Do learners see what we think they see?

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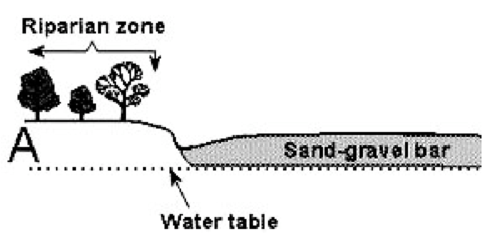
As teachers, we use images to convey all sorts of information. Some times, images are used to convey abstract concepts or tell stories; other times, images are used to represent far away places that we can't easily visit or processes that can't easily be visualized directly (Figure 1). At the University of Vermont, we are using predominately photographic images to step back in time and teach students about human/landscape interaction—our work is tied to the *Landscape Change Program,* which we consider to be a virtual time machine; its 10,000+ images are freely accessible on the web at www.uvm.edu/perkins/landscape.



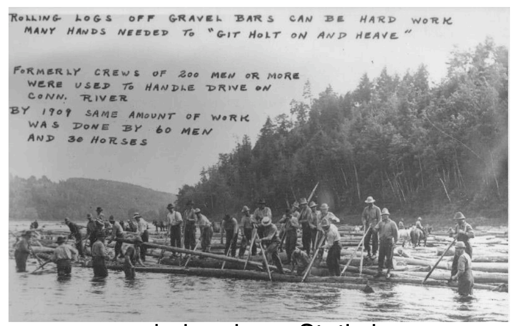


Figure 1. Compare these two images of a gravel bar on a meandering river. Static images similar to that shown on the LEFT can be found on many websites and in many textbooks; image above is from http://threeissues.sdsu.edu/three_issues_sandminingfacts02.html. Such images represent schematically what is seen photographically in the RIGHT image from the *Landscape Change Program* archive (http://www.uvm.edu/perkins/landscape/LS_FullDisplayM.php?FN=LS02113_000.jpg). Here, there are people and there is action. The caption sets the stage for a story telling us that men are moving logs off a gravel bar. The photograph is a catalyst for engaging discussions about the geomorphic effects of logging and riparian buffers. Teaching with both images gives the gravel bar meaning in a human context.

We are not alone in considering the power of the photograph to tell stories and influence thinking. Images show how natural forces alter human lives and societies, be it landslides destroying California homes or the devastating power of tsunamis washing over entire nations. With the Internet, images are transmitted immediately to people around the world. Not only has informal science education become image and data-rich but formal science training now depends heavily on imagery and computer-aided visualization. The trend is not surprising; images can code, display and preserve information far more densely that words. Indeed, advertising has harnessed the power of images for years (Figure 2).

Now Only You Can Save Grand Canyon
From Being Flooded…For Profit

Figure 2. Images matter! Here is the photograph (right) that lost David Brower and the Sierra Club their tax-exempt status for “lobbying” to save the Grand Canyon from flooding. Image (altered by BLM in 1949) shows proposed location of Bridge Canyon dam and associated reservoir. The headline above topped the full-page *New York Times* advertisement in which the image appeared on 6/9/1966.

We have just received NSF support (Educational Materials Development) to pilot web and classroom-based educational materials founded on the yet-to-be-formally-tested hypothesis that photographic images of landscapes are a more effective catalyst for student engagement and learning than traditional diagrammatic approaches. In other words, does the interest we see anecdotally in the classroom when we use such photographs, actually translate into sustained student attention, better learning outcomes, and more favorable impression of the learning environment as a whole? So far so good, but, how do we know what students really see in the images we show them?

Our work over the next few months, and one of our interests in attending this workshop, is to figure out how we will know better what students actually see when looking at an image. Unless we understand how the body of learners we seek to serve actually sees and interprets images, we won’t be able to design meaningful educational activities or even properly design evaluation exercises to see if the activities we create are working. Our immediate goal is thus to understand better the spectrum of ways in which students see and interpret images documenting the interaction of people and the natural landscape.

Understanding What Our Geoscience Students Learning: Observing and Assessing
May 12-14, 2005, Carleton College, Northfield, MN

Wine Tasting, Physics, and Formative Evaluation: Using Technology For Assessing Learning in Large (and Small) Classes

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Introduction

We have all been there, first as a student and then as a teacher. It happens in large and small classes, in elementary school through higher education. The past fifteen minutes have been spent reviewing important and complex material that is essential for the course you are teaching or taking. Upon wrapping up the presentation, the professor asks, "Ok, so are there any questions?" Silence, interrupted by a few coughs, dominates the room as information is spinning through students' minds. Why don't students raise their hands and ask questions? Why does the instructor assume that everyone has understood the material and seamlessly moves on to the next lesson? Is there a way to quickly and efficiently gauge student understanding of material in real-time? The answer to all three questions is "yes" and technology is something that can help you.

Since I am a second year doctoral student working on a dual degree in science education and natural resources, I do not have a classroom of my own. Instead I rely on my experience as a student, my knowledge of how people learn, and my time as an instructional technology manager for a university prior to entering my doctoral program. In 2002 at the University of New Hampshire, I was introduced to the world of using technology in large lecture classes to facilitate formative evaluation and student learning. After a rather extensive evaluation of available products, we chose eInstruction's Classroom Performance System (CPS) technology and installed it in two of the larger lecture halls on campus.

The sections that follow in my essay will serve three purposes:

- Briefly describe the history of using CPS at the University of New Hampshire highlighting lessons learned and results that may be useful to those interested in exploring the use of this technology in your teaching.
- Provide an introduction to using CPS for formative evaluation in the classroom including some theoretical and practical reasons for utilizing this strategy.
- Conclude with some possible applications of using CPS in the geosciences.

What is a Classroom Response System?

For purposes of this short essay, I will use the term Classroom Response System as the overall description of technology used to solicit, collate, and measure responses from students in the classroom setting using technology. CPS or Classroom Performance System referred to in the previous section is an example of one product available on the market presently. My experiences have been with CPS, therefore, this essay will refer to it specifically. However, it should be noted that there are several other classroom response systems available that you can use to facilitate formative evaluation.

In general, a classroom response system consists of three major components:

- Some kind of remote control-like or handheld device possessed by the students.
- Hardware installed within the classroom to collect the responses from the handheld devices.
- Software possessed by the instructor that collates the responses and displays them in some kind of useful form via a graphical user interface.

Setting the Stage for Formative Evaluation Using Technology
Here's the scene: The instructor displays a question via laptop and LCD projector to a lecture hall clamoring with about a hundred students. She "starts" the software by clicking a button and students point their handheld devices at several receivers mounted strategically throughout the classroom. On the screen, boxes numbered 1-100 (assuming 100 students are in the course) is changing from white to blue as students begin answering the multiple-choice question. After two minutes, the instructor "closes" the question and triggers the software compilation features. In a matter of seconds, a pie chart or bar graph is displayed to the students and instructor revealing only 18% of the students answered the question correctly. Taking into account this information, the instructor realizes that this lesson needs to be re-taught either in today's lecture or in the lab sections. Without this information, what are the chances that the instructor asks, "Are there any questions," and moves on to new material?

Obviously, I have provided an oversimplified account of using this technology and there are logistical and administrative issues that are beyond the scope of this essay. I should also let you know (if you are reading this before the workshop) that I plan to have a demonstration system available during the poster sessions so you can try it out for yourself and see it in action.) If you are interested in the details of our installation at the University of New Hampshire, I'd be more than willing to talk with you and/or put you in touch with the right people.

Will a classroom response system make me a better teacher?
The answer to this is "no." Like any other tool, the technology itself is not going to improve your teaching or students' learning automatically. Instructors that have been successful using a classroom response system all have three key characteristics:

1) They have redeveloped a lesson to incorporate the use of this technology. Instead of inserting questions within a 150 slide PowerPoint presentation, they take advantage of the technology's features and redesign their approach to delivering the content.
2) Closely related to this is the need for a pedagogical foundation that drives the uses of this technology. A great example of this is using something like Peer Instruction facilitated by a classroom response system for your large class. In other words, grounding your use of this technology with some type of learning theory will increase your chances of success.

3) Knowing how and when to ask questions is key to using this approach. Avoid asking "yes/no" questions or even multiple-choice. I have seen successful instructors present two solutions to a problem and ask students to convince the person sitting next to them that one of them is correct. After they come to a resolution, they then answer the question using their handheld devices and the instructor can immediately assess their initial level of understanding.

How does wine tasting fit into this?
In the following section, I will briefly describe a few of the courses at the University of New Hampshire that have successfully integrated CPS into their courses. I judge success by relying on anecdotal evidence from the professors, however, several of them have collected feedback from students during the first two years of the initial pilot project.

Beverage Management
CPS was used in an advanced business class in the hospitality management department. As part of this course, students (all 21 years of age and over) participate in wine tasting as part of their practical experience. The instructor solicits feedback anonymously via CPS as a way for students to safely make mistakes and errors in their evaluations of the many wines presented for review. The instructor has been teaching this course for many years and reported unprecedented levels of activity and discussion after using CPS. This is a medium-size class (50 students) and historically difficult to engage all students due to time and logistical constraints.

Nutrition
All sections of the Nutrition 401 course, the largest undergraduate course at UNH with enrollments regularly exceeding 275 students, have adopted CPS. The technology is mostly used as a "check for understanding" tool with questions strategically placed throughout the lessons. Before CPS, instructors were not able to accurately assess students' understanding of the material in class. This course also used the technology for administrative tasks such as taking attendance. Administrative uses of CPS have uncovered interesting issues such as cheating and loss/theft of remote devices.

Physics 101
CPS was used by one of our most experienced professors in the delivery of Physics 101 to approximately 100 students. This professor truly used a peer instruction approach to the teaching of this large lecture class and utilized CPS to gather data on student understanding. Most of his questions presented 2-4 solutions to problems. Students would collaborate in small groups to work on the problems and record their answers using the handheld devices.

Conclusion/Resources
A classroom response system has the potential to impact the assessment of learning in the geosciences in several ways. First and most practically, something like CPS can help you, as the professor, gain perspective into how student learning is progressing in the classroom. If you teach a field course in addition to a lecture, this understanding of foundational material can be critical as students attempt to apply this knowledge to real-

world research situations. Second and more complex, CPS could potentially be utilized in the field as students could share field notes, observations, and answer questions all from a handheld device or cell phone. In fact, a previous workshop sponsored by this same group included work being done at the University of Michigan where this is quickly becoming a reality (see Peter Knoop's Geopad page at http://geopad.org/).
However you choose to utilize a classroom response system in or out of the classroom, you will most certainly open new possibilities for real-time formative evaluations which can lead to better student understanding and an overall improved learning experience for all.

Resources mentioned in this paper:

eInstruction CPS
http://www.einstruction.com

Mazur and Peer Instruction
http://mazur-www.harvard.edu/education/educationmenu.php

University of New Hampshire eInstruction project
http://at.unh.edu/idc/peerinstruction/

Wiley Higher Education Classroom Response System FAQ Page
http://he-cda.wiley.com/WileyCDA/Section/id-103706.html

Geopad
http://geopad.org/

THE ROLE OF E-PORTFOLIOS AND ACADEMIC ROADMAPS (i.e., CONCEPT MAPS) IN AN OUTCOME- AND ASSESSMENT-BASED GEOSCIENCE CURRICULUM

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This essay has links to PowerPoint, WORD, and EXCEL files that will be uploaded to the Cutting Edge server. They should be viewed while reading the essay.

The Geosciences Department resides in the College of the Environment and Life Sciences (CELS) of the University of Rhode Island. In the late nineties CELS made a significant commitment to re-align all (ten) majors to outcome-based programs, in which the "assessment cycle" would play a major role. (In retrospect this was a wise commitment, as the State of Rhode Island has since mandated that by 2006 all public education institutions, K-16, must have in place outcome & assessment-based programs.) Towards this end the college, and individual departments, developed rough drafts of outcomes and assessment tools to can be used to evaluate the attainment of those outcomes. I am a member of a small group of faculty and administrators charged with implementing this agenda. Early-on we decided to develop (or buy into) an electronic portfolio system, as a means by which we could efficiently track the assessment component of the new outcomes-based curricula that was emerging within the college. Thus we joined a group of schools using TRUE-OUTCOMES, an electronic portfolio program that manages assessment-based science and engineering curricula. It allows or provides the following things: 1) a way in which students can easily see what materials they need to produce for assessment, as part of the evaluative component of the stated outcomes for their major; 2) a way in which they can upload, digitally, the materials to be assessed as demonstration of achievement of outcomes; 3) and an access to courses, outcomes, and other issues that are relevant to their management of their four-year experience at URI. The PowerPoint presentation covers these and other benefits that accrue from using this program.

The TRUE-OUTCOMES portfolio provides a powerful tool for students and faculty alike to enhance the educational experience. But--from the perspective of an incoming freshman (unsure as to what geology is, let alone whether she thinks she wants to major in it, other than she/he thinks it's neat, based upon a family trip to the western national parks), or an undergraduate science major (thinking about whether he or she should transfer into geology and still graduate on time and get a job/grad school stipend) or a high school senior and his/her parents--it is not overly welcoming. Thus we are developing an Academic Roadmap (or concept map) for current and potential majors in CELS. Our intent is provide to a visually compelling and user-friendly portal to the resources in our college, that will be easily accessible to a clientele that ranges from perspective high applicants (and their often first generation parents) to enrolled students who are trying to decide whether to major in geology, to colleagues who are interested in our geology program, and to other who are interested in geology, what it requires to be professionally viable, and what the relevance is of the various outcomes (and associated assessment instruments) that are embedded in the geology major at URI. Among other things, the academic roadmap will illustrate the relevance of skills (such as those demonstrated in lab field camp reports) to the demonstration of competency in the profession.

The following items will be uploaded to the Cutting Edge Workshop website. They elaborate upon, and elucidate the URI project just described.

- A PowerPoint presentation that covers the evolution of the CELS agenda, in terms of: 1) outcomes- and assessment-based curricula; 2) an E-portfolio to manage it; and 3) an Academic Roadmap to provide the curricula a "heart and soul", that makes it accessible to a broad audience. (CE-DPM OVERVIEW)
- A WORD file that describes the geology department outcomes. There are, currently, 44 geology outcomes, which represent the department's mapping of the college's outcomes onto our major. (CE-DPM OUTCOMES)

- A WORD file that describes which outcomes are addressed by the course's objectives, experiential component, and e-portfolio product; it is keyed by number to the list of 44 outcomes presented in the previous file. (CE-DPM COURSE)

- An EXCEL file that correlates outcomes with geology courses. This "matrix" illustrates the assignment of outcomes to courses. Each of the ~50 geology outcomes will be assessed. That matrix shows which outcomes will be assessed to core courses in the major. The core course numbers (across the top) refer to the following subjects. (CE-DPM MATRIX)

103	Introductory Physical Geology
150	Historical geology
210	Geomorphology
320	Mineralogy and Petrology
370	Structure and Tectonics
450	Sedimentology
483	Hydrology
484	Contaminant Transport
488	Colorado Plateau or California Trip (Capstone Course)

- An EXCEL file that lays out the architecture of the academic roadmap. Note: there are several pages to the file. If you set EXCEL to allow comments, you will get directions about the use of components on each page. (CE-DPM ROADMAP)

Earth Data, Science Writing, and Peer Review in a Large General Education Oceanography Class

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University of California, Santa Barbara
April 25, 2005

Introduction

This essay will discuss some of my (and my colleagues') work with a large general education oceanography class at UCSB (1995, 2000). The class currently has 70 to 100 students and satisfies a quantitative science and writing requirement for the undergraduate major. The students range from freshman to seniors and who represent a wide variety of science and non-science majors.

The course goals focus on 3 major learning themes:

1. Facts about oceanography
    a. ocean basins
    b. atmosphere and climate
    c. waves and beaches
    d. life in the ocean and world fisheries
2. Science process
3. Implications for the future

The strategies for attaining these goals are diagrammed in figure 1, below. These include the acquisition of factual knowledge through reading, homework assignments, and lecture, and the support for learning higher level skills through writing and reviewing science papers. Extensive research, and our own personal experience as scientists, supports the value of writing for increasing student understanding of both science process and content (Bazerman and others, 2005). The writing assignments focus on the development of argumentation skills that use earth data. The students are guided and motivated to achieve these goals through the use of online tools that automatically grade homework assignments, enable on-demand course grade calculation, and online writing that supports the "calibrated peer review" methodology (more later).

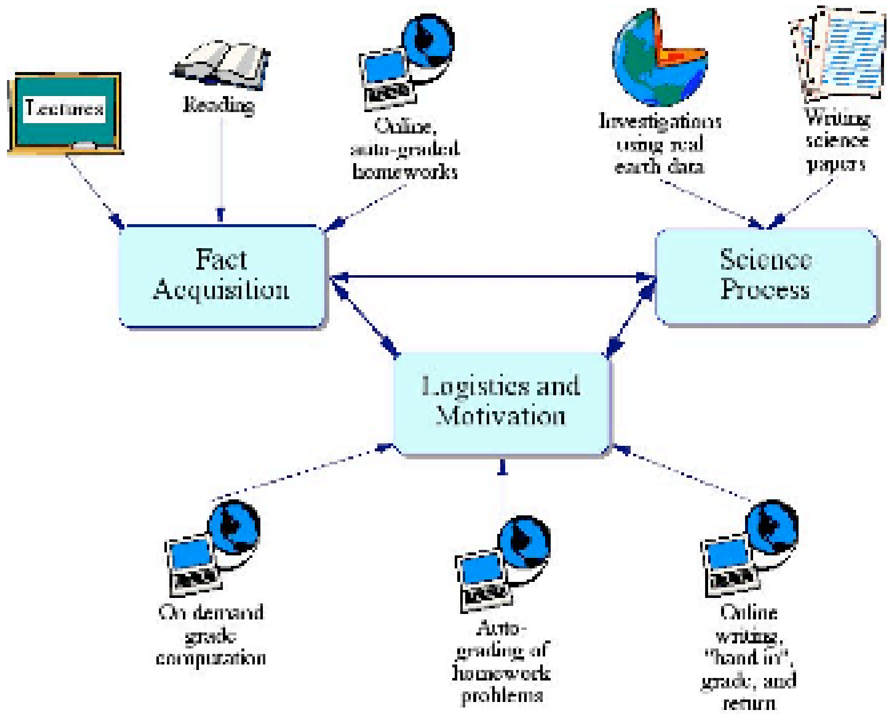

Figure 1. Diagram of strategies for achieving the goals of UCSB Oceanography.

The EarthEd Online Software

The course goals are supported by a course management system that I call "EarthEd Online" (Prothero, 2005). It supports the course goals by providing a secure interface for students to enter homework answers, compute their grades, access the course assignment descriptions, acquire Earth data, and engage in the online writing and peer review activities. It differs from commercial course management system in its extensive support for online writing and its integration with viewers for earth and ocean data. Graphic images that show, for example, earthquake epicenter plots, cross-sections, etc, are required for earth science writing. So the generation of data representations (images) and incorporation of images into the writing assignments (both data generated and student drawings) is robustly supported. In addition, the online writing module supports both online grading by the instructor or teaching assistants and the "Calibrated Peer Review" method (Rossel and others, 1998; Heise and others, 2003; SERC, http://serc.carleton.edu/introgeo/peerreview/cpr.html), which will be discussed in more detail later.

Assignments that use Earth data

Here I will discuss the 4 writing assignments that were part of the Winter quarter, 2005 oceanography class. Normally, it is only possible to give two writing assignments, but the efficiency and effectiveness of the "Calibrated Peer Review" method allowed 4 assignments without reaching acceptable teaching assistant workload limits. The topics were:

1. Plate tectonics: students were asked to study the plate boundary at two locations. One was a subduction zone and the other was a spreading center. Assignment description at: http://oceanography.geol.ucsb.edu/~gs4/w2005/writing_assignments/Plate Tectonics_Assig.htm
2. Indian Monsoon: use pressure, temperature, wind, and rainfall data to show the important driving processes for the Indian Monsoon. The assignment description is at: http://oceanography.geol.ucsb.edu/~gs4/w2005/writing_assignments/MonsoonCPR_Writing.htm Data links are at: http://oceanography.geol.ucsb.edu/~gs4/w2005/a_Ingrid_Data.html
3. Earth's Climate: discuss the major factors influencing the Earth's climate, discuss the paleoclimate and historical climate records, climate change scenarios, and recommend a climate policy. Assignment description at: http://oceanography.geol.ucsb.edu/~gs4/w2005/writing_assignments/Ocean_Climate_CPR.htm
4. World Fisheries: discuss the Pew Ocean Commission report ("America's Living Oceans, Charting a Course for Sea Change,") recommendations, contrary views, and develop a policy position for the sustainability of the world's fisheries. Assignment description at: http://oceanography.geol.ucsb.edu/~gs4/w2005/writing_assignments/FisheriesCPR.htm

The Data Viewers:

The data for the assignments are available through the "Our Dynamic Planet" CDROM, which was authored by W. Prothero. the IRI/LDEO Climate Data Library, and various other web browser available data sources. First, the "Our Dynamic Planet" viewer will be discussed.

"Our Dynamic Planet" is available as a stand-alone CDROM or integrated into the EarthEd Online software system. When combined with EarthEd Online, it supports seamless capture and upload of the data images for inclusion in student writing. Figure 2 is a screen shot of the module index, which shows the available functions.

Figure 2. Index screen of "Our Dynamic Planet." The CD contains a complete package of materials to help the learner understand the principles of plate tectonics, and acquire the data that supports investigations of plate boundaries and processes.

Figure 3, below, shows the MAP module where data are plotted, captured, and uploaded to the student's graphics library. When in stand-alone mode, the graphic images are saved to the student's local hard drive where they can be edited, printed, or imported to a word processor. Data types that are supported are elevation (ETOPO5 DEM), earthquakes in map and cross-section views (PDEs), seafloor age, volcanoes, island ages, and heat flow. With these data, it is possible to determine the difference between the 3 major boundary types, study seafloor spreading rates, and hot spots. Several high resolution DEMs are available for the East Pacific Rise and Mid-Atlantic Ridge.

Appendix I has more detail on the "Our Dynamic Planet" CDROM software and capabilities.

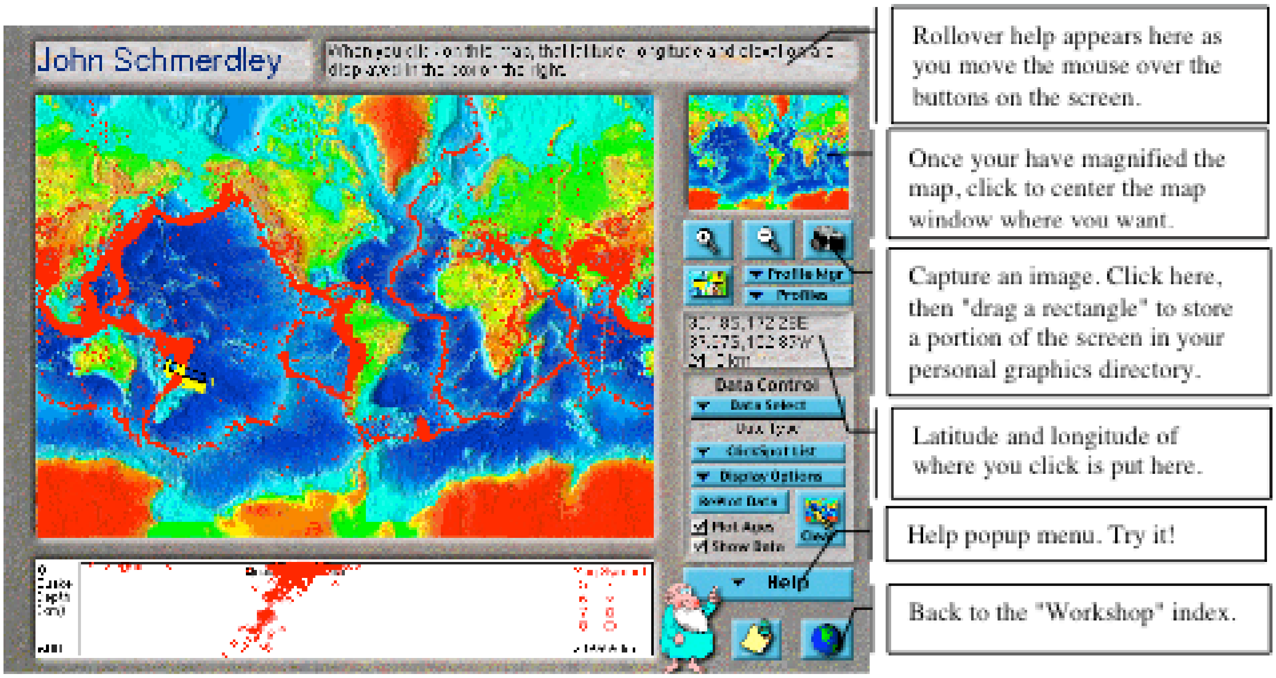

Figure 3. MAP screen, where earthquake, elevation, seafloor age, and other data are displayed.

A wealth of data is available from IRI/LDEO Climate Data Library. Unfortunately, this data site is meant for researchers and the user interface is not applicable, in its raw form, for general education student use. However, it is possible to create links that take students to the correct data

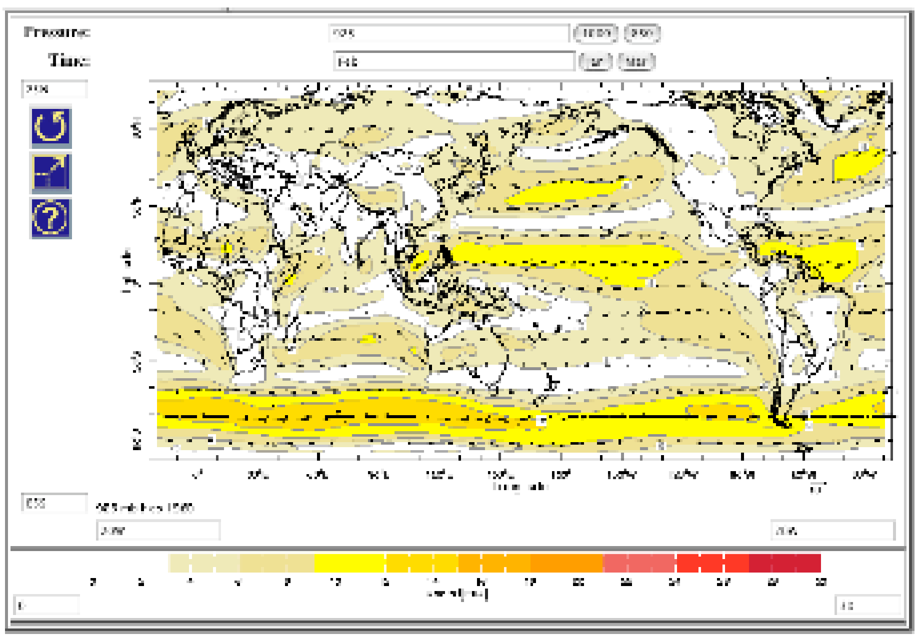

Figure 4. Wind vector plot from the IRI/LDEO Climate Data Library. This plot was accessed from the Oceanography data links web page.

display, allow them to select the time periods that they want and copy the images to their clipboard for the EarthEd Online upload process. In this way, inexperienced students can still access the relevant data without spending a great deal of time learning a complex user interface. Figure 4 shows a wind vector plot from this library.

The data resources for the assignments on Climate and World Fisheries are from the web pages of various government agencies (NASA, EPA, National Academy of Sciences, Scientific American, etc.). The World Fisheries assignment was also supported by web links to publicly available web sites (NOAA, Monterey Bay Aquarium, National Fisheries Institute, etc.).

Some other data viewers

There are two other data viewers that I have helped develop. These are mentioned because they are also potentially useful in oceanography courses. The first is the "Marine Virtual Explorer." It consists of a virtual reality exploration of the seafloor on the East Pacific Rise at 9^{0}N. It also includes a tour of the Alvin and its support ship, the Atlantis II. Figure 5, below shows the exploration screen. The learner explores the region by moving the submarine through a network of "nodes" while making a map of the area. The goal is to interest the learner in life at a mid-ocean ridge and to acquire map-making skills in the process.

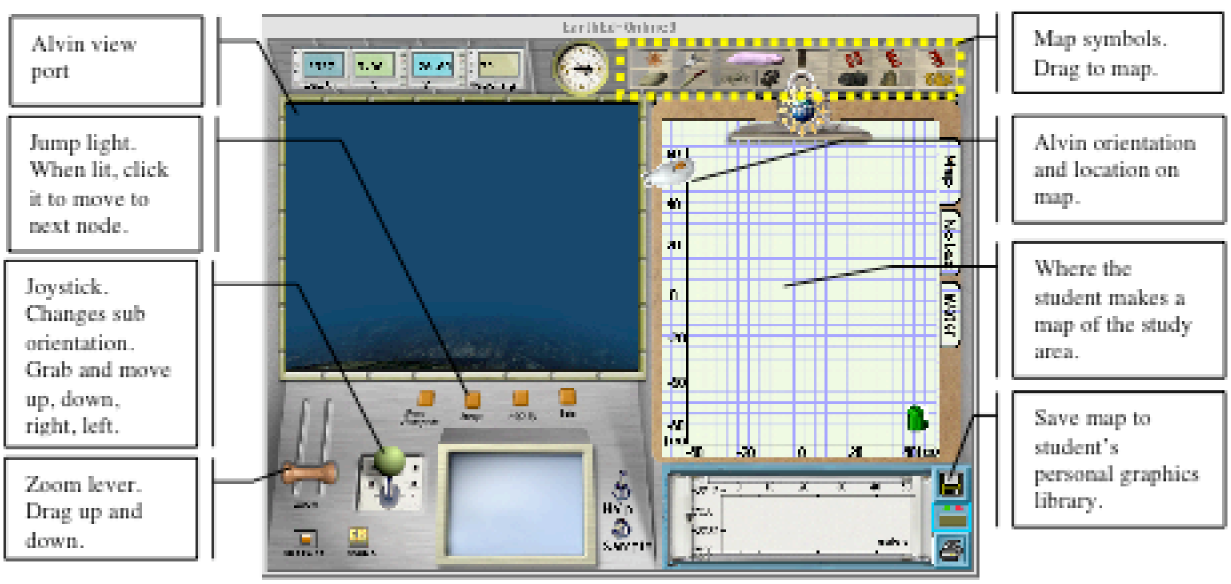

Figure 5. Alvin submarine control panel. Move the mouse over each screen item to see determine its function. The most important functions are indicated in the text boxes above.

The Global Ocean Data Viewer (GLODV) accesses and displays data from the World Ocean Atlas, 1998, and also selected data from the IRI/LDEO Climate Data Library.

It was created using a combination of the ESRI computation engine and Macromedia Director. The project was a trial run collaborative project between myself and New Media Studio. New Media Studio is anxious to develop other collaborations with scientists/educators to develop data access and visualization modules using this resource.

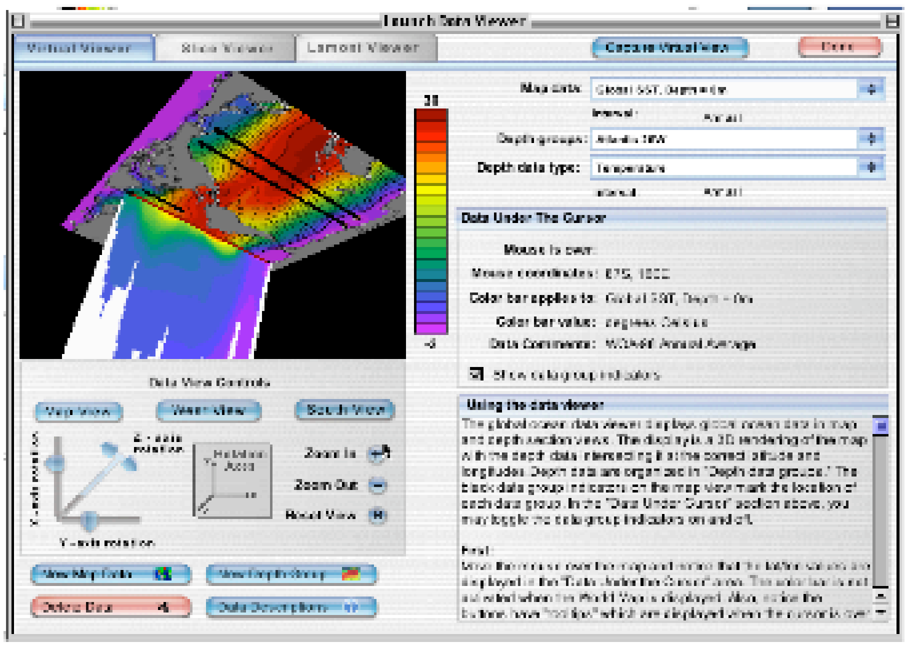

Figure 6. Global Ocean Data Viewer. This viewer displays Ocean Atlas 98 data in map and section view.

The current GLODV allows the student to select map or cross section plots of ocean data for display. When monthly or seasonal data are selection, it can be animated so that temporal changes can be viewed. The data display window can be captured and uploaded to the student's personal graphics library.

The World Ocean Atlas-98 data is climatology data. This means that it is averaged over many years. For monthly data, the average is over the same month, for many years. The corresponding average is done for seasonal and yearly. This means that variations that occur over a single year are averaged out. This kind of data is very good for looking at overall global patterns, but not so good for looking at what is happening during a specific year (e.g. El Nino).

The GLODV viewer has been expanded to access selected data from the IRI/LDEO Climate Data Library. The PMEL ferret data library is another possible library that can provide data images for GLODV.

Posing Effective Writing Assignments Using Data

There are a number of issues that must be addressed if students are to be successful in science writing assignments that use data. Most have very poor science writing backgrounds, so it is necessary to explicitly teach them how to construct a science paper. At another level of detail, most students need to be instructed in how to create a scientific argument. The separation of observations and interpretations is the first challenge. This is not trivial, because this discrimination is content and context specific. For example, suppose a geologist picks up a rock sample and wants to get it dated to construct a tectonic model. She sends the sample to a dating lab, which puts it in an analyzer that provides isotope ratios, then returns it to the geologist. To the tech at the dating lab, the readings on the mass spectrometer chart are the observations and the isotope ratios are the interpretations. To the geologist, the isotope ratios are the observations and the dates derived from them are the interpretations. It's a good idea to appreciate the challenges a naïve student faces when trying to sort this out. I solve this problem by explicitly telling students that figures from the MAP (for the plate tectonics assignment) are observations and their inference about plate boundary types are interpretations.

Depending on the length of the assignment, I ask students to prepare their paper with the following headings:

- Introduction
- Methods
- Observations
- Interpretations
- References

A more extensive paper might also include an abstract and discussion section. Appendix II contains the instructions I provide students for the first plate tectonics writing assignment. It explains, in detail, what I expect for the contents of each heading of the paper.

Calibrated Peer Review (CPR) and the Writing Assignments

As scientists, we know the value of peer review. Reading the good (or bad) writing of others helps us improve our own writing. As teachers, we also know the difficulty we have in explaining the difference between a good paper and a mediocre paper. The best tactic is often to let the student read a good paper and try to figure out the differences for him/herself. The grading process is also extremely burdensome. In large classes where TA's do much of the grading, we have to rely on the skills of the TA, and the paper shuffle makes it extremely difficult to monitor TA commenting and grading. Online writing and grading helps solve these problems and the CPR method (Russell, 1998; Heise, 2002; also: http://cpr.molsci.ucla.edu/) helps even more.

I began to assign science papers in 1993. Students handed in two copies of their papers, which were graded by TA's and returned to students. This left me without a permanent record of the TA comments. Later, when working with colleagues to study student writing in more detail, I found numerous instances where papers given an A were really C papers, etc. (Takao, 2002). In fact, the correlation between grades that I would have assigned and TA assigned grades was not strong, even after discussing sample papers with TA's and making sure they understood what I wanted. As I developed the EarthEd Online software, I implemented online writing capability. Students gather data images and upload them to their personal graphics library (through EarthEd), write their paper, and hand it in online. The TA or professor then assigns points according to a score-sheet that is displayed on the screen. A comment is simply dragged into the text from eithr a preset list of comments or from immediate text box entries. When the paper commenting and grading is complete, the paper can be stored in a holding area or returned to the student.

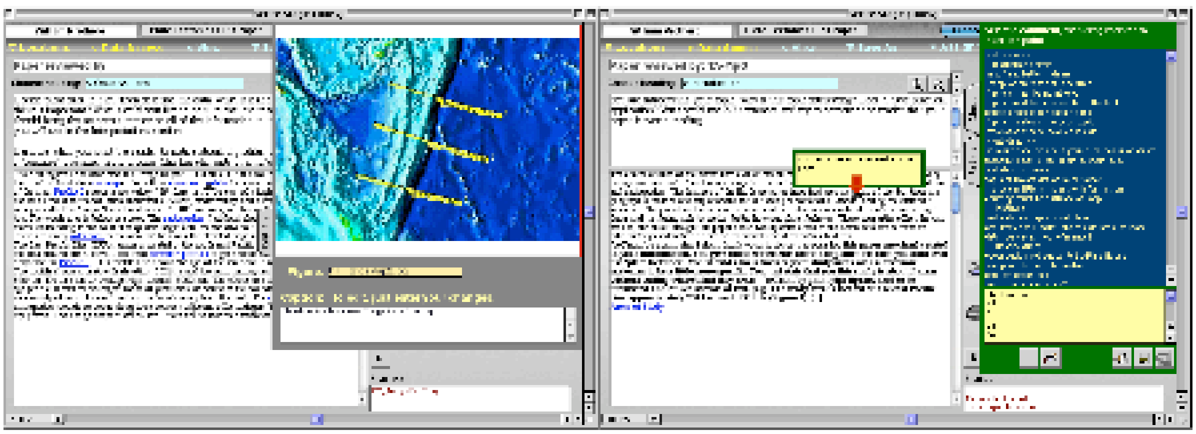

Figure 7. EarthEd Writer screens. The figure on the left shows a student paper with a linked image displayed. The figure on the right shows what a TA would see when grading the paper. The comment box is open and a comment is being dragged onto the paper text. The "Rubric" tab displays the score-sheet, where item grades are assigned.

The online writing software made writing assignments easier to manage. I could review TA grading and comments before papers were returned to students and papers didn't get lost. But, the grading still required a great deal of TA time.

During the Winter quarter of 2005, I added software to allow students to review each others' papers according to the "Calibrated Peer Review" method. With this method, students score 3 instructor prepared papers, 3 of their peers' papers and their own paper. Learning is increased and effort spent grading is reduced. Here's how it works:

Elements of a "CPR" assignment:

1. The assignment description
2. A scoring rubric that students will use to score papers
3. Three "calibration" papers, scored by the instructor
4. Other resources, instructions, etc. that students need to complete the assignment.
5. For data intensive explorations, a list of links or resources to allow acquisition of data or data representations

To do the assignment, the student:

1. Writes paper. Use EarthEd Online screen or write in Word and paste in text.
2. Hands in paper before due date/time (click the "hand in button")
3. Begins review of "calibration" papers 24hrs after the hand-in due date. (Students are prompted if their average item grade for a "heading" is greater than a preset value)
4. Reviews 3 peer papers (randomly assigned and anonymous)
5. Reviews own paper

The paper grade is computed from:

1. Peer grades (3) weighted by each reviewer's rms variation from the calibration paper item scores
2. Prof or TA grade if student requests it. This grade over-rides the peer grade.

A grade is also given for the quality of the student's reviews. It is based on:

1. Difference between grade given peers and final grade each peer received
2. Difference between final grade for own paper and score for own paper
3. RMS deviation of calibration paper scores relative to "correct" scores
4. All weights and point settings are configured by the instructor.

The system encourages students to carefully grade their peers because of they get points for the quality of their reviews.

The ease with which students can copy text from web pages makes academic integrity a serious concern. The online system makes it possible to compare student papers and/or submit them to an online service such as turnitin.com. There is also an advantage of having a permanent record of student writing, which includes the scores received for each item of the score-sheet and TA comments. The EarthEd software allows the instructor to configure it so that text pasted from outside the writer is italicized. However, some students prefer to write in Word and paste text into the heading fields, which makes the italicized approach inconvenient.

The effective use of CPR requires some care. The instructor must identify measureable outcomes from the assignment and be able to embody those outcomes in a score-sheet that the students can use without being writing experts. I suspect that a greater number of shorter assignments are better than a few longer ones. Shorter assignments allow the student to see how much their writing is improving and it also makes the peer review process more manageable for them. When I implemented the plate tectonics assignment, I made the score-sheet items more explicit than the score-sheet used for assignments given in previous courses, graded by TA's. For example, the TA graded score-sheet had the item: "*Multiple data sources are used, when appropriate, to identify geological features*." The CPR assignment item was changed to: "*Multiple data sources are used, when appropriate, to identify geological features. Elevation, quake and volcano data should be used for region A, and elevation, age, and quake data should be used for region B*." I was even more explicit for the monsoon assignment, specifying each data type that should be used. Appendix III is the score-sheet for the plate tectonics writing assignment.

Teaching Scientific Argumentation

Most scientists, especially myself, learned scientific writing through practice, not through direct instruction. I found that it took some reading and reflection on my own practices to isolate the critical elements that I included, almost without thought, into my own writing. These elements were clarified through the work of Kelly, Chen, and Prothero (2000) through studies of the writings of my oceanography students. Kelly and Chen isolated a number of "rhetorical levels," which I translated into a somewhat more student-friendly language. These levels consist of 6 issues that must be addressed by my students in their papers. One or more statements must be made that:

1. Include an observation, or description of an observation.
2. Name or classify an observation in terms of geological features.
3. Describe a feature that has been observed and classified, or that the author implies has been observed and classified.
4. Describes relationships between different observed and classified features.

5. Describes or explains a model or theory.
6. Describes relationships between and/or observed features that match (or disagree with) model features.

So, for the plate tectonics paper, the student would access the MAP software and capture images of elevation plots, earthquake plots, etc (1). Then she/he would identify the feature as, for example, a trench (2). The observations would need to be sufficient to identify the feature. The author could then describe the feature, e.g. a trench 1,000km in length, descending to a depth of 8,345m, trending North/South (3). The topographic feature could then be compared with a plot of volcanoes and noted that the volcanoes follow parallel to the trench (4). When a sufficient amount of data and a variety of data types are discussed, the model could be discussed. I ask students to draw a cartoon like model of a cross section of the structure, e.g. a subducting slab. The student needs to describe the model and discuss its major features (5). Then, the model must be matched up with the observations(6), e.g. the cartoon shows the quakes descending with the downgoing slab and volcanoes receiving melt from depth.

Appendix IV is an activity to help students become aware of the elements of a science argument. It asks students to classify statements in two papers and attempt to determine which one has the best argument. Unless they are instructed, most can't tell the difference. Prof. S. Thomas at Baldwin Wallace College has used the "Our Dynamic Planet" CDROM to support science writing in an introductory geology class. She requires students to count, in their paper, the number of each kind of the sentence types listed above, and finds that it results in better papers (S. Thomas, pers. comm.).

Scaffolding for the writing assignments

It is important to prepare students for the writing assignments. They need to learn the principles and processes important for an understanding of the topic, learn how to manipulate the software to acquire the data images, learn to use the Writer software in EarthEd, and become familiar with the data that will be used. Further complicating the matter, students are likely come into the course with expectations that they will be given a procedure to follow, especially when the come from a high school where education standards focus on content memorization for quizzes. Students may resist an expectation that they develop understanding and that they engage in some exploration and struggle with the meaning of the data prior to beginning their writing. So, it is desirable to explicitly address this issue, at least for the first writing assignment. Students should be informed, up front, that they need to first understand the topic, then figure out, based on their understanding, what data are important and how it can be used to support a model or theory.

Sequence of scaffolding activities for plate tectonics:

The plate tectonics paper is due at the beginning of the fourth week of class. This gives students enough time to become familiar with the course, EarthEd software, and the data they will access for their paper. The labs consist of 2 hour sessions in a room with computers around the periphery and empty tables in the center.

1. **Week 1**
    a. Lecture
        i. History of Oceanography
        ii. Earth formation
        iii. Earth Interior
        iv. in-class activities (e.g. Appendix IV), prior to lab 2
    b. Prelab homework: familiarization with syllabus and course requirements
    c. Lab section:
        i. familiarization with Class resources
        ii. EarthEd logon, homework entry, and grade calculation
2. **Week 2**
    a. Lecture
        i. Physiography
        ii. Plate tectonics
        iii. Reading about plate tectonics, prior to lab.
        iv. in-class software demonstration (EarthEd and "Our Dynamic Planet" module), prior to lab session
        v. in-class activities (e.g. Appendix IV), prior to lab 2.
        vi. Alternate possibility: discussion of answers posted online to thought questions prior to lecture ("Just in Time Teaching": this has been used in the past, but was not used during Winter 2005)
    b. Prelab homework
        I. Due at lab 1: math review, units, units conversions, significant figures, etc.
    c. Lab section
        i. Writer: beach description activity and discussion of interpretations and observations
        ii. Profile game and "Our Dynamic Planet" data resources
        iii. How to make a class presentation
3. **Week 3**
    a. Lecture
        i. Evidence for plate tectonics
        ii. writing about plate tectonics

iii. Inside Hawaiian Volcanoes video
b. Prelab homework
i. questions about maps, lat/lon, and plate tectonics
c. Lab section
i. "Our Dynamic Planet" activity to find the major plate boundaries
ii. Presentation of findings to peers in lab section
4. **Week 4**: Plate tectonics paper due
5. **Week 5**: Peer reviews due

The beginning assignment is introduced at a somewhat leisurely pace to allow students to fully familiarize themselves with the EarthEd software system. The schedule for the subsequent activities is much tighter, with a CPR assignment due about every two weeks. Each writing assignment is preceded by a lab section to familiarizes students with the data they will be using.

Results from Winter, 2005 Oceanography application of CPR method

In this section I will discuss the results of my first attempt at using the CPR method. Overall, I was quite pleased with the quality of the peer reviews. Figure 8 shows a plot of the curved score

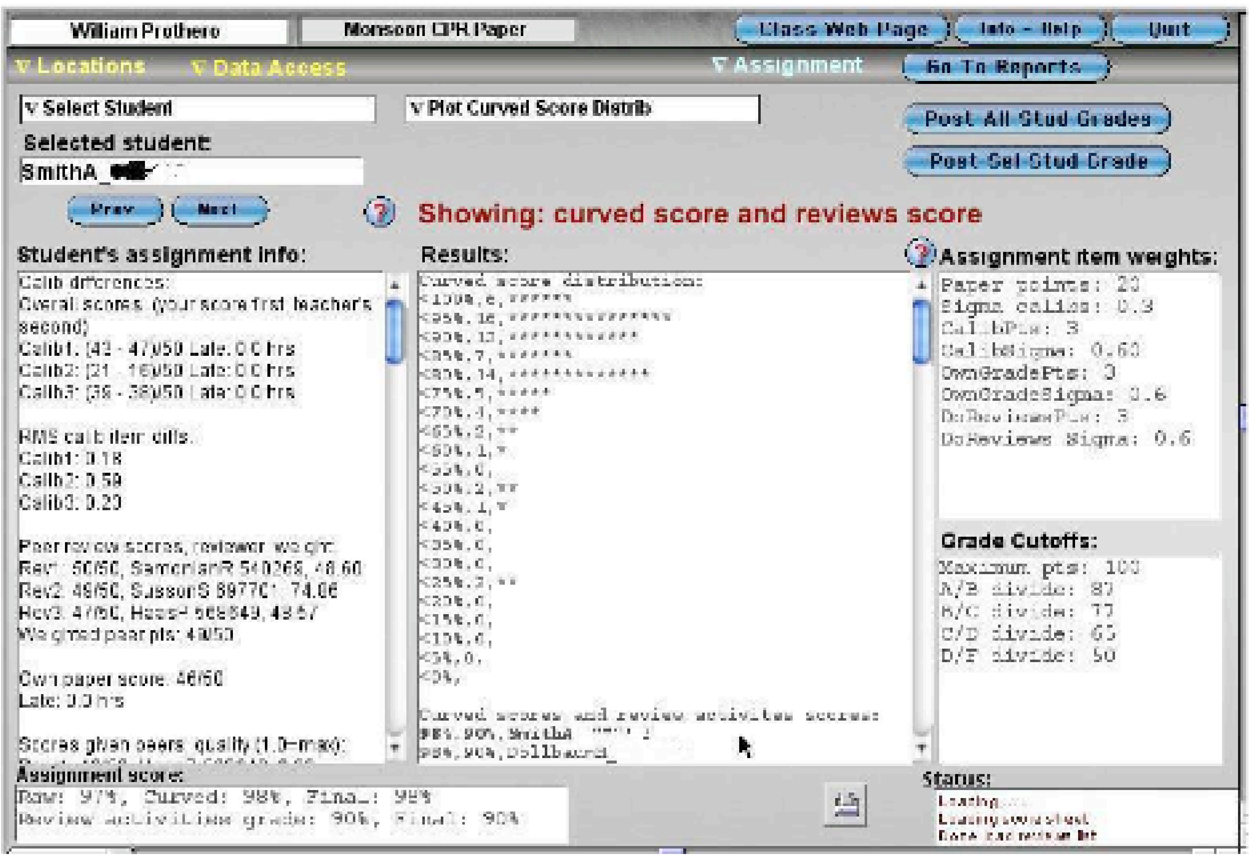

Figure 8. Report screen showing curved grade distribution for Monsoon CPR paper.

distribution for the Monsoon CPR paper. Grades are A: 90-100%, B: 80-90%, C: 70-80%, D: 60-70%, F: < 60%. The cutoffs and weights for the various grade calculation items are set by the teacher. Each student's detailed grade items are listed in the "Student's assignment info:" text field. The main question is whether peer grading is accurate enough to use for assigning a grade for the paper. However, to mitigate any possibility of unfairness, a student may request a TA to grade his/her paper, for any reason. The plot of figure 9 (left) shows the distribution of the difference between peer assigned grades and grades students gave their own paper. On the right, the distribution is for the difference between the peer assigned grade and teacher assigned grade, for the 20 papers that were graded by a TA or myself.

```
Own/Peer grade differences:
<100%,0,
<95%,0,
<90%,0,
<85%,0,
<80%,0,
<75%,0,
<70%,0,
<65%,0,
<60%,1,*
<55%,0,
<50%,1,*
<45%,1,*
<40%,0,
<35%,0,
<30%,1,*
<25%,4,****
<20%,3,***
<15%,9,*********
<10%,23,***********************
<5%,28,****************************
<0%,
```

```
Teacher/Peer grade differences:
<100%,0,
<95%,0,
<90%,0,
<85%,0,
<80%,0,
<75%,0,
<70%,0,
<65%,0,
<60%,0,
<55%,0,
<50%,0,
<45%,0,
<40%,0,
<35%,0,
<30%,0,
<25%,0,
<20%,1,*
<15%,2,**
<10%,11,***********
<5%,6,******
<0%,
```

Figure 9. Distribution of differences between raw peer assigned scores and author assigned scores (left) and difference between teacher and peer assigned grade (right). The teaching assistants graded 21 out of the 61 papers that were submitted.

The distributions show a good relationship between the peer scores and teacher scores. 17 out of 20 papers graded by the TAs were closer than 10%. There was a wider variation in how students rated their own paper vs how their peers rated their paper. Prior to assigning a final grade, papers with the greatest difference between the author's self grade and the peer grade were graded by the TAs, who in almost every case agreed with the peer grade to within a very few points. Most of the times the TA score was lower than the peer score. For this assignment, a one point difference is about 1% of the final paper grade, so a 10 point score difference would produce a full grade level change. These results show extremely good consistency, in my opinion. Comparisons of my grades with TA grades for past oceanography papers show differences of 20% or more and only marginal correlation with more detailed rhetorical analyses (Kelly and others, 2000; Takao and others, 2002). Part of this effect is most likely due to a significantly more specific scoring rubric and to less TA burnout reading and commenting on student papers.

Students were asked how the CPR assignments affected their learning. One of the questions, posed in an online survey near the end of the course, was:

> *"Compared to a normal writing assignment where the paper is handed in on paper, graded by a teacher or TA, then returned,do you think the calibrated peer review system helps you learn the subject matter better? (comments welcome)"*

- Learned more responses: 25
- About the same responses: 8
- Learned less responses: 8
- Completely ineffective: 11

Some of the positive comments were:

"Even though EarthEd has it's problems, providing a universal piece of software that allows for multi-content access at home, and provides a standard for accessing/grading/doing assignments, cannot be surpassed.

More classes need to be software supported such as this one."

"It's a great format."

"It's nice to have immediate content with peer reviews, as well as being able to compare the paper to the rubric on hand."

Typical negative comments were:

"What would have helped more is an outline from you telling us how to write a science paper on each of the subjects."

"Complete waste of time."

"Most of my peers' papers that I have read were not what you wanted and seemed to talk about things that weren't relivent (sic) to the course."

"My peers do not know how to write as well as my TAs"

Some of the comments indicated that students may have interpreted the question to be asking whether they learned from their peers' papers, rather than from the CPR system as a whole. I looked, in more detail, at students who rated the CPR method as "completely ineffective" to see what was going on with them. Among them were final course grades of 1 D, 4 C's, and 6 B's. All but one did not do the last paper assignment. Two of the students had A's for all 3 of their papers, but did not do the last one. Most of the comments asserted that the grading methods were unfair or had a complaint about the way the assignment was posed (from too vague to too restrictive). Three were critical of the EarthEd software, complaining that it was not Word, didn't have a spell check or was difficult to learn and use. There was some justification for software complaints because they were exposed to a new version and a few students were adversely affected by bugs, but these were quickly fixed and distributed to students through an automatic update system. Class announcements and email messages invited students who felt their grade was unfair to ask for a TA grade, so apparently the students who thought CPR was unfair were not at lecture or were not listening. There were complaints that assignments were not completely spelled out. One student was very critical that the score-sheet was not made public prior to the assignment due date. Another criticized the existence of a score-sheet and preferred to just write everything he knew about a subject, to get a higher grade.

I also examined the final exam scores to see if there was a difference that might be attributed to the CPR method. I taught oceanography almost the same in Winter 2004, Spring 2004, and Winter 2005. The only difference was that in Winter 2005 I removed the weekly thought question assignment and reduced the homework workload, but added the CPR writing assignments. I gave an identical final exam during the 3 versions. The exam was not particularly targeted toward the CPR assignments and past attempts failed to see differences in final exam scores when I changed the course. Of course, the final exam only tests content knowledge and I hope that the writing activities improve student understanding of science process, etc. The final exam copies were collected after the exam, so copies were not circulating among the student population. The mean scores were:

Average scores:

Winter 2004: 20 students, average: 69%
Spring 2004: 52 students, average: 67%
Winter 2005: 74 students, average: 75%

The winter 2004 and spring 2004 courses had very close averages, with the winter 2005 version up by 5 to 7%. Could this happen at random? The standard deviation of the mean for Winter 2005 is 1.5%. If it is assumed that the grades are normally distributed and there are no biasing effects, the likelihood of this happening at random is less than 0.1%. The similarity of the classes and consistency in average grade for winter 2004 and spring 2005 classes, except for the CPR writing assignments during winter 2005 argues for a positive effect in content assimilation due to the CPR method.

Other Observations about UCSB Oceanography

I would like to offer some additional observations about the oceanography students at UCSB. First, most students own their own computer. I always install the EarthEd software in a UCSB computer lab that is available to students, but very few use it. All but a few students are able to install and successfully use the EarthEd software on their own computer. This is their preferred way to access the course resources. On the whole, they are bright, interested, resourceful and forgiving of minor glitches. The biggest technology problems students have are caused by viruses, spyware, corrupted systems, and no place to go to get technical support. Learning EarthEd is challenging for some students. Some do not seem to read instructions and ignore emails. Also, there seems to be a fairly high initial dropout rate during the first two weeks. The workload is higher in my version of oceanography, and I have polled students who reply that they have dropped out because of this.

Conclusions and Summary Comments

I have discussed the use of earth data and writing assignments in a general education science course. The importance of a science literate populace to the well-being of our society is unarguable. Investigating, writing, and analyzing others' assertions is a skill needed for voters to support sensible environmental and science policies. The best way to learn a skill is to do it. The same applies to science. We have the tools to deliver robust science experiences to our students, so let's get on with it!

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Appendix I

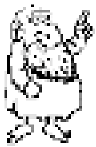
Our Dynamic Planet for Plate Tectonics Investigations

The following section describes the modules in Our Dynamic Planet. This is a demonstration that is best if you have the CD running on your computer and go through the specified operations. After you click on the "Our Dynamic Planet" button in the Office screen you will see the screen of figure 2, below.

Figure 2. Workshop screen. This is an index of the tools that are available to you.

Move the mouse over the icons along the bottom of the screen to display the purpose of each of the tools. The Plate Tectonics Lecture is from a 30 minute animated video created by Prof. Tanya Atwater in the 1980's. It is broken into segments so that you can repeat any portion that you find confusing. The Profile Game helps the student focus on aspects of the elevation profile that will be needed to effectively interpret the MAP data. The geography game was created for students who have not had experience recognizing important geographic features on a world map. It will review the oceans, continents, seas, and other features of interest to marine geologists. The MAP tool is where earth data are accessed and displayed for the science investigation. The Graphics Workshop allows the student to edit and print images that are captured using the MAP tool. The Graphics Workshop to create free form drawings. The drawings can be printed or copied to a floppy disc or zip disc for use on another computer.

The software tools are easy to figure out. They will be discussed in more detail below.



Be sure to notice "rollover help" at first to familiarize yourself with the function of each button. This help works differently from that in the EarthEd modules. The help instructions appear in the text box at the upper right corner of the screen.

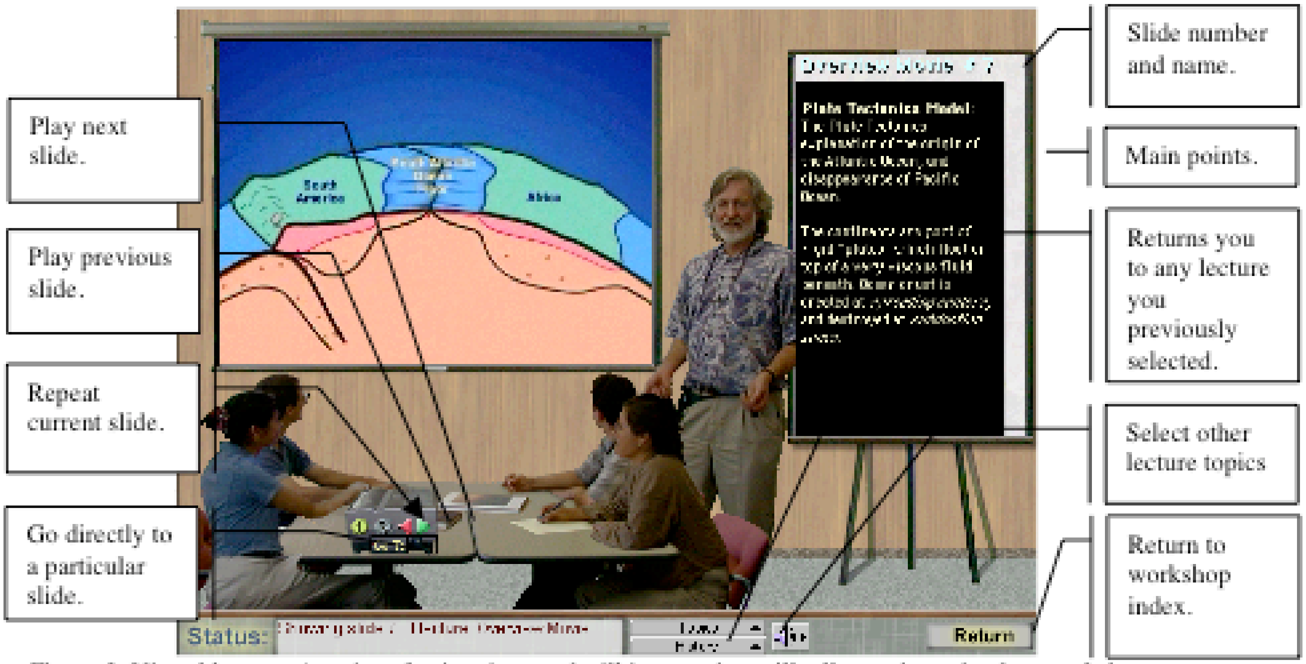


Figure 3. Virtual lecture. A series of animations and still images that will tell you about the theory of plate tectonics and interesting facts about volcanoes.

Plate Tectonics Lecture (video by Prof. Tanya Atwater, 1980)

The plate tectonics lecture will let you, at your leisure, view an animated explanation of the theory of plate tectonics. You can also access interesting information about volcanoes. Figure 3 shows the computer screen for this tool. The controls on this tool are very straightforward. You can advance the slide projector forward and backward, or select a slide randomly. In addition, the "Topics" menu allows you to access other short narrated lectures of interest about volcanoes.

The access to lectures in the "Topics" menu is a bit tricky. 1) hold down on the "Topics" menu, a popup menu comes up, **2)** drag the mouse over the list (of 2) topics, and **3)** when you've decided on the topic you want, the mouse button is lifted. The list of lectures stays visible. **4)** move the mouse over the lecture you want and click it. The list of lectures then disappears.

When you are finished watching lectures, click the "Return" button and you will get back to the workshop screen.

Profile Game

The "Profile Game" is extremely important. It will help you understand how to use profiles when you get to the MAP tool, where you must use them to identify geological features for your study of the topography of the earth. The purpose of the game is to find the unknown feature and answer some questions about its dimensions and shape.

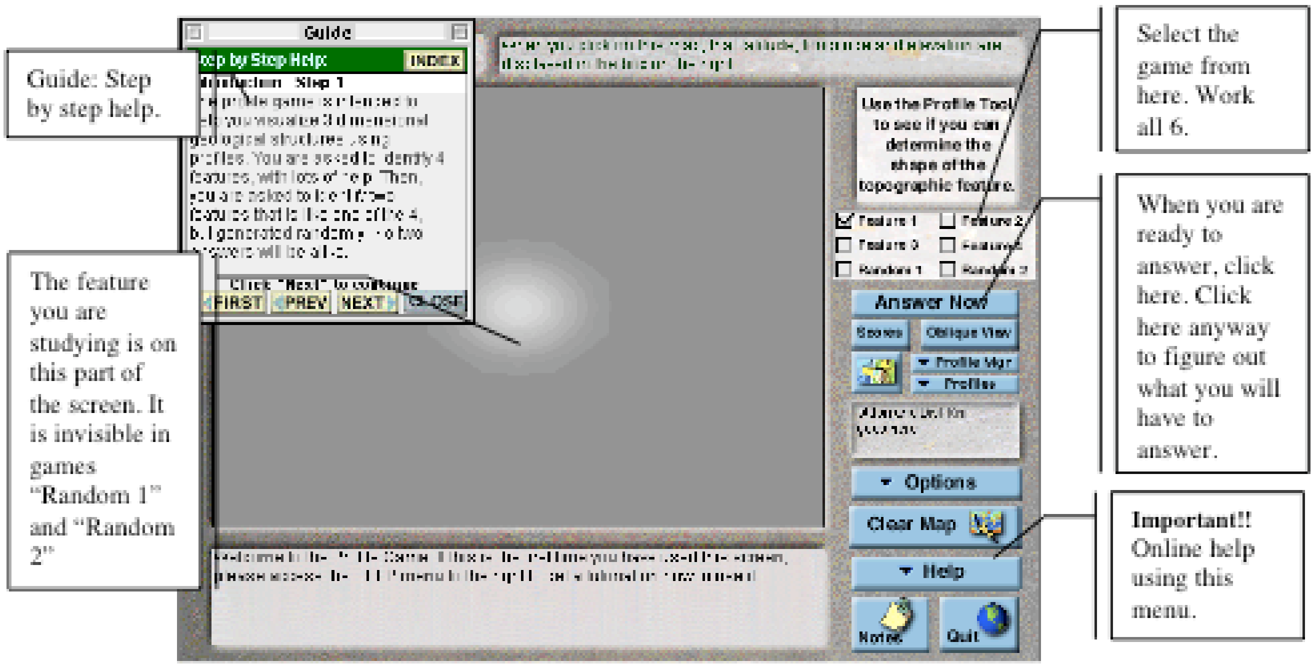
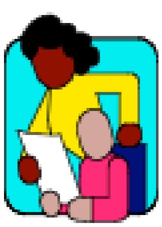


Figure 4. Profile Game. This game has been designed to help you understand how to classify geological structures using elevation profiles.



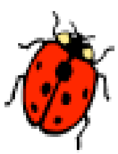
Teaching tip: The Profile Game provides a good opportunity to introduce the idea of observations and interpretations. The profiles that are used to determine the shape of the geological structure are **observations**, while the name of the structure (trench, basin, etc.) is the **interpretation**.

To get to the Profile Game from the "Our Dynamic Planet Workshop", click on the "Profile Game" button. When you get to the screen shown in figure 4, take a moment to notice its help features. When you move the mouse over a button, its function is explained in a text field at the upper right of the screen. Notice the "Help" popup menu near the lower right. You can bring up the "Guide" window, or an animation that helps you visualize what an elevation profile represents.

Important features to notice: This screen (figure 4) shows several important features of this software. First is the "Guide" window. The Guide gives you step by step instructions on how to use each of the tools on the CD. You can click on the "Index" button (on the Guide) to see a list of particular tool features that you might want to use. Another important feature of the screen is the "rollover" help you get when you move the mouse over the buttons. This can help remind you what each button does. In addition, the "Help" popup menu brings up the Guide at any time.

Profile Game Rules:

You may select from 6 possible games. The first 4 games are designed to make it easy for the student to succeed, and to learn the game. The "Random" features are a bit more difficult. After you score the random game, you can continue entering new answers, but they will not be scored. You only get one chance on each random game, but the game allows you to generate new random games for "Random 1" and "Random 2", and try again. The highest score is the one that applies for your grade. Click the "Scores" button to see your current highest scores.



Bug Alert: ***The profile game shows a dialog box when entering your answer or setting options. When you close these dialog boxes, use the "Done" or "Ok" buttons. Do not use the small square in the upper left corner. Also, do not click the mouse outside the dialog box, when it is showing.***

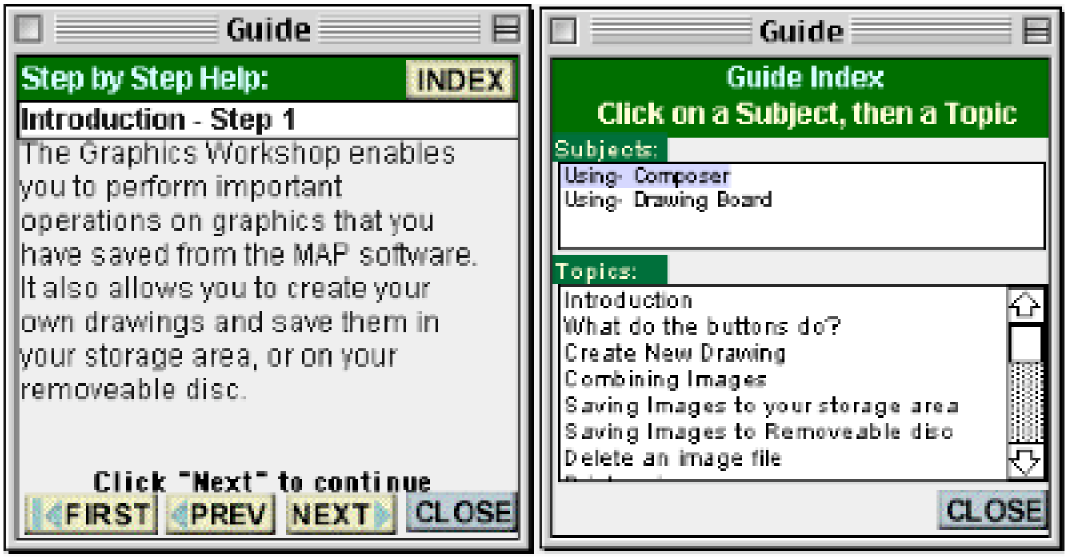


Figure 5. This shows two views of the "Guide" window.

"Guide" window

The Guide is your most powerful online help. You can use it to learn how each of the software tools can be used. It even points out interesting tectonic features in the MAP software. The guide only lists topics relevant to the tool that you are currently using.

The view on the left (figure 5) is displayed when you load a tool that has a Guide. It is set at a general introduction for that tool. Click the "Next" button to go through a series of steps that orient you. For a more comprehensive set of instructions, click the "Index" button on the upper right, and a list of topics will be displayed in the top text box. When you select a topic, a list of short subjects under that topic will be displayed in the lower text box. Select a subject to bring up the information.

Geography Game

The Geography Game is intended to help the student review basic earth geography. After all, how can a student write about plate tectonics if he/she doesn't know the names of the continents and oceans? The game is full of cheering and clapping sounds and is fun to play. In a classroom of computers, headphones may be required, or the sound can be turned down to zero. There are 5 games. The score for each student is recorded and the highest score for each game can be displayed.

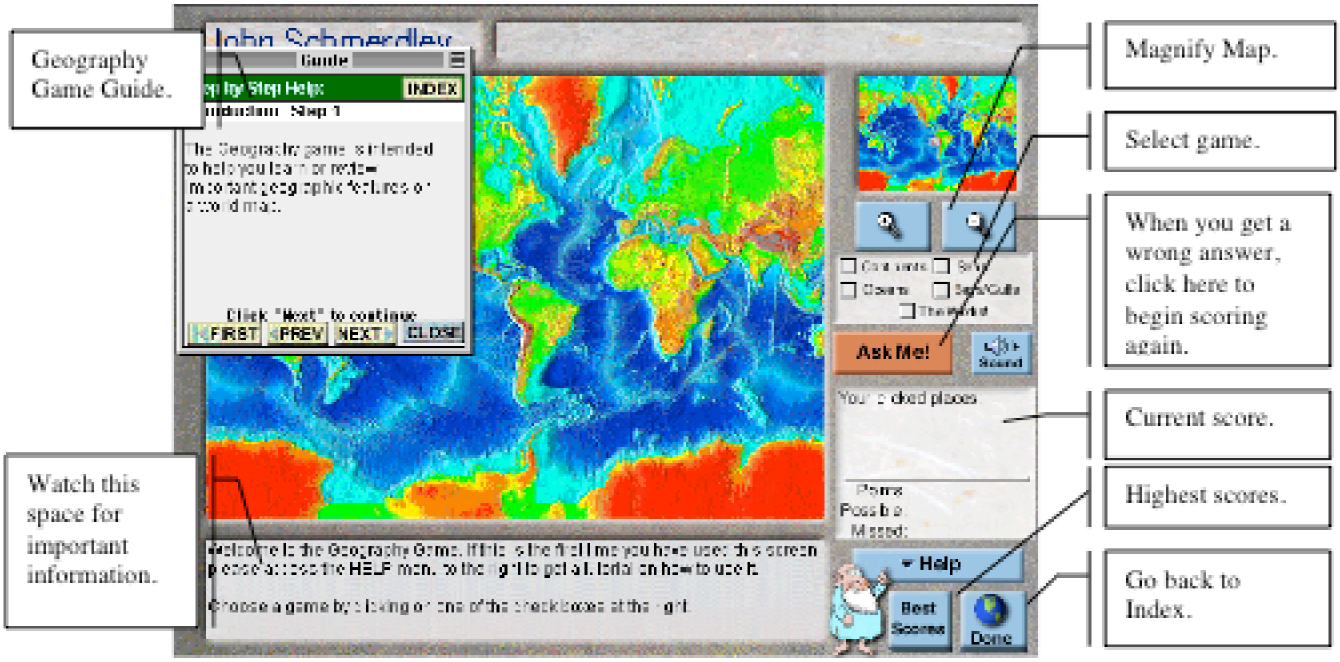


Figure 6. Geography Game. Use this game to review your knowledge of geography. You must be able to identify the continents, oceans, and seas from a world map. This makes it fun.

Map: Where the earth data are displayed

The most important tool is the MAP screen. It allows access all of the geological data that a student will need for a science investigation. By simply clicking the mouse, he/she will be able to make profiles of the topography, plot volcano and earthquake locations, and view movies and photos of interesting earth features. Figure 7 shows this screen.

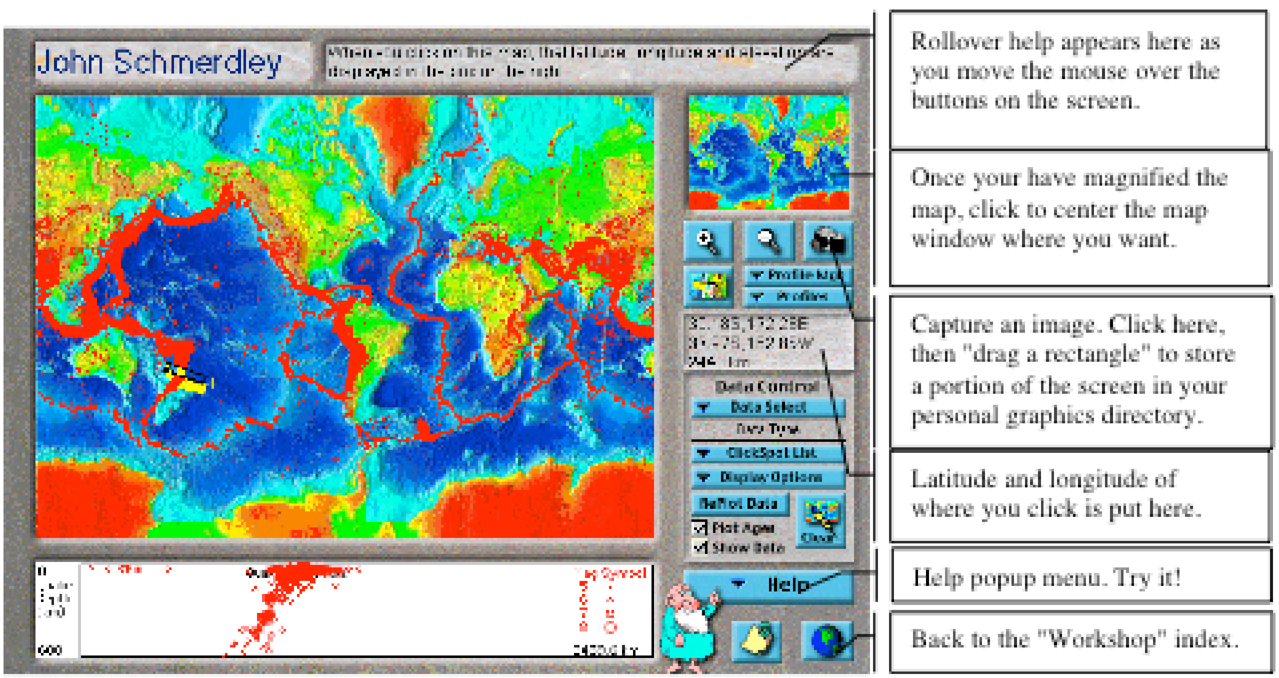


Figure 7. Map. This is the access center for acquiring and plotting earth data. Notice the "Rollover Help" to find out what each button and field means. Please read it carefully. Notice the "Help" popup menu, which provides a choice of various kinds of help and information.

The map screen is best learned from its help features. Balloon help and the tutorial movie under the "Help " button will allow you to explore the function of each of the buttons. The most powerful help feature is the set of tutorial movies available from the "Help" popup menu. The Guide also provides detailed help and even points out interesting map features. Choose whichever help is most effective for you.

Caution: The profiles are generated from a topographic database (called ETOPO5). It varies in quality and may be wrong or lack detail in certain regions. For example, since it averages over approximately 5 mile squares of the surface, sharp mountain peaks will not show up, since their height will be averaged with surrounding lower elevations. **The volcano database is also limited.** It is a compilation by the Smithsonian Institute and is the best available. However, it does not contain any of the multitudes of unmapped volcanoes that we know are on the seafloor.

Important operations available in the Map software:

Latitude and Longitude:

A location on the map is determined by its latitude and longitude. When you click on a spot on the map, the latitude, longitude, and depth are displayed in a text box. Be sure you can use this, as it is very useful in describing your results and determining locations.

Magnifying and Scrolling the Map:

There are two magnifying glass icons on buttons at the upper right. Click on one and the cursor will change to a magnifying icon. Move the cursor over the point you want to magnify and click. The map will expand, with the clicked point at its center. The second magnification causes a rather large map to be loaded, which will take awhile. However, this is the way you get the most resolution. To scroll the magnified map, you click on the small index map at the upper right. Try it!

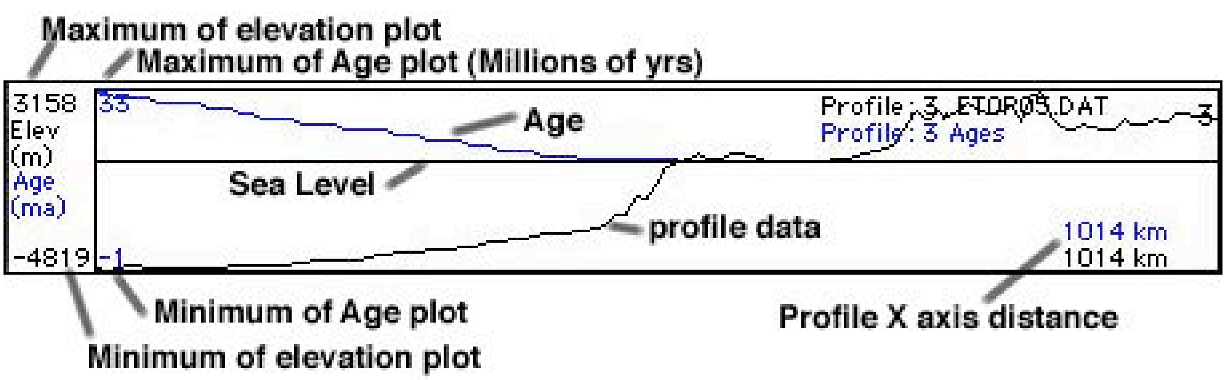


Figure 8. Description of the profile plot. Notice that the maximum and minimum elevations on the plot are 3158and -4819 meters. Sea level is at 0 meters, which is shown as a solid line. The length of the profile is 1,014 km. Notice the distance is in km and the elevation is in meters. The Age data shows up blue on the

screen. The plot shows 33Ma maximum age and -1Ma as minimum age. The true minimum age 0, because -1 would be in the future.

The Profiles:

A profile is made by first clicking on the "Profile" button, then at the two locations on the map that define the start and end of the profile you want. The profile button is the one on the right of the map, with the small line plot on it. You can make as many of these profiles as you want. All profiles are saved and can be plotted at any time. You access previous profiles using the popup menu to the right of the profile button. It is possible to plot more than one profile on the plot, but you must turn off the automatic scaling of the plot first, using the **Display Options** button.

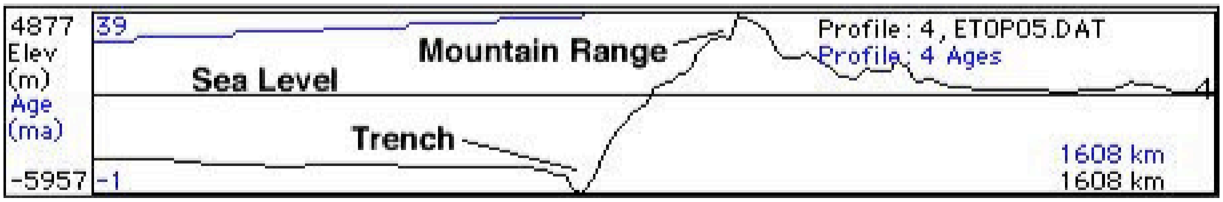


Figure 9. This is a profile where the scales are manually set. The depths range between +6000m and -8000m. The distance of the plot is 5000 km, but the profile is not that long.

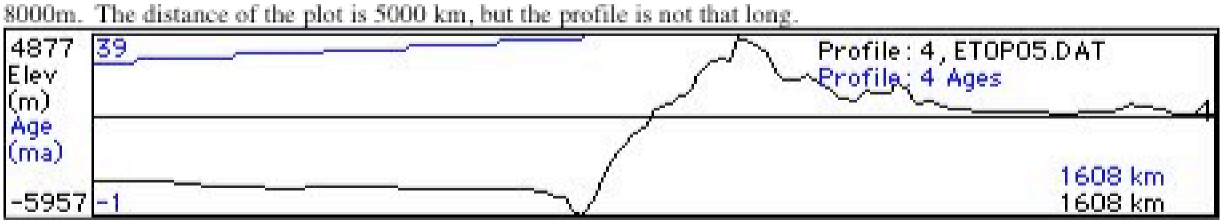


Figure 10. This is the same data of figure 12, but plotted with auto scaling. Since the auto scaling sets the plot limits equal to the data limits, we can see that the maximum height is 4724m, the maximum depth is -7424m, and the length of the profile is 2,528 km.

When you plot profiles over the ocean, you will notice that the seafloor age is also plotted. The portions of the profile on land do not have ages in the database, so age is not plotted.

The Profile on the line of the Great Circle Path:

The great circle path between the two endpoints of the profile is plotted on the map. The profile plot is plotted using this path as the plot axis. This will be called the "GC profile". The path is drawn in black and the profile is in red. The purpose of this plot is only to locate general features, not to determine the actual depths. The GC profile is scaled to the maximum values. The GC path (black line) is 0 depth (sea level). If the profile is below the line, the depth is negative, which indicates a region covered by water. If the maximum depth is 6000 meters, then the maximum amplitude of the GC profile will correspond to the 6000 m depth. This distance is set to 15 pixels (the smallest unit of Macintosh screen resolution) by default (it can be changed using the "Scales on Great Circle Path" choice on the "Display Options" popup menu). But, if the maximum depth is 100 meters, the maximum amplitude of the GC profile will still be 15 pixels. So, the GC profile plot for a constant depth of 6000 meters will look precisely the same as a GC profile plot for a constant depth of 100 meters. To determine actual depth values, use the profile plot at the bottom of the MAP screen, or click on the location where you want the depth and read its value from the text box.

Selecting Data to be drawn on the map:

The type of data to be plotted is selected in the "Data Select" popup menu. You must also make sure that the "Show Data" box is checked.

The Volcanoes:

You can plot the volcanoes by selecting "Volcanoes" data from the "Data Select" popup menu. Remember that the large number of volcanoes on the seafloor are not shown because most of their locations are not known. When you click on the symbol for a volcano, wait until the cursor returns to normal, and information about that volcano appears in a box below the map.

Earthquakes:

You can plot earthquake hypocenters by selecting "Quakes" in the "Data Select" popup menu. The quakes are all quakes greater than magnitude 5.0, which have been measured by the world-wide network of seismic stations operated by many organizations who report their measurements to the National Geophysical Data Center in Boulder, Colorado. Earthquake hypocenter cross-sections can be plotted by first making a profile line where you want the cross-section. Then click on "Replot Data" (Earthquake data must first be selected) and the quake database will be searched. When it is done plotting, or when you hold down the mouse button, the cross-section plot will be created. Quakes that are included in the cross-section plot are plotted in yellow on the map.

Note: The cursor shows the year of the data being plotted. To stop earthquakes from plotting, hold down the mouse button until plotting stops.

Heat Flow:

Select "Heat Flow" from the "Data Select" popup menu. You will see a grid of small red squares appear on the map. Click on any square to get its heat flow value displayed in the box below the map. **The most useful way to use the heat flow data is by plotting a profile of values.** You can get a profile of heat flow data the same way earthquake profiles are plotted. First, make a topographic profile between the points for your desired heat flow profile. Make sure you have selected "Heat Flow" from the "Data Select" popup[menu. Then click on the "Replot" button. A box will be drawn around the profile line and heat flow values within it will plot as yellow. A profile of heat flow values will then be plotted in the box below the map.

The Click Spots:

Select "Click Spots" from the "Data Select" menu. When you click on one of these dots, a database of images and movies is accessed. Movies "linked" to the spot you clicked on will show up in the "ClickSpots" popup menu. Select one and it will appear. To close a movie, click on the close box on the upper left corner of the window. To close a graphic, just click on it and it will disappear. **Black rectangles** on the map indicate a figure that spans approximately the area of the rectangle. Click inside it to access the figures linked to it.

Area Maps:
Select "Area Maps" from the "Data Select" menu. A number of black boxes will appear. These define the boundaries of each area map. Click inside one of the boxes, then select the map from the "Clickspots" popup menu. A detailed area map will appear. You can then plot volcanoes, quakes, or click spots on this map. To return to the base map, select "Base Map" from the "Data" menu.

Place Names:
Select "Place Names" from the "Data Select" menu. A lot of rectangles will show up on the map. These rectangles approximately enclose important earth features. Click inside of one of them and use the "Clickspots" menu to see the names of the enclosed features.

How to:
* **Get the maximum and minimum depths on a profile**: When you make a profile, the plot is scaled to the maximum and minimum depth of the profile. Just read it off of the plot.

• **To set the maximum and minimum depth on a profile plot to specific values:** You might want to do this if you want to compare different profiles. Autoscaling could make comparisons between profiles difficult to visualize. From the "Display Options" popup menu, select "Elevation Plot". Then enter the maximum and minimum values into the indicated boxes. Notice that the "Auto Scale" checkboxes become unchecked. To return to auto scaling of the profile plot, come back to this dialog and set the autoscale check boxes for each of the axes.

• **Age plot idiosyncrasy:** Sometimes the minimum age on the age plot (on the same display as the elevation profile) will show a minimum value of -1ma. Since ages are figured backward in time, the -1 value is actually in the future. Ignore it. It should be 0 age.

* **Put more than one profile on the depth plot**; Select "Elevation Plot" on the "Display Options" popup menu and click in the "Multiple Plots" box. You must not have any of the "Auto Scale" boxes checked. This assures that each profile has the same scale on the plot.

* **Get the depth at a place on the map**: Click on the place you want the depth. It will be displayed in a field to the right of the map.

* **Get the length of a profile, in km**: The length of the profile is always displayed in the box to the right of the "Budget" button. You can tell what it is because its units are km.

* **To save an image from the MAP screen:** Display the data the way you want it. Click on the "Camera" icon. Then move the mouse over the upper left hand corner of the

rectangle you want to capture. Hold the mouse down. Drag the mouse (moving the mouse without letting up on the mouse button) to the lower right corner of the rectangle you want. Note that a square bounding box is drawn. If this box does not start at the corner you specified, you need to hold the mouse down a bit longer before dragging it. When you lift the mouse, you will get a small dialog box asking you for a name for the image file. Don't make your names too long.

Read "Example Investigations into Plate Tectonics." This material is in another section of the workshop notebook. It discusses how the Our Dynamic Planet data can be used to investigate a number of interesting topics relevant to plate tectonics.

Appendix II
Anatomy of a Science Paper

Assignment Description

The purpose of this writing assignment is to help you understand how convergent and divergent plate boundaries differ and how to use earth data to determine the boundary type.

Preparation for the assignment:

1) Carefully read this description. You can print it out by clicking the "Print" icon below this text field.
2) Read the textbook on plate tectonics. You can also watch the Virtual Lecture in the "Our Dynamic Planet" module. This shows animations of how plates move on the earth. Next, read the "Plate Tect Summary" file. You can access this file from the help files list on the right. This document emphasizes the data that can be used to develop your interpretation, so is very pertinent to this assignment.
3) You will also need to become proficient with annotating the figures that you capture from the "Our Dynamic Planet" module. The Guide has several tutorials about annotating figures, and they will save you time on this and future writing assignments, as well as improve your grade.

To begin the assignment:

1) Select "Our Dynamic Planet" from the "Data" dropdown list that is visible on the Assignment Index screen.
2) Go to the MAP module.
3) Select "Small Area Maps" from the "Data" dropdown menu.
4) The two regions you will focus on will be the Tonga region at about 29deg S, 180degW (region A), and the East Pacific Rise at about 50deg S, 115deg W (region B). You can find these places on the MAP by clicking on a location and noting the lat/lon in the location field.

Your task(s):

1) Use the data available in the MAP module of the "Our Dynamic Planet" module to characterize the plate boundaries at the two specified locations specified above. Make a "model" of each location. This must be a simple sketch that you draw yourself. It doesn't have to be pretty, but does have to include the most important features that characterize the particular plate boundary. Use as many different data types as are appropriate (and available on the CD) to support your model.

2) Follow the structure given in "Anatomy of a Science Paper". This resource is in your lab book, or can be downloaded from here from the Resources list (here it's called "Science Writing Styles").

Ways students improve their grade:

1) Start early so there is time to interact with the TA and Prof., and recover from any computer problems.
2) Read the instructions.
3) Write clearly and briefly. If you were telling your non-science friend about this, how would you express it to him/her?
4) Explicitly demonstrate how the data that you illustrate lends support to the model figure that you draw. It is not enough to just show a data plot. You must describe the salient features and show how it agrees with your model's features and predictions.
5) Attend class, where these issues are often discussed.

Ways students sometimes lower their grade:

1) Don't read the instructions for the assignment

2) Don't read "Anatomy of a Science Paper", in your lab book, which clearly spells out how to write this paper.
3) Use too many figures
4) Use too few figures
5) Scan your model figure from the book, rather than drawing your own.
6) Write a "book report" where no data are used.
7) Don't use a location map
8) Don't annotate figures
9) Don't start until the last evening before the due time
10) Don't interact with your TA or professor when questions arise. This can happen when you start so late that they are not available.

Writing the paper

The following sections explain, in great detail, how to put together your short science papers. Please read it carefully. This format is very common in science writing and will help you present your thoughts in an organized and clear way.

This description is specific to the plate tectonics paper. The other writing assignments will follow the same format and principles, but will vary in some details, so be sure to carefully read each assignment.

General writing tips:

1) The paper should be organized carefully. Follow the structure discussed below.
2) Each section of your paper will be composed of paragraphs. Each paragraph should begin with a topic sentence which states the point you will make in that paragraph. Every sentence after that should support the topic sentence. Paragraphs are typically four to eight sentences long and each sentence should address only one point.
3) Make your sentences simple, but vary their length to make the paper interesting.
4) Avoid the passive tense. It is boring. An example of the passive tense is: "It was shown that......." An example of the active tense is: "I have shown that ...."
5) Avoid contractions. These are for more informal writing, like that in this workbook. Say "can not" instead of "can't."
6) Be careful with "Replace All" on your word processor. You may replace words that you don't intend to replace.

Visual Presentation:

The online EarthEd writing software makes it easy for you to write your paper by providing the basic topic headings and guiding you regarding what each should contain. Your printouts will have a consistent format. Printing is meant mostly for proof reading and as backup in case something goes wrong. It is best to write your assignment directly into the EarthEd Writer screen. Save your file periodically, but become familiar with the automatic backups that get written to your hard drive every five or ten minutes. To access them, click on the "Disaster Recovery" button.

All figures are linked from your personal storage area, or from the common graphics library accessible to all students. Getting figures into your storage area is extremely easy with the EarthEd software. You can upload figures from any source, or draw your own using the graphics drawing tool.

Your paper should be thoroughly proofread.

Do not scan in figures from the book. Your work must reflect your own thinking and the book may provide beautiful images, but a crude sketch that shows that you understand the material is preferable.

Headings

Technical writing follows a specific format. This format varies, depending on the subject and requirements of the magazine or journal publishing the article. But, there are common features to all formats. The format described here will be. **Your paper must have headings matching those described below**.

- Introduction
- Methods:
- Observations
- Interpretation
- References

Introduction Heading

A very important parts of a science paper is the introduction. You should orient the reader. Why are you writing this essay? In just a few sentences, explain the topic of the paper and why it is important or interesting.

Here are some examples of weak and strong sentences that might appear in an introduction:

<u>Strong statements:</u>
I will discuss the general shape of the sea floor and discuss how the motion of the plates affects that shape. I will show how the topography is related to the distribution of volcanoes and earthquake and how these data can be used to determine the kind of boundary between the various plates.

<u>Weak statements:</u>
Plate Tectonics is really a neat subject. I'm writing this to satisfy the writing requirement and will discuss lots of interesting features.

<u>**Introduction checklist**</u>
The Introduction should cover:
___ What is the topic of investigation in your paper?

___ Why should anybody care? Don't just say it's interesting and important. Say *what's* interesting and why.

Methods Heading

This section is where you discuss how and where you got the data. Maybe you made your own measurements, for example, if you went to sea and measured depth profiles, or possibly you measured earthquakes with seismic equipment. For this course, you will be accessing data from existing databases. You should describe those databases and explain any of the inherent limitations of the data.

Here are some examples of statements that might appear in a Methods section:

Strong statements:
This study is based on sea surface temperature data acquired by the Nimbus satellite. The data are available from NASA at http://www.nasa.gov/data/nimbus/SST/ and are accurate to about 0.5 C. The temperature data are available on a 5km grid spacing at 1 week intervals.

Weak statements:
The software used in this course is really cool. It shows the locations of volcanoes and earthquakes, and the topography can be displayed using the ETOPO5 database, which is on the " Our Dynamic Planet" CD. This is a really cool course and I will learn a lot from these data.

Methods checklist
The Methods section should contain:
___ A description of how the data were collected (reference any web sites or the "Our Dynamic Planet" module.
___ State the source and accuracy of the basic data that you will use
___ References to data sources (see Lab #3 for a description of the "Our Dynamic Planet" data)

Observations Heading

Your observations or "data" are described in this section. It is not necessary to talk about conclusions or reasoning here. Just stick to what you observed.

Qualitative Observations:
Qualitative observations are not really specific, often relating to some arbitrary and unspecified reference. For example: "the waves are big," or "that hill was quite steep." To an experienced big wave rider, the waves may be quite small, but to a non-surfer, they may seem quite large. Steepness of a hill on a hike is also very subjective. A person who hikes a lot may find a hill much less steep than a couch potato. Qualitative observations are not very useful in technical writing, unless you are specifically discussing your reaction to an observation (which is rarely done).

Quantitative Observations:
Quantitative means you are actually observing **Quantities**. For example: "the waves are between 10 and 12 feet high," or "the hill rises at a 45 degree angle," or "the hill rises at a 50% grade."

Clarity of Observations:
The discussion on "Using Figures" should be read carefully. You should be sure to first tell the reader where you made your observations. The location could be marked on a map. When maps are of a very local area, an inset showing a larger area that is more familiar to the intended reader will be provided.

You observations should include statements that:

- describe the data you are presenting (including figures). Note that figure captions should point out the most important features in a figure. Use the figures you need, but be economical with figures. See the discussion on figures.
- name features that are evident in the data
- describe relationships between observations

Examples of observations:

Strong observations:

Many volcanic mountain ranges (chains) such as the Andes, the Aleutians, and the Japanese Islands run parallel to deep, long oceanic trenches.

The Japan-Kuril trench is ____ km long and ranges in depth from ____ to more than 9000 m.

The East Pacific Rise begins at about 56°S 118°W and ends near the end of the Gulf of California. It has a typical elevation of -2800m, significantly higher than the surrounding seafloor which is typically 4000m or more beneath the sea surface

Weak observations:

Volcanoes are next to trenches.

The trench near Japan is deep and long.

Observations checklist:
The observations section should contain:
___ A description of each observation
___ Figures illustrating your data
___ A reference to each figure in the paper. Don't assume that the reader knows why you put in a particular figure. Explain, in the text, what the figure shows.
___ Quantitative observations, whenever possible

___ Figures must be in the order they are referred to in the text. Refer to Figure 1, then 2, etc.
___ Make sub-headings, if appropriate, for observations in different areas. For example, you might have, for area subheadings: *South America, Tonga-Fiji Region, Global Observations*, etc.
___ Use more than one profile to characterize a linear feature. There may be interesting variations along the feature that will add substance to your paper.
___ Use multiple kinds of data to support your interpretations. For example, elevations, quakes, volcanoes, and sefloor age can usually all be used to support a plate tectonic interpretation.

A good way to get a C or less on this paper is to ignore the data on the CD-ROM "Our Dynamic Planet," and make a book report on plate tectonics. This kind of paper misses the point of the assignment.

Interpretations Heading

Here is where you relate your theory or model to the observations. You may need to adjust the theory to fit the data. Generally, this is an iterative process of creating a model or prediction of the outcome, taking data, and then modifying the model to fit the data.

Each interpretation must be backed up by one or more observation(s). Simple sketches or cartoons should be used at this point.

Conflicts in the data:
Unfortunately, the real world is not so nice as your textbook. Data rarely agree perfectly with your interpretation. Data also have errors, so may be expected to disagree to some extent. It is important to be forthright about where the data disagree with your model. Maybe you can refine or improve your model if you expand your thinking to consider modification or complexities in your model.

You will find that earthquakes do not always produce "classic" textbook patterns, and the volcanoes dataset may be missing volcanoes where observations are not available.

Honesty:
It is very important to refrain from over-interpreting your data, or exaggerating its accuracy. It is also important to include all of your data, rather than only select data which agree with your preconceived ideas. Sometimes we observe data that do not fit with our expected conclusions. It is very tempting to just forget about it or blame it on a malfunctioning measuring instrument. Discarding good observations is a way to miss a very important discovery that might just disagree with preconceived ideas.

Science has a very high "trust factor." This is because the ethics of science are based on honesty and openness of reporting. Experiments must be repeatable by others, and important experiments are always checked or repeated. Journal articles are critically reviewed by other scientists who are experts in the field. Of course, there may be great debates about the meaning of the observations. These debates are part of the scientific process. Scientific honesty means that the person making the observations is scrupulous in reporting "just the facts." The facts are not only the observations, but also the accuracy of the observations.

Your interpretations section should include statements that (refer to Lab 3 homework, part 2):

- emphasize relationships between observations (e.g. volcanoes and trench, earthquakes and volcanoes, elevation and age, etc)
- describe your plate tectonics model (**a sketch, not a figure from a book or web page**)
- show correspondence between your model and the observations
- discuss areas where the observations do not support the model. This could occur from genuine conflicts between observations and model, or simply because there are no data that can tell you about it.

Example, Observation and following Interpretation:
The Observation: *The topography shows a trench-like feature (Figure 3) which plunges to a depth of 8,000 meters from a depth in the West of 3,000 meters. This trench extends along the full Western margin of South America, for about XXXXX km. The Andes Mountain Range lies to the West, along the western boundary of South America*. **The Interpretation:** *The many active volcanoes in this mountain range suggest that it was built by volcanic activity (Figure 4). Several cross-sections of earthquakes (Figure 5) show a descending pattern characteristic of subduction zones. Figure 6 shows a sketch of my model for this structure, which is a classic subduction zone.* **Note that these interpretations are backed by observations**.

You should be particularly careful to look at more than one profile in your study area. For South America, you would want to do a number of sections along its western boundary. This might allow you to make a more detailed picture of the shape of the descending slab.

<u>Interpretations checklist:</u>
The Interpretations section should contain the following:
___ Interpretation of each of the observations that you present in the Observations section
___ How your interpretations relate to those of others (e.g. your textbook)
___ References (see "References" discussion) to any material discussed from other sources
___ A sketch (model) of your interpretation of the observations
___ A discussion of the sketch (model) and how your observations support it.
___ A discussion of any data that disagree with your observations

Note: Most science papers also include an abstract, discussion and conclusions section. This assignment incorporates the most important features of scientific thinking, though, without getting too detailed in specific formats.

Using figures to illustrate your paper:

The old cliche that says a picture is worth a thousands words applies especially in science and technical writing. This kind of writing can get complicated and extremely difficult to understand. Any time you can illustrate a point with a picture or sketch, the clarity of the presentation is enhanced. Most people are not really very good at visualizing geometrical shapes and physical phenomena that have been described with words. A picture fills in questions in the reader's mind and lessens the tedium of pages of text.

The busy reader may only look at your figures and read the captions. This underscores the importance of good captions. Figure captions should briefly describe what the figure shows. For this example, Figure 2 would have a caption that said something like: "Locations of the three studies discussed in this paper." That would be enough.

When writing a technical paper related to the Earth, it is important to show the reader where the study took place. Where is the study location on the Earth? Figure 2 shows how this can be done on a Mercator map of the world like the one in your lab manual. Each study area is clearly marked so that you can refer to it in the text without requiring the reader to remember previous location descriptions. All locations that you mention in the text must be indicated on the location map.

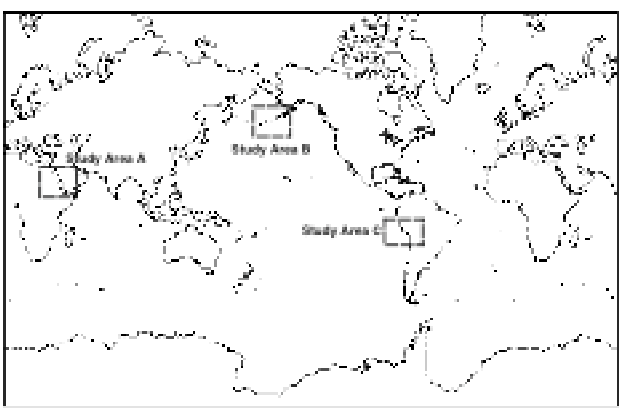


Figure 2. Areas of study.

Since you will be using profiles in your paper, you will want to use figures to show samples of profiles. Maybe you want to illustrate the geometry of a trench, or show profiles across a mid-ocean ridge. Figure 3 shows a representation that would successfully show the location of a number of profiles.

Figure 4 shows an example of how you might print a series of detailed profile plots, which give vital information like the elevations and distances. You should think of the Figure 3 profiles as merely locating the profile positions, which Figure 4 shows the actual profile data.

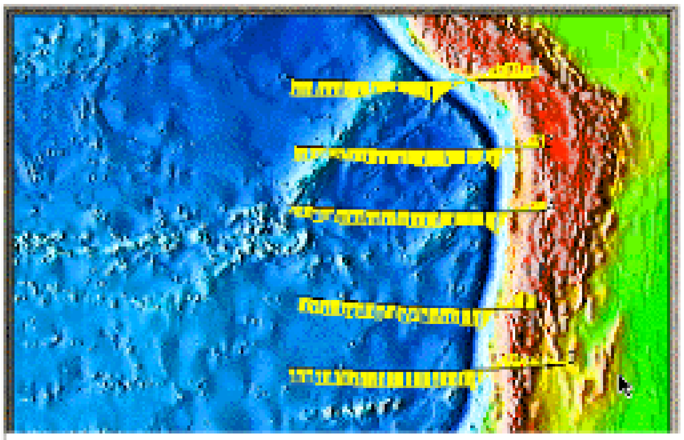


Figure 3. Locations of profiles in area C. (Students: To get the best printout of the profiles, change the color of the "Great Circle Plot" to yellow [Options menu]).

Mistakes using figures:
Believe it or not, ***you can over-use figures***. A big pile of figures showing everything you did will simply not produce a good paper. It is the job of the technical writer to condense the information so that the reader can easily assimilate the information and come away convinced of the correctness of the conclusions. That is the main purpose of using figures, but don't overdo it. If you have lots of figures, you might try combining them. However, each figure should not be too complex. You have to exercise some judgement and restraint to keep the balance between having too many figures and having figures that are too complicated.

Notating figures: Another mistake is just using raw figures. A reader should be able to glance at the figure and caption and get a good idea of what the figure expresses. This means you should use to graphics editing tool to draw arrows to important features that you are examining in your investigation. Captions should also describe the purpose of the figure.

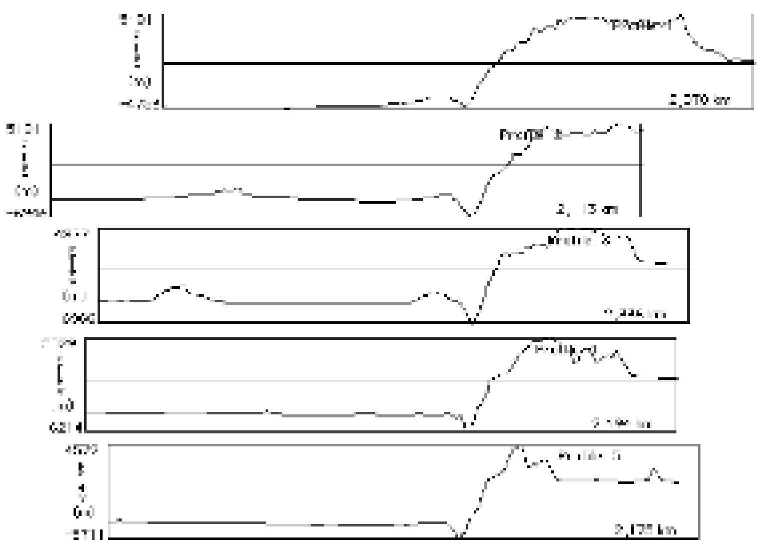


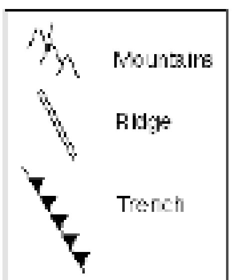
Figure 4. Detailed plots of profiles shown in Figure 3.

Here are the Figures referred to in the text. For readability, it is best to put the figures near to where they are referred to, rather than group them all at the end of your paper.

Symbols to use on maps:

The symbols to the left can be drawn on the map to indicate the presence of mountains. If the mountains are volcanoes, you could put a wiggly line indicating smoke coming out. Colored pencils can be used to advantage, to make your map more readable.

The above symbols are used to represent ridges, which are places where the lithosphere is spreading apart, and trenches, where the plates are pushing together. The cross section view shows the geometry of the down-going side of the trench. The saw teeth are pointed in the direction of motion of the plate that is being subducted.



Legends:
Although the use of particular symbols may follow a convention, it is always important to include a "legend." This is a section on the map that shows the meaning of the symbols. An example of a legend is shown at the left. It is simply a listing of what each symbol, line type, or line color means. Other information that you should put on a map is an arrow showing the direction of north. For the world map, north is obvious, so you don't need it. Smaller maps require a north arrow.

Figures checklist:

___ Each figure shown has a numbered caption, which describes the figure.
___ Each figure is mentioned and explained in the text.
___ Figures are numbered according to the order in which they are mentioned in the text.
___ Figures are clear and easy to read. If the data do not show up clearly on the figure, mark on it with colored pen.
___ There are no figures that are photocopied/scanned from the text, or any other source.

References:

All data, text, and figures that you get from other sources must be referenced. When you speak of other peoples' work in the body of your text, you use a reference. For example:

> *In recent years, considerable effort has been directed towards investigating the biological consequences of climate change (see Bolin et al. 1986; Chapin et. al. 1992; Fautin et al. 1992, for reviews).*

Or:

> *Ocean uptake of carbon is simulated with the world ocean general circulation model (OGCM) of Toggweiler et al. [1989], as modified by Toggweiler and Samuels [1993]. etc.*

There are various styles for referring to others' work, and you may choose any style that is clear. Don't mix styles, though. Notice that you are referring to the author's name, and a date. This will identify a specific reference in the reference list, which must appear at the end of your paper.

Examples follow:

References:

Toggweiler, J.R. and B. Samuels, 1993. Is the magnitude of the deep outflow from the Atlantic Ocean actually governed by southern hemisphere winds? in *The Global Carbon Cycle*, edited by M. Heimann, pp. 333-366, *Springer-Verlag*, New York.

Hurley, P.M., (1968) Absolute abundance and distribution of Rb, K, and Sr in the Earth. *Geochem. Acta*, 32, 273-283.

Note that the first reference is to a book and the second is to a scientific journal article. Each journal requires a slightly different format for references. You may use the format above.

Form of book reference to use:
<Author>, <Year>, <Title>, <Title of book>, <editor or edition of book>, <page numbers of your reference>, <Publisher>, <City of publisher>.

Form of paper reference to use:
<Author>, <Year>, <Title>, <Name of journal>, <Volume number of journal>, <page numbers of article>.

Internet references:
An action-alert posted on the web:
American Psychological Association, (1995) *APA public policy action alert: Legislation would affect grant recipients* [Announcement]. Washington, DC: Author, Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/ppo/istook.html

An article from a newspaper on the web:
Sleek, S. (1996, January). Psychologists build a culture of peace. APA Monitor, pp. 1,33. Retrieved January 25, 1996 from the World Wide Web: http://www.apa.org/monitor/peacea/html

Be sure to reference quotes from your textbook and from the lab workbook.

Final checklist:

__ Name, section, and perm number at the top.

__ All specified headings included (see "Format of Paper").

__ The paper may include any number of figures and drawings. Small figures should be included in the text (drawing them on the computer is optional). Full page figures can be inserted at the closest spot where they are referred to.

__ Do not include any figures photocopied/scanned from the textbook.

All papers will be handed in on-line through the EarthEd system, unless otherwise specified.

Appendix III

Plate Tectonics CPR Assignment Scoresheet

This is in the format used by EarthEd. Items for each heading follow a delimiter with "####" and the heading name. The "Overall" heading applies to items that pertain to the entire paper. The numbers at the end of each item are the possible point values for each item.

Overall#
****
Author shows an understanding of the theory of plate tectonics.
0,1,2
****
Punctuation and spelling are accurate
0,1,2
****
All paper sections are included and include the appropriate content. This means that observations are in the observations section and interpretations are in the interpretations section.
0,1,2
****
Figures are numbered, referred to in the text, have informative captions, and are organized in the order that they are referred to in the text (Credit is reduced for using irrelevant or superfluous figures)
0,1,2
****
Data and others' work are adequately referenced throughout the paper
0,1,2
Introduction#
****
The topic of investigation is easy to identify.
0,1,2
****
The region A and B study areas are clearly indicated on a world map and more detailed country map, if needed. This item should also receive credit if the location map is linked to in the Observations section.
0,1,2
Methods#
****
Methods of data collection are described.
0,1,2
****
Accuracy and limitations of the data are discussed.
0,1,2
****
Data and sources are accurately referenced.
0,1,2
Observations#
****
The location of all elevation, volcano, and quake cross-section profiles that are discussed in the text are shown on the detailed area map.
0,1,2
****
All cross section profiles are labelled so their location on the detailed area map can be determined.
0,1,2
****

Observations are clearly supported by figures that show data and location of data
0,1,2
****
Data and data representations are described in the text. Quantitative descriptions are used (e.g. depth of trench, depth of quakes, etc).
0,1,2
****
Multiple data sources are used, when appropriate, to identify geological features. Elevation, quake and volcano data should be used for region A, and elevation, age, and quake data should be used for region B.
0,1,2
****
Relationships among observations are made clear (e.g. does author show how quakes and volcanoes lie parallel to the trench?)
0,1,2
Interpretations#
****
A simple sketch model of both of the regions shows the most important features of the boundary type. Locations of the various data types should also be shown (e.g. shows where are the quakes expected, shows where are the volcanoes expected).
0,1,2
****
The author describes clearly how the data match with the features illustrated in th model (simple sketches).
0,1,2
****
The author correctly identifies region A as a convergent boundary.
0,1,2
****
The author correctly identifies region B as a divergent boundary.
0,1,2
References#
****
References are cited in correct format
0,1,2

Appendix IV: Example activity

Question of the Day: *Making a Scientific Argument*	**Name:**
Your bar code label here	**Perm:**

A scientific argument must persuade the reader that the data you present, and your arguments are strong enough, to support your theory, model, or proposed action. The effective writer will make it easy for the reader to understand her/his arguments and the data that support them. This means that figures must be annotated clearly, irrelevant material must be left out, meanings and descriptions must be precise, and the conclusion must follow from the arguments that are presented.

It turns out that the elements of a scientific argument consist of 6 kinds of sentences. In a broader context, there will be variations, but if you master this simple method, you will be able to apply this method in a wide variety of contexts.

You will read the two papers and classify each sentence according to the six choices listed below. The quality of the presentation of the data and scientific discussion in the two papers varies widely. The figures have not been included and we will take it as "given" that the figures are of acceptable quality.

For each of the sentences in the two papers, classify according to whether it:

7. Includes an observation, or description of an observation.
8. Names or classifies an observation in terms of geological features.
9. Describes a feature that has been observed and clasified, or that the author implies has been observed and classified.
10. Describes relationships between different observed and classified features.
11. Describes or explains a model or theory.
12. Describes relationships between and/or observed features that match (or disagree with) model features.

Paper 1: For each of the numbered sentences, enter the corresponding classification from the list above. Ignore sentences that don't fit any of the above classifications.

1	**2**	**3**	**4**	**5**	**6**
7	**8**	**9**	**10**	**11**	**12**
13	**14**	**15**	**16**	**17**	**18**
19	**20**	**21**	**22**	**23**	**24**
25	**26**				

Paper 2: For each of the numbered sentences, enter the corresponding .

1	**2**	**3**	**4**	**5**	**6**
7	**8**	**9**	**10**	**11**	**12**

13	**14**	**15**	**16**	**17**	**18**
19	**20**	**21**	**22**	**23**	**24**
25	**26**				

Paper 1:

Introduction

The area of study is the Kurile trench, identified as a small area on the class CDROM (Figure 1).**(1)** This area corresponds to a plate boundary thought to exist by geologists between the Pacific plate and the Indo-Australian plate (Segar, p.62). **(2)** The data collected supports the theory of plate tectonics at a convergent plate boundary.**(3)**

Methods

The data includes topographical profiles created through the ETOP05 elevation dataset which consists of digital elevation data of sea floor and land.**(4)** The sources for this data come from: Ocean Areas—US Naval Oceanographic Office; USA, W. Europe, Japan, Korea, US Defense Mapping Agency; Australia: Bureau of Mineral Resources; New Zealand: Department of Industrial and Scientific Research; US Navy Fleet Numerical Oceanographic Center.**(5)** Gridded data varies in resolution from 5 minutes latitude/longitude to 1 degree.**(6)** Earthquakes are from USGS preliminary determination of epicenters and volcano data are from the Smithsonian Institution Volcano database. **(7)**

Observations

Three profiles taken along the coastal region of the Khamchatka Peninsula display the topographic features of an oceanic trench (see Figure 2 for profile locations).**(8)** Thousands of volcanoes exist parallel to the trench and 200-400 km inland (Figure 2).**(9)** The trench lies at 60 degrees N latitude and 160 degrees E longitude and extends for 2,200 km in length along this coast.**(10)** One profile displays the gentle upward slope of the Pacific Ocean Basin which then becomes drastically altered by the sudden drop-off of the trench (Figure 3).**(11)** Following the trench, a virtual linear rise occurs as the profile moves northwest and inland.**(12)** A second profile confirmed the presence of the trench 500 km to the south of the first profile, but showed a 400 km long basin located behind the vertical rise of the volcanoes. **(13)** The basin dips 3,000 m below sea level (Figure 4).**(14)** A third profile shows both the existence of the trench another 250 km to the south and the land features described by the first two profiles (Figure 5).**(15)**

Earthquakes' foci were also plotted along the same path as the middle topographic profile of the Khamchatka coast.**(16)** The plot shows earthquakes occur consistently along this trench

(Figure 6).**(17)** A cross section of earthquake activity along the middle profile shows a descending pattern of earthquakes to depths of 600 km (Figure 7).**(18)**

Interpretations

Areas such as the Kurile Trench along the Khamchatka coast show the characteristic patterns of a continental convergent margin between two plates.**(19)** In this scenario, a plate containing oceanic crust collides with a plate made of continental crust**.(20)** One of the plates descends beneath another, into the Earth's asthenosphere (Figure 8).**(21)** A topographic trench is formed where one of the plates begins its descent.**(22)** This process is called subduction.**(23)** The sinking plate causes a corresponding pattern of deep earthquakes along its boundary.**(24)** Melting magma along the upper edge of the plate rises to the surface, creating volcanoes.**(25)** Figure 9 shows a cross-section diagram across the middle profile, showing the subduction model and observations of topography, quakes, and volcanoes that occur in agreement with the model.**(26)**

Paper 2

Introduction

I will discuss the motions of the plates and their effecting result on the sea floor and the Earth.**(1)** At the center of my discussion will be the Mid-Atlantic Ridge and why it has formed into an S shape.**(2)** It is an underwater mountain range, also known as an oceanic divergent margin.**(3)**

Observations

The Mid-Atlantic Ridge is a very interesting part of our Earth.**(4)** It is an underwater mountain range, also known as an oceanic divergent margin.**(5)** This ridge runs north to south down the center of the Atlantic from the North Pole to Antarctica.**(6)** Many different plates meet at the ridge including the North American, the Eurasian, the South American, and the African Plate.**(7)** The ridge extends at one point as deep as 5,625 m below sea level.**(8)** It stretches east to west from Europe and Africa to the east coast of the Americas, 2,547 km.**(9)** This is evident in Figure 1.**(10)**

An oceanic divergent margin means that the plates, which form the Earth, meet and disperse in opposite directions.**(11)** The resultant gap from these diverging plates is filled up with uprooted, low density magma.**(12)** This process leads to the series of volcanoes which form into a ridge in the gap left by the plates.**(13)** This process is known as sea floor spreading.**(14)** This is also illustrated in Figure 1.**(15)** The aging crust then sinks steadily down, while the mountains in the ridge slowly move outward while new ones fill in their place.**(16)** The mountains move in the direction of the plate.**(17)** This part of the process, combined with narrowness of the Atlantic and the shape of the continents, leads to the S shape formed by the ridge.**(18)**

Interpretations

My study shows the Mid-Atlantic Ridge is an oceanic divergent margin that is formed in an S shape due to many different factors including ocean size, plate motion, volcanic activity, and sea floor spreading.**(19)** This is proven by the data gathered from the map program and is reinforced by the area's topography, which includes volcanoes and earthquakes.**(20)**

After you are finished with the classification exercise, which paper do you think presented the most effective argument? Can you tell which paper is the most effective by the relative numbers of various classifications of statements.

Technology-Based Assessments of Student Learning

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The Center for Technology in Learning at SRI International has conducted a number of projects creating assessment designs and examplars relevant to the geosciences. In general our approach has been to focus on assessment designs that can probe more deeply into conceptual understanding and extended inquiry than traditional assessments typically do. Our methods draw from theories of learning to develop cognitively principled assessment designs. This paper summarizes the design principles we have forged and some of the assessments we have developed that are particularly relevant to geoscience.

Assessment Design Principles. Research in cognitive science on the development of expertise in many domains indicates that individuals proficient in a domain have large, organized, interconnected knowledge structures and well-honed domain-specific problem-solving strategies (Bransford et al., 2000). Balanced assessment systems, therefore, should aim to measure both the extent and connectivity of students' growing knowledge structures and their problem-solving strategies (Pellegrino et al., 2001; Glaser, 1991). Many assessments in science tend to focus on conceptual understanding, often using multiple choice formats. Although inquiry skills are important standards in all sciences, they are not easily measured by traditional formats, and they are less frequently addressed in formative or summative achievement tests.

Much of our work at SRI's Center for Technology in Learning has employed performance assessments to elicit evidence of students' ability to go beyond selections of correct answers in highly-structured problems. We have designed performance assessments in which students solve authentic, complex problems requiring use of key concepts and use of inquiry strategies. Performance assessments are particularly well suited to measuring students' conceptual understandings and abilities to conduct and communicate investigations of significant, recurring problems (Baxter & Glaser, 1998; Bransford et al., 2000; Pellegrino et al., 2001). Quellmalz and Haydel (2003) also found in cognitive analyses of think-alouds that students were more likely to use schematic and strategic knowledge on performance assessments than on multiple-choice items. Assessment approaches that require students to construct and explain thinking as they solve problems can measure distinct components of inquiry and problem solving, including stating research questions, posing hypotheses, planning and conducting investigations, gathering evidence, analyzing data, considering disconfirming evidence, and communicating explanations.

Our assessment designs incorporate advances in measurement science that integrate cognitive research findings into systematic test design frameworks. Evidence-centered assessment design is a method for structuring an assessment argument by relating the learning to be assessed, as specified in a student model, to a task model that specifies features of tasks and questions that would elicit the evidence of the learning targets, then to an evidence model that specifies the quality of student responses that would indicate levels of proficiency (Messick, 1994; Mislevy et al., 2003; Pellegrino et al., 2001). Simply put, principled assessment design involves specifying the knowledge and skills to be tested, the types of tasks and items that would elicit evidence of the learning, and the scoring that would report levels of progress.

We have also created a modular approach to the design of extended performance assessments. In these designs, a unifying problem or driving question is addressed in a series of related modules that focus on skill sets related to planning, designing, and conducting an investigation, observing and displaying data, analyzing and interpreting data, drawing conclusions, employing alternative representational formats, and communicating results in the form of a scientific argument. The modules can vary according to the complexity of the content, inquiry, and technology required. Thus a template for an assessment can shape numerous variations of component modules to fit the assessment purpose and population.

Assessment Resources. Types assessment resources we have developed include:

- Digital collections of performance assessments for science, mathematics, and technology;
- Alignment protocols and tools for linking assessments to standards and curricula;
- Online professional development tools for creating and adapting performance assessments;
- Online tools for professional development on scoring student work;
- Prototype assessment exemplars for assessing science inquiry, mathematical problem solving, data literacy, and use of a range of technology tools including visualizations and modeling tools.

Digital Collections. We have developed online collections for science, mathematics, and technology.

PALS. Performance Assessment Links in Science (PALS) is a well-established digital library of resources and technical assistance that supports science and assessment reform that can "break the mold" of on-demand, traditional assessment (see: http://pals.sri.com/). PALS, an online, standards-based, interactive resource bank of more than 300 K-12 science performance assessments with documented technical quality, pioneered digital library collections and assessment resources (Quellmalz, Schank, Hinojosa, & Padilla, 1999). Assessments are indexed to science and mathematics standards and to curriculum programs.

PALS differs from other assessment collections in that it draws assessment that have been developed by a wide range of established assessment development programs. The system can be searched for assessments by science and mathematics standards, curriculum unit, grade range, and content area. The system generates search results as assessment planning charts (Stiggins, Rubel, & Quellmalz, 1986), showing which tasks in the collection are designed to test selected standards. A PALS Guide offers professional development guidelines for adapting and developing science assessments (Stiggins, 2002). Communities of practice are supported by task rating and comment tools in a threaded discussion board and through informal and formal sessions in the CTL virtual professional development center, TAPPED IN™ (Schlager, Fusco, & Schank, 1998; http://tappedin.sri.com/).

Visits to PALS have exceeded150,000 in total, averaging 20,000 visits per month. PALS users include teachers, teacher professional development programs, assessment programs, curriculum evaluators, and researchers. The PALS Web site is linked to the National Science Teacher Association's SciLinks, the Eisenhower National Clearinghouse, ERIC, and the U.S. Department of Education's Gateway to Educational Materials Web site, among others.

Data evaluating PALS have been collected from a wide variety of users. Teachers and professional developers show great enthusiasm for PALS resources. Respondents to evaluation questionnaires indicate that PALS resources were highly useful and easy to navigate. A study of two district models for using PALS indicated that district personnel and teachers regarded the PALS resources as the only source of high-quality and useful assessments of standards. Moreover, many agencies and organizations have written letters of support for the PALS project and its further development. (Quellmalz, 2003).

PALM. A sister site under development, Performance Assessment Links in Mathematics (PALM), can be viewed at http://palm.sri.com . The site presents both performance assessments for mathematics and ones developed to assess science but that require use of mathematics. The tasks have been aligned with NCTM and with NSES.

IPAT. The Integrated Performance Assessments of Technology (IPAT) Web site presents our innovative assessments of students' abilities to use technology to solve complex problems. http://ipat.sri.com These assessments illustrate the modular design approach. For example, in one assessment students are use the ArcView visualization tool to gather data to determine which states have appropriate climate conditions that would allow them to apply for solar energy grants.

Innovative Assessment Designs. We have developed a number of assessment tools and prototypes that test students' abilities to use science knowledge and technologies to solve significant, recurring, authentic science problems.

GLOBE. In the Global Learning Observations to Benefit the Environment (GLOBE) project, we developed classroom assessment tools that test students' deep understanding of GLOBE concepts and their ability to conduct and interpret GLOBE environmental investigations. For example, in GLOBE learning activities, students learned about visualization of climate data, phenology, and the reasons for seasonal change. We indexed the GLOBE assessment framework to the National Science Education Standards (NSES), the Third International Mathematics and Science Study (TIMSS) science framework, and the National Assessment of Educational Progress (NAEP) science framework. Assessment tools included tests of GLOBE students' appropriate use of measurement protocols and solutions to integrated investigation problems. These assessments take data from the GLOBE data archives and have students solve authentic problems, analyze and interpret the GLOBE data, and communicate their findings and recommendations. Templates for the assessments serve as models for teachers to develop new assessments. In addition, the project has developed approaches for aligning GLOBE with state standards (see http://globeassessment.sri.com). SRI and GLOBE systems staff designed an alignment database linking state science standards to GLOBE materials.

Calipers. One of our most recent NSF projects is Calipers: Using Simulations to Assess Complex Science. We are partnering with Concord Consortium in a project to demonstrate the value of simulations for measuring deep conceptual understanding and extended inquiry. The project will document the prototype assessments technical qualities, particularly their validity. We will also examine the logistical and economic advantages on technology-based performance assessments.

An Assessment Based Approach for Evaluating Learning in Natural Science General Education Courses

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Student learning that is consistent with goals of the General Education Program can be evaluated using a multi-tiered, assessment-based approach that integrates content, concepts and higher-order thinking skills assessments into the class. The Department of Geology at The University of Akron evaluates content and conceptual learning in the general education class, Earth Science, using the Geoscience Concepts Inventory (GCI) and, more recently, using concept map development. Students complete the GCI in the first and last week of this large classroom setting (160 students), active learning course. A comparison of pre- and post-test results from the GCI indicated that students improved in their ability to answer conceptual questions related to the Earth by 13% over the course of a semester (paired results; $n = 58$; $p < 0.00001$). Similar gains are consistently found for pre- and post-course analyses of logical thinking scores. Gains to contextual and conceptual understanding of the earth system are also being tracked using pre- (and eventually post-) course concept maps that are scored using a quantitative approach. Student pre-course scores on this exercise average 11 +/- 8 (n= 132) compared to 44 +/- 15 (n= 7) for faculty-generated concept maps using the same terms. Post-course scores are not yet available. Synthesis-level exercises embedded in the course allow for formative and summative assessment of higher order thinking skills. In one such task, students are required to integrate contextual knowledge and understanding of rock-forming processes with conceptual understanding of geologic time principles by constructing a geologic cross section for a set of randomly arranged events. These diagrams are then scored using a standardized rubric. Similar exercises requiring students to evaluate risk for a variety of natural hazards (e.g. earthquakes, hurricanes, floods) compel students to integrate scientific information with social decision making. Such results demonstrate that natural science courses can help develop a scientifically literate society by achieving goals of developing critical thinking skills and independent thought. The data also show that students begin to develop the analytical skills needed to make sound qualitative and quantitative judgments and that they are acquiring knowledge of science and its impact on society. This study is showing that evaluation of progress toward meeting general education goals can be effectively accomplished by including multiple, embedded classroom assessments directly into the class.

DESIGNS FOR ASSESSING FOUNDATIONAL DATA LITERACY

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Introduction

Geoscience education could benefit from assessment instruments that validly and reliably assess students' foundational data literacy skills (e.g., sample size, sample selection, database structure, data distribution, central tendency, natural variability, measurement error), using appropriate item formats that provide valid and reliable evidence of different levels of skill and understanding. When geoscience educators engage students in investigating real data sets in pursuit of geoscience content objectives, lack of these fundamental skills and understandings can hinder the students' abilities to complete the geoscience tasks successfully. Conversely, data literacy problems can hide and hinder the demonstration of geoscience content understanding, leading to erroneous diagnoses of the causes of student problems when asked to carry out data-immersive geoscience tasks.

Data literacy is recognized in national standards as critical components of science, math, and social studies curricula:

> "Students…need to learn how to analyze evidence and data. The evidence they analyze may be from their investigations, other students' investigations, or databases. Data manipulation and analysis strategies need to be modeled by teachers of science and practiced by students. Determining the range of the data, the mean and mode values of the data, plotting the data, developing mathematical functions from the data, and looking for anomalous data are all examples of analyses students can perform."[1]

> "To understand the fundamentals of statistical ideas, students must work directly with data... The data analysis and statistics strand allows teachers and students to make … important connections among ideas and procedures from number, algebra, measurement, and geometry. Work in data analysis and probability offers a natural way for students to connect mathematics with other school subjects and with experiences in their daily lives."[2]

> "During the middle school years, students relate their personal experiences to happenings in other environmental contexts. Appropriate experiences will encourage increasingly abstract thought as students use data and apply skills in analyzing human behavior in relation to its physical and cultural environment."[3]

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[1] National Research Council, Science Content Standards, 9-12, Science as Inquiry, Content Standard A (1996)
[2] National Council of Teachers of Mathematics (2000)
[3] National Council for the Social Studies, People Places, and Environments Thematic Strand (1994)

This essay describes assessments developed and piloted at SRI International that measure data literacy. The work has been funded through four National Science Foundation-grants and one grant commissioned by the U.S. Department of Education. Though they vary somewhat in purpose, audience, and item formats, each assessment engages students in investigating real data sets, then scores them for deep understanding. Each can be a tool for teachers and instructors who want to formatively assess their students' readiness to handle the components of their units that rely on knowledge and skills about the collection, organization, and analysis of data, as well as, in some of the assessments, other aspects of scientific inquiry.

The assessments vary in the data literacy outcomes they measure, grade levels they target, and item formats they use, which include performance tasks[4], constructed response items[5], multiple choice items, and justified multiple choice items[6]. Described below, EPA Phoenix, Solar Power, and the GLOBE Integrated Investigation Assessments are performance tasks about geoscience topics. The Thinking with Data and Foundational Tools in Data Literacy assessments present constructed response and justified multiple choice questions that require students to demonstrate data literacy skills and understandings learned and practiced in various interdisciplinary units that combine math with science and social studies.

Descriptions of the Assessments

EPA Phoenix and Solar Power

EPA Phoenix is an 8th grade assessment developed and piloted with funding from the U.S. Department of Education under a project known as Building a Foundation for a Decade of Rigorous, Systematic Educational Technology Research. Solar Power is a high school-level assessment designed for an NSF funded project called Innovative Designs for International Information Communication Technology Assessment in Science and Mathematics Education. Both assessments were designed and piloted as instantiations of a modular approach to assessing the outcomes of school ICT (information, communication, and technology) programs that have students carry out various technology data-related tasks: Internet research projects in the case of EPA Phoenix; geographic information systems in the case of Solar Power. EPA Phoenix focuses on air quality and Solar Power focuses on the feasibility of solar energy for electric power. To lessen the risk that low content knowledge in the topics of the assessments could confound the assessment of data literacy and other skills made possible in the assessment

[4] Sets of assessment items that revolve around common introductory materials and require longer, deeper attention than what would be required of the learner on more traditional tests are generally known as "performance tasks." The major part of most performance tasks has to do with constructing responses to items that elicit divergent thinking, though there is nothing to preclude the inclusion of items using different formats if they are relevant to the overall task.

[5] Constructed response items require constructed (as opposed to selected) answers and can range from simple fill-in-the-blank exercises or problem completion exercises to essay writing.

[6] Justified multiple choice items require that respondents construct an explanation for why they made their selections. Hence they require a multiple choice selection, followed by an explanation or by computation that led to their selection.

tasks, all the science content-specific information that the students would need to fulfill the tasks are provided in the assessments.

In EPA Phoenix, the problem posed is to help a regional soccer league determine whether air quality and temperature are optimal enough to hold championship games in Phoenix, and the best time of year in which to hold the games. Students are sent to graphs showing air quality ratings in Phoenix that have been generated from the Environmental Protection Agency's Air Quality System (AQS) database.[7] They examine trends in air quality from these data, then compare the overall air quality ratings in Phoenix to ozone ratings in nearby states, represented on a color-coded map. Data literacy outcomes addressed in EPA Phoenix include comparing trend lines on graphs, transferring relevant data about air quality from one type of representation (line graphs) to another (data table) in order to facilitate analysis, critiquing the relevance of specific data for answering a research question, and synthesizing data from different representations to formulate an overall conclusion.

In the Solar Power task, students use GIS representations to compare and contrast air temperature data, then compare and contrast model-generated data about incoming solar radiation. They also observe data about percentage of cloudy days over the course of specific periods of time and perform some calculations.

EPA Phoenix and Solar Power are both performance tasks. The items stem from a common problem and require that the students investigate data, then synthesize it in order to formulate and communicate evidence-based conclusions in the form of a report or presentation. As a culminating activity in the Solar Power task, they recommend a state that should rely more on solar energy for its electrical power. As a culminating activity in the EPA Phoenix performance task, students are asked to write an evidence-based recommendation for whether the soccer games should be held in Phoenix. By this time in the task, they have examined the data sources. The students are scored on a 4-point rubric on the basis of how well they can formulate an evidence-supported conclusion. Either a recommendation of yes or no is acceptable, as long as it is supported by evidence. Figure 1 below illustrates the range of responses that were obtained in the pilot.

[7] The EPA no longer provides public access to the visualizations.. Hence, current students who do EPA Phoenix access images of the relevant AIRS Graphics representations about Phoenix that are archived at the Integrative Performance Assessments in Technology web site (http://ipat.sri.com).

Figure 1. Examples of student responses to culminating item in EPA Phoenix

Example of score of 4:

"In our research we discovered that Phoenix would be a moderate location for the championship game competition. Phoenix has a serious problem with pollution, but in comparison with other counties, it was not the worst. With 9 years to fix their problem, it is not as bad as 20 years such as Sacramento Metro, South Coast, Ventura, and the Southeast Desert.

With recorded information from our table of highly polluted months, we figured that the months April-June are the best months to have the championship games. These months are not the least polluted but they have the best temperature range. The mean temperature for May, the middle month is 78.8 degrees F.

Some of the health affects of the ozone problem for the soccer players are as follows: Breathing problems, reduced lung function, asthma, irritated eyes, stuffy nose, reduced resistance to colds etc."

Explanation of score of 4:
The required conclusions and supporting evidence are made. There are no flaws in accuracy or relevance. The evidence is sufficiently specific to provide adequate support for the conclusions made.

……………………………

Example of score of 3:

"We think that Phoenix would be a good place to have the Soccer Tournament because the air temperature is not to hot or not to cold. The average temperature in May was 81.3° which is average for Arizona in that month. The temperature we think would be good because the temperature is just right.

If the soccer tournament were to be held in Phoenix the best months would be April-June. This is because the number of unhealthful days is the lowest in three years. That is good because if there were many unhealthful days the children would not be safe in that weather and it could cause distraction on the field. The only time that the ozone would affect the soccer players is if the pollution for air and water got really bad. That would be awful because the more pollution there is the better chance of people getting sick is more likely."

Explanation of score of 3:
The required conclusions and supporting evidence are made -- that Phoenix would be a good place for the games because it has a good temperature, and that April-June would be the best time for the games because there were fewest unhealthful days then over the course of a three-year period. There are flaws however, including an unsupported claim (that 81.3 degrees is average for Arizona in May rather than just for Phoenix), and an inaccurate association of ozone to water pollution in the second paragraph.

………………………………

Example of score of 2:

"Phoenix is hot and polluted with ozone, which can make you sick if you are not careful with your body. We recommend that you go somewhere else to play soccer. If you have to play there, play in April-June because it's less hot then than at other times during the year."

Explanation of score of 2:
Only one piece of marginal evidence is cited -- that April - June is less hot than other times of the year, but no specifics are offered about how less hot is. Hence, the requirements for evidence are not being met.

……………………………

Example of score of 1:

"Phoenix would be a good place to have the games. The scenery there is great and the pollution keeps getting better and its not too hot. Enjoy yourself!"

Explanation of score of 1:

There is a major ambiguity (e.g., that "the pollution keeps getting better"). No recommendation or supporting evidence is included about the season. The scenery is irrelevant.

EPA Phoenix and Solar Power can both be found at SRI's Integrative Performance Assessments in Technology web site (http://ipat.sri.com).

The GLOBE Integrated Investigation Assessments

The GLOBE Integrated Investigation Assessments are web-based sample student assessment tools and frameworks that provide teachers and students with evidence about progress on GLOBE program goals related to data literacy and other aspects of scientific inquiry. Students participating in GLOBE take atmosphere, hydrology, soils, and land cover/phenology measurements, post their data on the web, and create maps and graphs with the data. Content areas covered in the assessments include atmosphere, hydrology, landcover, soils, and Earth systems. In contrast to EPA Phoenix and Solar Power, the GLOBE Integrated Investigation Assessments require that students already possess significant content knowledge in order to conduct investigations with the data. Data-immersive activities posed to students include:

- examining GLOBE data/graphs and coming up with possible questions regarding the data
- finding observable trends in the data
- looking through the data for possible measurement or data entry errors and suggesting ways to avoid these types of errors in the future
- identifying relationships between two variables
- representing data in a graph or table
- using data to generate new data representations to analyze trends
- summarizing graphed data in terms of range, median, mode, and mean
- comparing and contrasting same-variable data sets from different locations
- drawing evidence-based conclusions about the data.

Like EPA Phoenix and Solar Power, the Globe Integrated Investigation Assessments are performance tasks. The assessments and supporting information can be found at http://globeassessment.sri.com.

Like EPA Phoenix and Solar Power, the Globe Integrated Investigation Assessments are performance tasks. For the sake of illustration of the sorts of responses that students provide for GLOBE assessment tasks, Figure 2 presents an example of an adequate response to an item that focuses on seeing if high school students can pose relevant research questions after examining data readings about water temperature and pH in a particular river over a two-month period.

Figure 2. Example of item and exemplar on a GLOBE Integrated Investigation Assessment

Prompt: Holcomb Elementary and Jefferson Elementary are two schools located within 5 miles of each other in Fayetteville, Arkansas. Both schools sit next to the same river, with Holcomb located upstream from Jefferson. Even though the schools are relatively close to each other, the plant and fish life appears to be different between the two sections of the riv You and several other students have been asked to report to your science class what some c the differences are and why you think they exist. To the left is data from the two schools between late November and late January to help you in your investigation. Look at the GLOBE data in the tables (not shown here). Think of two questions you might ask regarding the data. A sample question might be "What is unusual regarding water temperature between the two schools considering they take measurements from the same river?

*Example of adequate response: "*One question I might ask: is there any relationship between water temperature and pH? In other words, if temperature goes up, what happens to pH? Another question I might ask: is there a trend in how temperature changes over time (or how pH changes over time?) By this I mean since the measurements go from Nov. 22nd until Jan. 24th, is there an increase or decrease in either of the variables?"

The GLOBE Integrated Investigation Assessments and supporting information can be found at http://globeassessment.sri.com.

Thinking with Data and Foundational Tools for Data Literacy

The Thinking with Data and Foundational Tools for Data Literacy assessments assess upper elementary and middle school students' abilities to transfer data literacy skills and understandings learned in integrated math/science and math/social studies units to other data literacy tasks that are conceptually related. Students doing the units for which these assessments were designed examine real data sets having to do with water scarcity, pulse rate, and plant growth.

The Thinking with Data assessment assesses outcomes of an integrated 6th grade math/social studies unit about water scarcity in Middle Eastern nations. In the unit, students explore how to make fair comparisons among nations with different populations, water uses, and water availabilities. Assessed data literacy tasks include applying proportional reasoning and knowledge of the concept of per capita to evaluate the fairness of comparisons of data about different countries.

The Foundational Tools for Data Literacy assessments assess outcomes of integrated math/life science units about pulse rate and plant growth. In the unit on pulse, 4th grade students collect, organize, and analyze data about pulse rate from samples of people drawn from different populations. In the unit on plant growth, 6th grade students conduct experiments in which they grow sets of "fast plants" under different conditions, test hypotheses, and analyze results. In both units, the students use Tabletop, a computer-based data tool, to view the data and do analyses of results. Assessed data literacy skills and understandings include understanding which types of research questions can be addressed by collecting data; determining the appropriateness of different data representations for different analyses; and analyzing data distributions to a) evaluate the strength of relationships between variables, b) detect measurement error, c) detect central tendency, and d) critique the viability of conflicting claims about the data.

The assessments in both projects present students with tasks that require them to demonstrate transfer (Bransford, Brown, & Cocking, 2000) of the data literacy skills and understandings acquired in their units to other content. For example, in the Thinking with Data assessment, students identify whether they have enough information to fairly compare the severity of the car theft problem in France and Japan. In the Pulse Unit assessment, the students compare and contrast data about the heights of students who vary by age and gender. In the Fast Plants Unit assessment, the students examine the results of an experiment about how fast different breeds of kittens grow when fed different diets.

Item formats employed on these assessments are largely constructed response and justified multiple choice. In the Foundational Tools for Data Literacy assessments, several items focus on a common problem or other stimulus, such as an experiment or data analysis procedure. In almost all cases when selected response questions are posed, the students are asked to explain why they made their selections. On many items, they are scored on the extent to which their explanations show understanding of the underlying data literacy concepts. Many of the rubrics provide cues that the rater can use to differentiate between a response that:

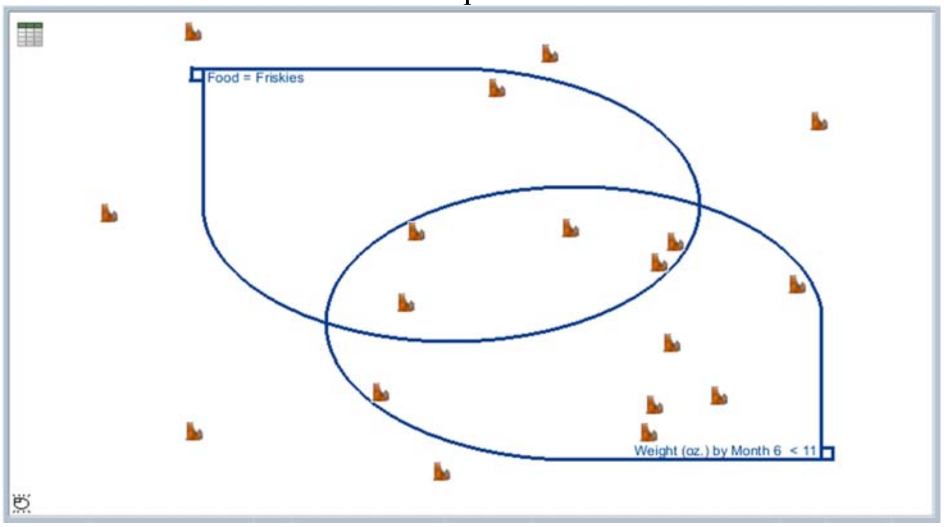
- demonstrates full understanding (Score of 3)
- is too vague to demonstrate full understanding, yet is on-track enough to infer emergent understanding (Score of 2)
- demonstrates no understanding due to it being confused, insubstantial, off-base, or inaccurate (Score of 1)

On the justified multiple choice items, student responses are coded to differentiate in the results data base between a correct selection and a rubric score for the explanation about why the particular selection was chosen. This permits examination of how many students who select correct answers also can communicate adequate explanations.

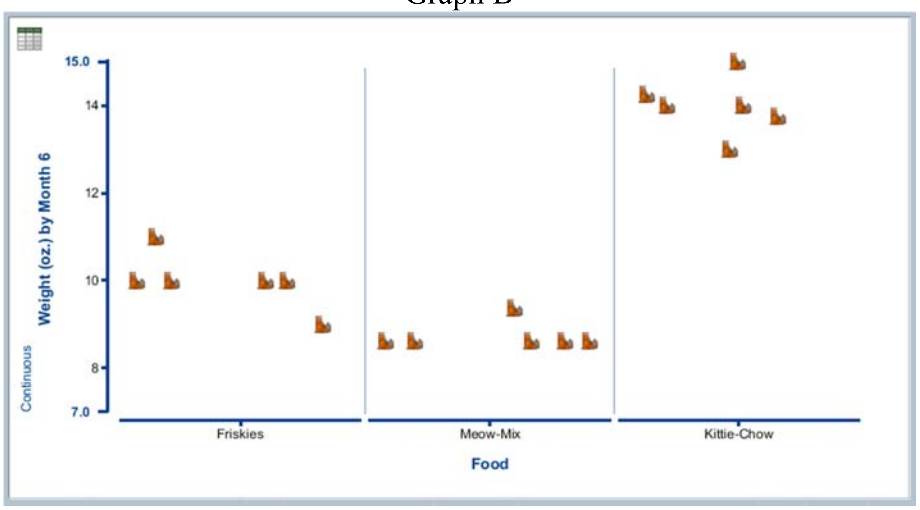
These items have proven especially worthwhile in uncovering student problems that multiple choice items alone would hide. For example, in the assessment for the Fast Plants unit, students are shown three data graphs representing data from the experiment on the different breeds of kittens and their diets. They are asked to select which of the graphs would be best for seeing if, by the end of the experiment, there was a relationship between the how much the kittens weighed and what food they ate. The graph choices are presented in Figure 3.

Figure 3. Plots of data used in Fast Plants Unit Assessment

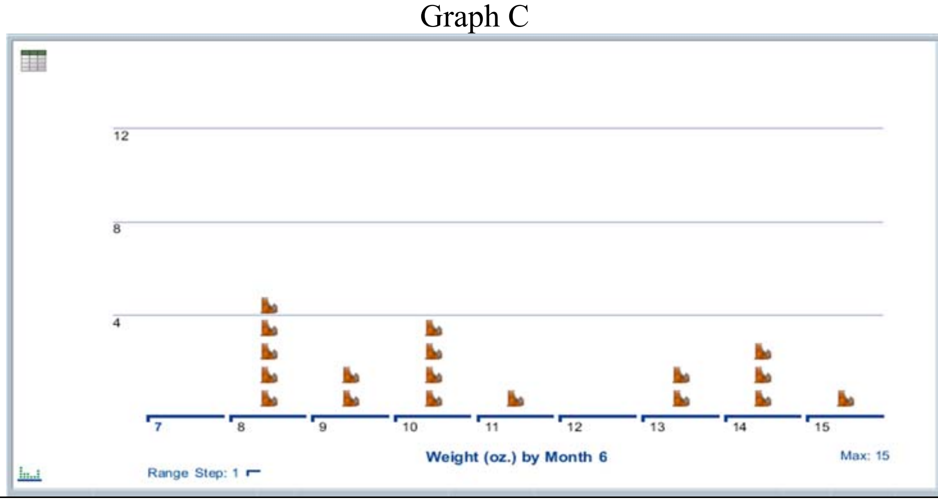
Graph A



Graph B



Graph C



The following are explanations of three students who made the correct selection of the 2nd graph, utilizing the 3-point rubric described above.

- Score of 3: "Graph B is best because it compares all weights and foods, when A & C do not."
  Explanation of score: the noting of the fact that all the weights and foods are represented on graph B demonstrates full understand of the superiority of that graph for the intended analysis
- Score of 2: "Because it is the most exact and it's easy to see the differences."
  Explanation of score: the noting that graph B is "the most exact" is on the right track, but too imprecise to qualify as a demonstration full understanding
- Score of 1: "In my opinion, graphs like that are always the easiest to read. But Graph C would have been my second choice. Graph A I couldn't understand."
  Explanation of score: Despite the fact that the student selected the correct graph in the multiple choice question, there is no evidence in this response to indicate any understanding. The explanation is insubstantial and the student admits confusion.

The Thinking with Data and Foundational Tools in Data Literacy projects are still in progress. Hence, reports on this work are not yet available.

Conclusion

Working with data is central to scientific inquiry, in the geosciences as in other sciences. Technological advances in data access and data visualization have created unprecedented opportunities for students and teachers to use real data sets as vehicles to understanding and applying the epistemologies and research practices of the different geoscientific disciplines. At the same time, immersing students in data as a vehicle for improved geoscience education has its risks. Students may or may not come to a data-immersive geoscience class prepared to handle the components of the curriculum that require foundational data literacy proficiencies. Without this background, they may be ill-equipped to carry out data-rich tasks that require them to learn and apply the proficiencies to the distinctive requirements of research in the respective geoscience disciplines.

Part of this problem stems from the fact that, in most K-12 schools, the teaching of the fundamentals of data literacy straddle content areas. Instruction about data, especially about central tendency, graph interpretation, proportional reasoning, and statistics occurs in math class, yet usually in isolation of scientific inquiry. Other data skills and understandings having to do with sampling, distribution, measurement error, natural variability and other data-related facets of inquiry receive less, if any attention, in math class. This leaves it to the science or social studies teacher to teach these other data literacy fundamentals, and many do not.

In the future, more assessments measuring foundational data literacy could be designed in a systematic, comprehensive manner. They could conform and align to a developmental set of benchmarks about what students should be able to know and do with data at different points in their education. These could support and render more systematic and explicit the school's role in building foundational data literacy skills and understandings that can then be adapted and applied to the different scientific disciplines, in the geosciences and in other areas. To develop such a resource bank of assessments, a challenge would be to differentiate between foundational aspects of data literacy and aspects that cannot be taught or assessed independently of their application in specific scientific or social scientific disciplines.

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