Cindy Shellito, University of Northern Colorado (lucinda.shellito@unco.edu) [Author Profile](#)

► This material was developed and reviewed through the InTeGrate curricular materials development process.

Summary

Making Sense of Ocean and Atmospheric Data Depicting Climate Variability

In this lesson, students will be provided with data depicting the cyclic changes in tropical Pacific climate associated with the El Niño-Southern Oscillation. Students will try to identify patterns in the data and discuss their findings with the class. An auxiliary lab or homework exercise provides students with data from the North Atlantic and guides them in identifying cyclic changes associated with the North Atlantic Oscillation.

Learning Goals

Unit 2 Teaching Objectives

- Cognitive: Provide students with an understanding of how ocean-atmosphere interactions lead to short-term climate variability, such as the El Niño-Southern Oscillation or the North Atlantic Oscillation.
- Behavioral: Provide students with experience examining climate data from observations and formulating hypotheses regarding the cause of change.

Unit 2 Learning Outcomes

- Case Study 2.1
 - Students will be able to interpret lat-lon contour plots and Hovmöller diagrams.
 - Students will be able to explain how temperature and pressure anomalies affect the location of precipitation in the tropical Pacific.
- Case Study 2.2
 - Practice reading lat-lon contour plots of pressure and precipitation.
 - Depict changes in pressure and precipitation over time on a map of the North Atlantic.
 - Explain how pressure changes and precipitation patterns may be connected.
 - Be able to explain the importance of examining an anomaly.

Data-Rich Classroom Activities: GETSI



Infinitesimal strain analysis using GPS data:
Module for structural geology or geophysics course



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 - [Basic Module](#)
 - [2014 Napa Quake NEW](#)
 - [One Day Option](#)
 - [Extension Options](#)
 - [Background Documentation](#)
- [Module Development](#)

Goal

Students are able to access and analyze GPS data in order to calculate and interpret ongoing strain in the region between three neighboring GPS stations.

Play Slideshow ◀ Previous Photo Next Photo ▶

UNAVCO Plate Boundary Observatory [View full image](#)

Figure 1. Plate Boundary Observatory station velocities in the Pacific Northwest of the USA.... [Read more](#) »

A row of four small thumbnail images: a map of the Pacific Northwest, a photograph of a GPS station on a mountain peak, a photograph of people in a classroom setting, and a technical diagram of a GPS station.

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Departments

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Site Guide: Teaching with Current Research and Data

Jump to: [Topical Teaching with Data Resources](#) | [Classroom and Lab Activities](#) | [Geochemical and Geophysical Instrumentation, Analysis, and Facilities](#)

About Site Guides

Each Site Guide tackles a particular topic of interest to educators and highlights relevant resources from within project websites hosted at SERC

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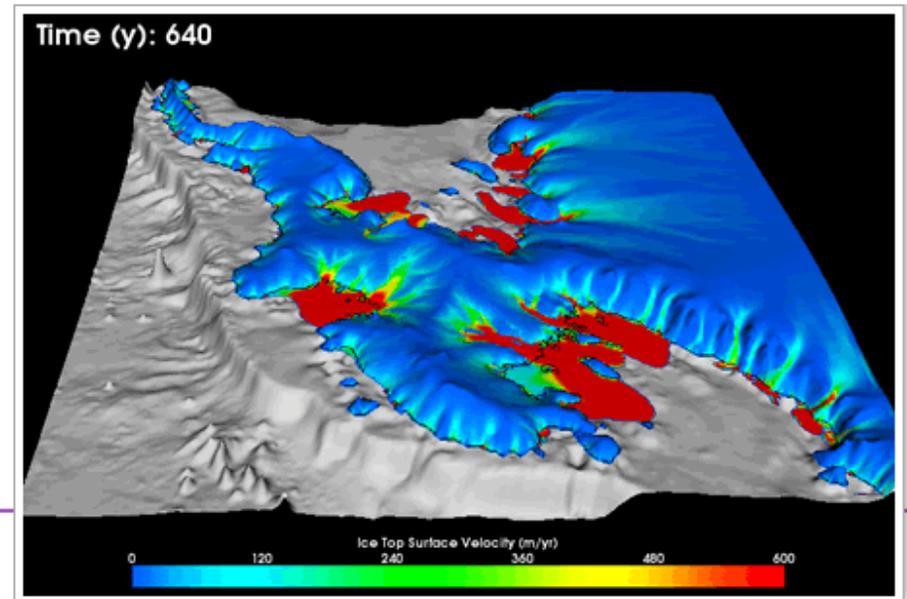
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[Teaching with Data, Simulations, and Models](#) from [On the Cutting Edge](#) - Today's geoscience education reaches beyond the traditional teaching tools such as rock samples and topographic maps. With the addition of computers in many geoscience classrooms and laboratories, faculty have unprecedented opportunity

Teaching with Data

- It can be done
- Time consuming – but worth it in the eyes of faculty
- Success grounded in learning theory
- Following other projects' examples can make it easier



An image created with the [Visualization Toolkit](#) showing a model of Antarctic ice growth. Image by Chuck Anderson, Penn State University.

Questions or comments?