Hands On!
A publication for mathematics and science educators
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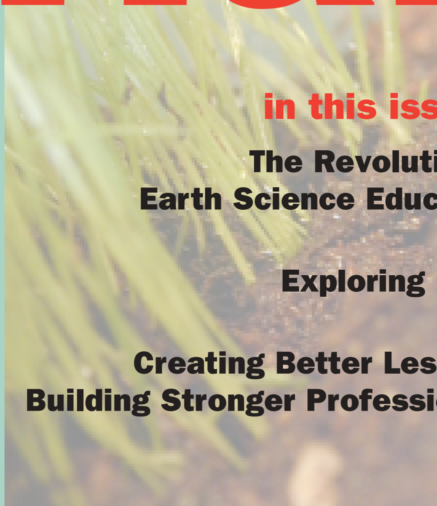
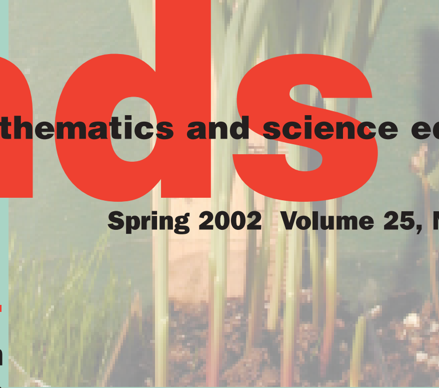
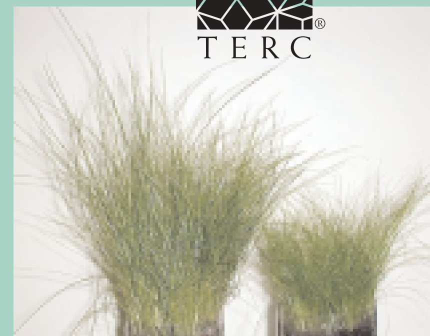
TERC

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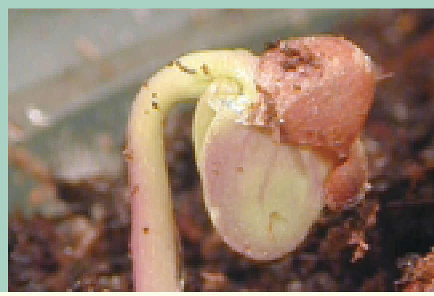
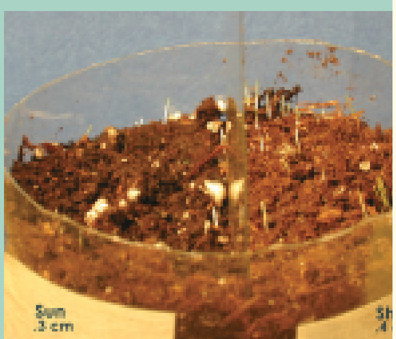




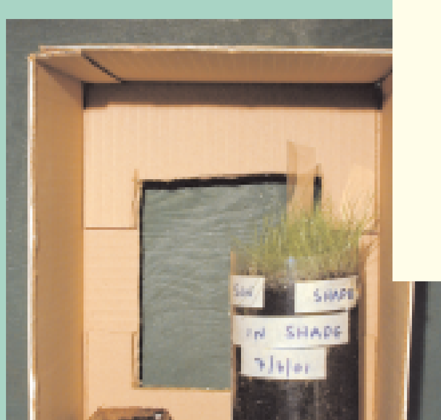
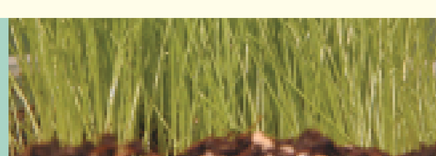
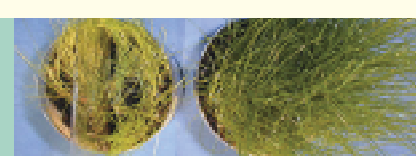
Watching Grass Grow

biology explorations online

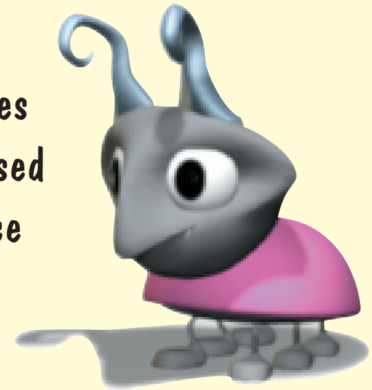
by Gillian Puttick

For teachers enrolled in the TERC/Lesley online master's degree program in science education, the simile "it's about as exciting as watching grass grow" has taken on a whole new meaning. By exploring how grasses are adapted to the environment, the teachers engage with the complex phenomena of adaptation and natural selection using labs set up in their homes and collaborating with other teachers through the Internet. Their course this semester is Biology Explorations, the third in an innovative program that seeks to expand and extend online learning to include true scientific inquiry.

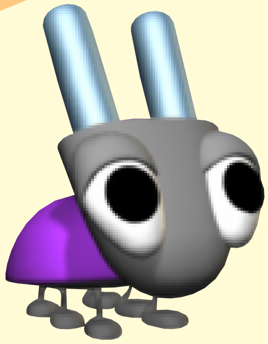
(continued on page 4)

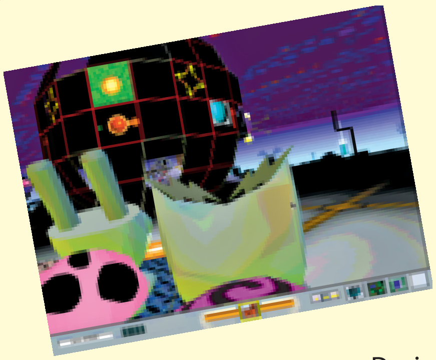





Fun Software for Serious Learning



TERCworks software combines TERC's rigorous, inquiry-based approach to math and science learning with engaging informal learning activities. Yoiks!™, Tabletop™ and Tabletop Jr.™ provide students with a hands-on path towards improved mathematics proficiency.





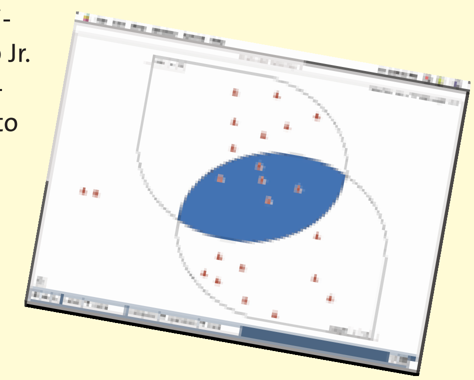
Yoiks!

Chase data-munching bugs through 30 layers of challenging multi-media puzzles. Yoiks! offers an off-beat learning environment from which to explore the scientific process of observation, hypotheses formulation, and experimentation.

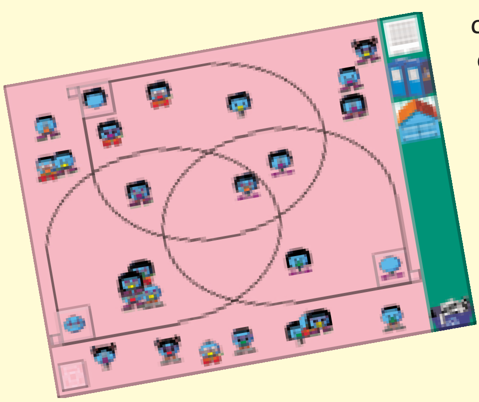
As an addition to a separate math and technology curriculum, Yoiks! encourages students to build logical reasoning and critical thinking skills, and to develop algebraic thinking skills.

Tabletop and Tabletop Jr.

Designed to support classroom projects and activities in every curricular area, Tabletop and Tabletop Jr. give students a new way of interacting with information. Tabletop (grades 4–12) is an introduction to databases that provides students with practical experience with abstract data manipulation and analysis.



Tabletop Jr. (grades K–5) is a tool to creatively introduce the key math concepts of data visualization, statistics, analysis, sorting and graphing, and logic and interpretation. Tabletop Jr. includes a number of visualization tools that allow for seven different arrangements of objects like pizzas, stick figures, clocks, and party hats.



Yoiks!, Tabletop, and Tabletop Jr. are available from Sunburst.

800-321-7511, www.sunburst.com

Also by TERCworks

Looking for more math fun? Try the award-winning games **Zoombinis Logical Journey™** and **Zoombinis Mountain Rescue™**. Available from **www.zoombinis.com.**

Editor's Note

Revolutionizing Earth and space science education. Pioneering an inquiry-based approach to science learning online. For TERC, these aims are just part of our effort to harness the power of emerging technologies to further math and science education. Our emphasis has never been on technology for its own sake, but on how a technology can enhance or facilitate learning.

The cover article of this issue of *Hands On!* highlights the experience of a group of science teachers who are pursuing a master's degree in science education through a fully online program developed by TERC and Lesley University.

Beginning on page 8, we offer two examples of how TERC is working to change the way Earth science is taught. We include an excerpt from *Blueprint for Change*, the report from a national conference calling for all students (grades K–12) to have access to Earth and space science education. And in *Exploring Earth* we give an example of how TERC is changing an Earth science curriculum by integrating it with web-based visualizations and investigations.

We also include an article on lesson study, describing one school's initial experience with this approach to professional development—an approach that has the potential to transform the teaching profession.

—Kenneth Mayer, Editor

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Contents

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During the first two courses, Try Science and Investigating Physics, participants conduct new investigations of related scientific phenomena each week and, at week's end, discuss the investigations online with their colleagues. In Biology Explorations, the schedule is different because it must conform to a timeline imposed by the life cycles of living things. Extended investigations span several weeks as the participants wait for their grass to grow.

The teachers in the program have been together for more than a year. They are now colleagues, familiar with the program's inquiry approach to science and its process of scientific dialogue, as well as the many new technological applications they have encountered as online learners. The teachers are accustomed to posing questions and making predictions. They design investigations, make observations, and collect data. They construct explanations for their findings, support them with evidence, and then revisit predictions, considering new points of view.

The course follows an approach to phenomena, questioning, and investigations that a biologist would use. The aim is to enculturate teachers into the community of science by providing them the opportunity to explore science as scientists—or apprentices in science—rather than simply as students learning science content and inquiry methods.

Extended Inquiry: Why Watch Grass Grow?

The focus of the course is the biological phenomenon of adaptation. Using items from a kit they receive in the mail, teachers grow plantings of grass under grow lights at home. The teachers observe their growing grass plants and examine features of the grasses through the "lens" of adaptation, considering two key questions:

- What environmental challenges do grasses have to face?
- What features do grass plants have that help them cope with these challenges?

The course design stresses the importance of observation as a foundation for most—if not all—good questions in biology. At the beginning of the course, the teachers use their observational skills to draw seeds and seedlings, detailing features of the grasses and thus generating "data" that they keep as a permanent record. (See Figures 1 and 2.) Online, they also examine time lapse images of germinating seeds. They discover features of seeds that they had not even thought to look for before. Their observations lead to many questions. One teacher, Libby, posts some of her questions at the beginning of the second week. It is evident from the way she frames her questions that she is considering her observations in light of the two overarching questions of the course and is already grappling with the adaptive function of the features she has seen.

> My first question is does the seed covering serve any function to the plant/seed other than protection? Once it is removed or shed, similar to removing the shell on a hard boiled egg, is it of no use to the plant/seed? Also, is there a top and/or bottom to the seed? In other words, does the hard casing I mentioned earlier need to orient itself downward for the seed to grow most effectively? Is that where the root stem begins? Once I got some of the seeds opened, I was wondering what I was looking at. What exactly is inside the seed itself? Does it contain the genetic information necessary for the plant to grow and if so, do all seeds contain the same information or are they as different as people?

Throughout the course, Libby and her colleagues carry forward this habit of close observation, drawing, and posing questions as they explore adaptations to various environmental pressures in the lives of grasses. This includes adaptations for survival until conditions are suitable for germination, adaptations for thriving in sun or shade, adaptations to withstand grazing by herbivores, and adaptations to varying moisture levels.

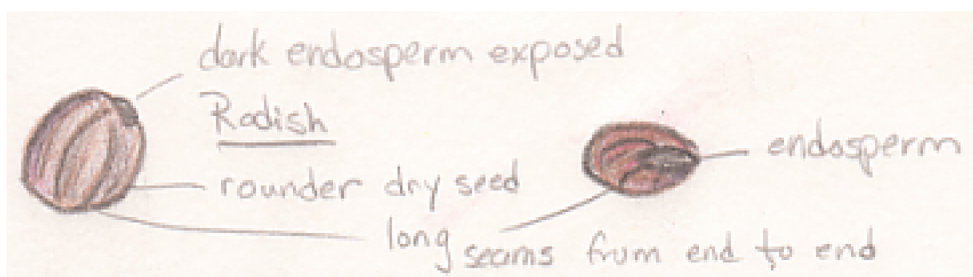

Figure 1. Teachers return to their observational drawings frequently during the course, using them as one source of data.

Simulating Grazing

The course emphasizes the ways that scientists draw on what they know to formulate predictions. The teachers are asked to use their knowledge in the same way—even though they might not consider their everyday knowledge a resource for formulating predictions. They ask themselves: What do I

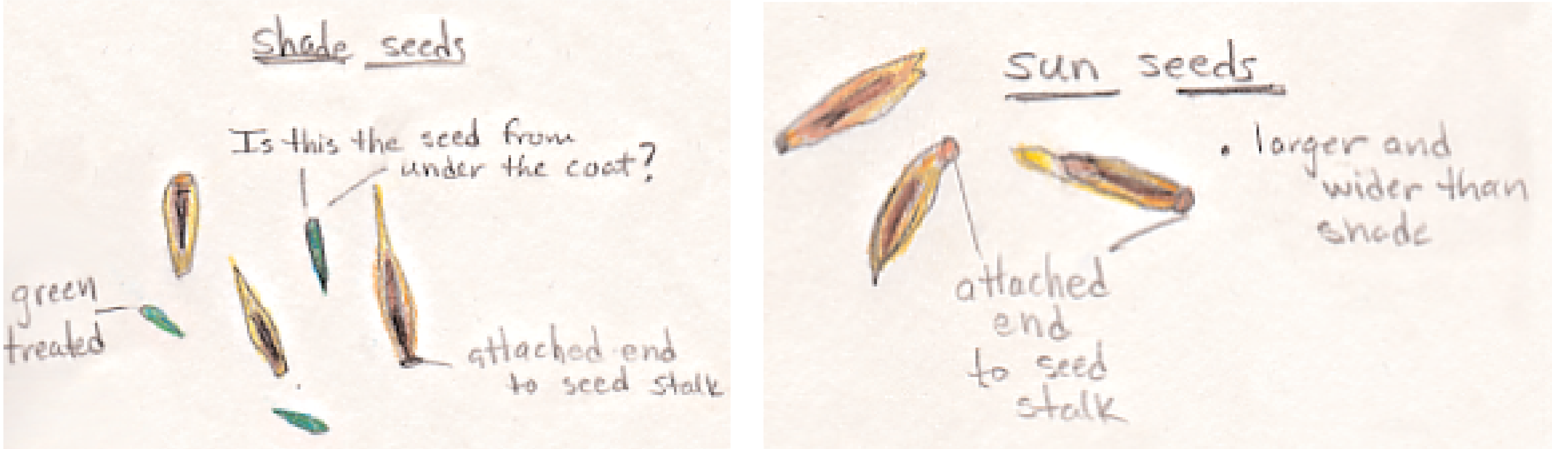

Figure 2. In observing and drawing the features of seeds, the teachers begin to form questions for investigation.

know about plants? Based on this knowledge, what predictions can I make?

For example, in two consecutive sessions, participants explore grazing and consider the question: What features of grasses make it possible to support large herds of grazers? The teachers simulate grazing using scissors. They cut their grass plants off close to the soil surface and predict what will happen. They do the same with radish plants which they have grown for comparison. Will the plants grow back? If so, where will new growth occur? Will the cut leaves change with time? What will happen to the damaged edges? One teacher, Reba, draws on her everyday knowledge to formulate her prediction and gives this rationale:

> I feel pretty certain the grass will grow back and fill in. I think this because I know despite what sometimes seems like constant mowing the grass grows back. The radishes? I'm not sure they will grow back. Thinking back to mom's garden I remember her planting radishes more than once over the summer along with her lettuce. I've removed all leaves and partial stems. My prediction is existing radish plants may not survive.

Over the course of the week, the teachers spend a few minutes each day observing the plants closely with a magnifying glass. At the end of the week, Prue posts her findings:

> My cut grass is just fine. I used my index finger knuckle as a measure, because I am having bad results using the ruler. The grass is growing back well, and it seems to be growing from the base of the plant, not the tip. The meristem [the growing tip] must be low in grasses. The cut radishes aren't doing anything at all. The places I cut look shriveled. I see no new growth. Could the meristem in dicots [i.e., radishes] be higher on the plant stem? If you cut the meristem, do you prevent further growth?

Prue not only observes that the grass is growing back and the radishes are not, but also that the grass seems "to be growing from the base of the plant, not the tip." The following week, through a guided exploration of "micrographs" (images that reveal a microscopic view of plants), participants look closely at the growing tips of corn—a monocot related to grass—and of a representative dicot, like a radish. Drawing on these images and her observations, Prue finds confirmation for her theory that grasses have "low meristems."

Extending the View to Generations: Adaptation as a "State of Becoming"

As the course progresses, teachers explore how adaptations come about through the process of natural selection. Adaptation is a complex phenomenon to understand deeply. To compound the problem, educational materials and the popular media often use overly simplistic language to describe special features of plants or animals that "fit" them for their environments.

For example, a television program on moths might focus on how brown wings enable them to hide successfully on tree trunks. The storyline: The moth wants to be able to hide from birds. What does it do? It takes on the color of the tree trunk. The moth has camouflage. Another storyline explains the adaptation of bears: The bear needs to get through the winter when there is not so much food, so it hibernates to avoid starving in winter.

This language about adaptation is ambiguous. It is easy to miss the subtle complexities and, in so doing, to misconstrue the process underlying these phenomena. In the end, the oversimplifications may make it sound like the individual organism has control over adapting its features.

For the first two-thirds of Biology Explorations, the teachers explore just such features that their grasses possess which make them "fit." We term this an exploration of the "state of being" of grass plants. But how do adaptations arise? And how are they perpetuated from generation to generation? In the last third of the course, the teachers focus on these two questions. We term these latter investigations an exploration of a "state of becoming."

Sun and shade plantings

In their explorations, the teachers consider case studies of artificial and natural selection in lab and field investigations. They measure and compare the heights of grass plants in two species in two experimental treatments and are surprised by the amount of variation they find. Then they compare their firsthand observations to the findings of other scientists. They analyze and interpret the results of artificial selection experiments using Fast Plants* and natural selection observations of Galapagos finches. From these, they come to understand that under environmental stress some variants in the finch population do not survive. They learn that selection pressure happens in each generation, not the countless generations which earlier accounts of natural selection had led them to believe. They revisit their understanding of natural selection and support each other in developing new understandings, as shown in the following exchange between Luisa and Prue. Luisa posts these thoughts online late at night:

Observing Fast Plants in the lab

> I think that although I understand that offspring of the surviving members [of a population] carry the trait that was selected by the environmental stressor, I think somewhere in the back of my mind I also think that the bird or organism while it lived its life, changed physically as well.[...] The giraffes with necks that stretched longer could reach higher and get more food. Does the stretching change that giraffe's genetics for a longer neck...?

Over the weeks of the course, the teachers begin to validate or challenge the findings or understandings of others. Prue, a colleague in Luisa's discussion group, responds to Luisa's thoughts the next morning:

> I hate to be a wet blanket but I'm 99% positive the only traits that are passed on to offspring are traits that are in the DNA of the egg and sperm cell. Losing limbs and stretching necks are individual differences that happen in the course of a life, and are not on the DNA.

Luisa's changing understanding of how adaptive features originate and are passed on shows a tension between one explanation ("offspring of the surviving members [of a population] carry the trait that was selected by the environmental stressor") and a second, expressed as a tentative question ("Does the stretching change that giraffe's genetics for a longer neck...?"). It is perhaps particularly profound that Luisa was able to make this tension public. Phrasing it as a question seems to indicate that she knows it isn't quite right and that she would like some help in thinking it through.

Prue answers with an unambiguous statement about inheritance of traits being a key feature of selection. This, and further discussion with her peers, enables Luisa to clarify the tension she has expressed about selection. In a statement about her understanding of adaptation and selection at the end of the course, Luisa reflects on how she used to think that "natural selection [was] the survival of the fittest..." Now, she thinks that "the fittest are those [species] with the greatest variation of traits, and therefore the ability to survive changes."

Prue, too, refines her understanding of natural selection, as shown in the following excerpt from her reflections at the end of the course:

> I didn't really see any value in the same kind of seeds germinating at different rates, and I thought that the sun grass seeds were faulty or I was making a mistake in the way I was treating the plants, when the sun grass seeds failed to grow as quickly as the other seeds. I didn't understand that seeds in the same species might vary slightly in their reaction to living and non-living factors in the environment.... Adaptation occurs when the environment changes, and natural selection favors an attribute for survival (like drought resistant grass).

*Fast Plants were developed from wild mustard plants by Paul Williams, a plant geneticist, as a laboratory tool for studying variation, genetics, and inheritance. The plants complete their life cycle in 35–40 days.

The Community of Science: What We Learned

As we, the developers, began designing the course, we wondered how or whether scientific inquiry could be successfully explored online. Aren't scientific apprentices traditionally located in labs to learn from practicing scientists? Isn't biology too complex for novices to engage with successfully without plenty of modeling and training?

The understanding the teachers glean from observation, investigation, and experimentation is enriched with other resources. In much the same way that scientists share papers and compare findings, the teachers have access to the work of evolutionary biologists from natural selection investigations. In addition, they explore online images representing biome distributions derived from large data sets collected by satellite. They read about various aspects of plant biology, mathematical modeling of population data, and adaptation and selection. The teachers are encouraged to adopt an inquiry stance towards all of these, asking questions and making sense of each resource, and discussing ideas derived from each resource in the discussion forum.

The teachers regularly hold their ideas up to scientific evidence, revisiting their predictions and understandings in light of data they have gathered individually. The discussion forum provides a venue for them to debate and discuss their predictions and their findings, just as biologists do. It enables them to construct explanations based on evidence and to examine their own predictions in light of the findings of their peers. By means of self-reflection and feedback from their peers, the teachers, as scientific apprentices, come to a scientific way of understanding and practice.

Our own understanding of the problems and promise of online learning has deepened considerably from observing and reflecting on the teachers' progress and success. As we move on to develop additional courses for the online master's in education program, we continue to explore this professional development model that enculturates teachers into a community of science. We are still learning how to "operationalize" scientific inquiry online. Fortunately, the teachers enrolled in our program are teaching us how much we can expect from this new medium!

Gillian Puttick is an ecologist and lead developer of the life sciences courses in the Lesley/TERC online master's program. gilly_puttick@terc.edu

Photos: Gail Matthews-DeNatale

The Lesley/TERC Science in Education Online Master's Degree project is funded by the U.S. Department of Education #P116D990066 and the National Science Foundation #ESI9911770.

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Course Schedule

Try Science (3 credits, prerequisite)
Summer and Fall 2002, Spring 2003
Science Content: science as inquiry and a human endeavor
Pedagogical Focus: Developing conceptual understandings through science inquiry

Investigating Physics (6 credits)
Fall 2002, Spring 2003
Science Content: Exploring the organizing principles of forces, motion, and energy
Pedagogical Focus: Paying attention to learner's ideas about scientific phenomena

Biology Explorations (6 credits)
Spring 2003
Science Content: A study of diversity, heredity, cells, and flow of energy
Pedagogical Focus: The role of the teacher

Earth Science From A New Perspective (6 credits)
Fall 2002
Science Content: Structures and changes in the Earth's system
Pedagogical Focus: Curriculum reform

From Science To Design (6 credits)
Spring 2003
Science Content: Meeting human needs, solving human problems, developing products
Pedagogical Focus: Assessment for inquiry science

Ecology (6 credits)
Fall 2002, Spring 2003
Science Content: The interrelationships between organisms and their environment
Pedagogical Focus: Literacy and mathematics in the science context

Contact Lesley University, 29 Everett Street, Cambridge, Massachusetts 02140; (617) 349-8300; (800) 999-1959 ext. 8300; science@mail.lesley.edu; www.lesley.edu/soe/science

The Revolution in Earth and Space Science Education

This excerpt is from *Blueprint for Change: Report from the National Conference on the Revolution in Earth and Space Science Education.*

Prepared by Daniel Barstow, Ed Geary, and Harvey Yazijian.

Earth and space science education is undergoing a remarkable transformation. Long-perceived as a minor science (in contrast with physics, chemistry, and biology), Earth and space science is emerging in both public perception and active science research as a profoundly important field. Our lives and future depend on the depth of our understanding of our home planet. The concept of Earth as a rich and complex system of interconnected components and processes has become a dominant paradigm in science. Furthermore, the Space Age has provided a revolutionary new perspective on Earth, enabling us to see, explore and investigate our world in ways never before possible.

This revolution in the knowledge and practice of Earth and space science is in turn revolutionizing education in Earth and space science. New methods of teaching and learning are taking hold, such as an increased emphasis on Earth as a system, greater opportunities for inquiry-based learning, and growing access to Internet and visualization technologies. As this revolution in Earth and space science becomes more prevalent, students at all grade levels have greater opportunities to learn through inquiry, exploration, and discovery, whether they are directly observing the world around them or gaining new ways of seeing from the perspective of space. Earth and space science is emerging as a premier exemplar for innovation, quality education, and successful science education reform.

The potential impact on our schools and students is not just in Earth and space science courses, but in the broader applicability of the skills developed by students to related domains of science, math, geography, and other fields. Furthermore, there are a growing number of jobs related to Earth science in fields as diverse as energy, resource management, emergency preparedness, space science, and visualization technology. In short, this revolution in Earth and space science education is not just for "rock hounds." It is a revolution for all students, and for our relationship with our home planet Earth.

A National Strategic Imperative

The national strategic importance of Earth and space science education is clear when one considers what Earth and space science is—an integration and synthesis of physics, biology, chemistry, geology, oceanography, meteorology, and all other sciences that study life, Earth, and the heavens. Fueled by 21st century technologies like data visualizations, analysis tools, remotely sensed imaging, and satellite photography, it consolidates these fields to offer new systemic understandings of Earth's components. Over the last 50 years, Earth and space science has revolutionized how we view and know Earth and its systems.

This accumulating body of knowledge, however, is far from academic. Our quality of life, it is fair to say, depends on the quality of our Earth scientists. This is because understanding the land, air, water, and life of our planet gives us the knowledge to best manage the world around us. Earth and space science enables us to learn from the past and prepare for the future. From community development to resource planning, from emergency preparedness to energy management, we, as citizens, are increasingly called upon to make vital policy decisions that affect, if not define, our lives, the economy, and the national well-being. We must know how to critically evaluate data, investigate the world around us, and assess environmental and economic impacts of our actions. To empower the electorate to arrive at informed and reasoned choices, our educational infrastructure must effectively teach Earth and space science to generation upon generation of students. Whether as citizens or as professionals, we require literacy in Earth and space science to ensure our prosperity.

Changing the Nature of Earth and Space Science Education

Here is a way to envision the changing nature of Earth and space science education. Think of a traditional middle school Earth science class in plate tectonics. Students might read from a textbook, learning how plate tectonics cause earthquakes and volcanoes, and then answer a few questions in the chapter review section of the book. Essentially, the experience is read the book and answer the questions.

Now let's visit a middle school classroom participating in NASA's EarthKAM project (www.EarthKAM.ucsd.edu). EarthKAM provides students with direct access to a digital camera flown on the International Space Station (ISS). Students use the Internet to select interesting targets along the Station's orbital track, send the requests to the camera, and then download the images to use in their Earth science classes. In this example, students apply what they learned in their textbooks by selecting as targets volcanoes along plate boundaries. These images become the focal point for a series of inquiry-based investigations, as students interpret the images, compare different volcanoes, map their locations and correlate the images with news reports of currently active volcanoes. In other words, the student experience is changed from simply reading Earth science to actually doing Earth science.

This example illustrates three key elements of the changing content and methods of Earth and space science:

Science as inquiry—The National Science Education Standards are quite explicit in their emphasis on inquiry-based learning: "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science." Earth and space science is an especially rich domain for inquiry because the "science lab" exists all around us. Students experience Earth and space science going to and from school, on field trips, in the daily news, and through Internet resources.

Earth as a system—Understanding Earth as an integrated system of components and processes has become the dominant paradigm in Earth and space science research—and should become the central unifying principle in Earth and space science education as well. Students should not experience Earth and space science as a series of topics, but rather as a whole system—the interconnected geosphere, hydrosphere, atmosphere, and biosphere. The National Science Education Standards consider "systems and models" as one of the key "unifying concepts and processes."

Internet and visualization technology—The Internet is now pervasive in schools. While Internet speeds and ease-of-access may not be ideal in all classrooms, the predominant reality is that the Internet is available and schools are looking for the best ways to use its power. Earth and space science may be the most powerful domain for the Internet, with the incredible wealth of visualizations to support student learning. (See *Exploring Earth* page 12.)

Declaration of Importance

As our nation deliberates on education policy and funding, we, as leading science educators and scientists, call for legislators, decision makers, and stakeholders to implement all measures that support science education in general and Earth and space science in particular.

Fueled by new technologies over the last 40 years, advances in Earth and space science are revolutionizing our understanding of Earth's systems and processes. This growing understanding is increasingly needed to inform political and economic decisions of local, national, and global impact.

For this reason, a science-literate citizenry is vital to the nation's well-being and security and will insure our nation's continued leadership in science and technology in the 21st century. To empower the public to make sound and reasoned choices, Earth and space science must be taught throughout the United States in K–12 classrooms and be accessible to all students.

Declaration of Importance signed by participants of the National Conference on the Revolution in Earth and Space Science Education, June 21–24, 2001. Snowmass, Colorado.

The Conference

The conference took place June 21–24, 2001, in Snowmass, Colorado, with the goal of developing a vision and "blueprint" for K–12 Earth and space science education reform for the next decade. The conference assembled a broad spectrum of stakeholders including K–12 teachers and administrators, Earth and space scientists, university faculty, representatives of educational and scientific organizations, key people from government agencies, and people from allied domains such as biology, chemistry, and physics.

The *Blueprint for Change* report is the first collective response from the Earth and space science education community to the National Science Education Standards, the Benchmarks for Science Literacy, and new State Science Education Standards. We hope that teachers, administrators, policymakers, and parents use the report as a resource and guide to Earth and space science education reform efforts in classrooms, school districts, and communities across the country. The report is also intended to be an invitation to other disciplines to support collaborative, large-scale education reform efforts in science, geography, language arts, and technology.

The National Conference on the Revolution in Earth and Space Science Education was funded by National Science Foundation grant #EAR-9978346.

The American Geological Institute Foundation and McDougal Littell provided additional funding.

The conference was organized by the Center for Science, Mathematics and Technology Education at Colorado State University, and the Center for Earth and Space Science Education at TERC.

Expanding Student Participation in Earth and Space Science Education

The nation needs to increase the number of students, the amount of time, and the types of opportunities for learning Earth and space science at elementary, middle, and high school levels. This also includes efforts to broaden the diversity of students learning Earth and space science. Policy reform and expanded opportunities for professional development are essential for achieving these goals.

The scope of the challenge can be seen in a few key statistics. Of the roughly 13 million high school students in our nation, only 7% (860,000) will take a high school Earth and space science course. Contrast this with roughly 88% of students who take biology. Only two states (North Carolina and Kentucky) require Earth and space science for graduation, and 17 states do not even consider Earth and space science as a standard lab science course (National Report on the Status of Earth Science Education, American Geological Institute, 2001). California and Texas, for example, accept biology, chemistry, and physics as lab sciences, but not Earth and space science (except under special circumstances). Ironically, both of these states are significantly impacted by Earth and space science-related issues, such as allocation of water and energy resources, and risks from natural disasters like hurricanes and earthquakes.

Hence a major challenge, and opportunity, is to greatly expand the number of students participating in Earth and space science at the high school level. As detailed in the report, we believe real progress can be made in this regard by enhancing the nature of Earth and space science, and by ensuring that all states accept Earth and space science as a lab course.

The growing presence of computers and Internet access in schools provides an additional opportunity and impetus for reform. There are currently over 8 million computers in schools and 98% of schools have at least one Internet-connected computer. Computers are now the norm rather than the exception. Earth and space science provides a very compelling context for using computers in powerful ways to support student inquiry, exploration, and discovery.

Diversity is an especially important challenge in Earth and space science education reform. Earth and space science is often perceived as more appropriate for schools located in rural or other areas that might be considered "closer to nature." This perception is far from the truth.

In reality, urban areas are very closely connected to the environment. Cities are often founded near rivers and grow in patterns defined by the physical environment. Construction of buildings and highways require deep knowledge of what lies underground. Natural disasters such as severe weather or flooding require careful planning and recovery. All of these are rich domains of study for Earth and space science classes, ripe with real-world topics for inquiry and investigation. Furthermore, cities are "data rich" with a wealth of aerial and satellite imagery, environmental measurements, sub-surface data from construction sites, and so on. Earth and space science is thus a field where urban schools should be at the cutting edge of the revolution rather than the trailing edge.

A National Educational Imperative

Earth and space science education is about the planet we live on, the third planet from the sun and the only known place in our universe where life occurs. It is about four and a half billion years of history involving fantastic stories of climate change, evolution, and extinction. It is about a planet alive with fiery volcanoes, sudden earthquakes, slow-moving glaciers, and fast-moving storms. It is about a planet of rich resources, beautiful natural wonders, and amazing plant and animal species.

Earth and space science education at its most basic level is about observing the world around us and asking questions. As young children we taste, touch, smell, see, and listen. We ask questions about rocks and sand, about clouds and rain, about the moon and stars. As we grow older and our questions, observations, and sampling techniques become more sophisticated, we learn that Earth and space science education is the study of a complex system of interacting chemical, physical, and biological processes, constantly changing, ever surprising.

All of us who live on this planet have the right and the obligation to explore and understand Earth's unique history, its dynamic processes, its abundant resources, and its intriguing mysteries. As citizens of Earth, with the power to modify our planet's climate and ecosystems, we also have a personal and collective responsibility to understand Earth so that we can make wise decisions about its and our future. The "Revolution in Earth and Space Science Education" is about ensuring that all citizens have the opportunity to learn the science of their planet from pre-school through college and beyond. We invite you to join us on this 21st century voyage of exploration, discovery, and change.

Daniel Barstow, director of the Center for Earth and Space Science Education at TERC, and Ed Geary, director of the Center for Science, Mathematics and Technology Education at Colorado State University, were co-directors of the National Conference on the Revolution in Earth and Space Science Education. Harvey Yazijian was developmental editor for the conference report.

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Summary of Recommendations:

- Establish state-based alliances to promote Earth and space science education reform.
- Develop and conduct an "Annual Snapshot" to gauge progress toward meeting the goals outlined in this report.
- Student learning experiences should have a stronger emphasis on inquiry-based learning, use of visualization technologies, and understanding Earth as a system.
- At the high school level, Earth and space science should be approved as a lab science, with depth and rigor akin to biology, chemistry, and physics.
- Develop a national database of high-quality, grade-level appropriate Earth and space science assessments.
- Create national and state professional development academies in Earth and space science.
- In high-needs schools, enhance access to high-quality Earth and space science education for students and professional development for teachers.
- Create new opportunities for students and parents to learn about Earth and space science in informal settings.
- Develop a strong research program in Earth and space science education.

Get the Report

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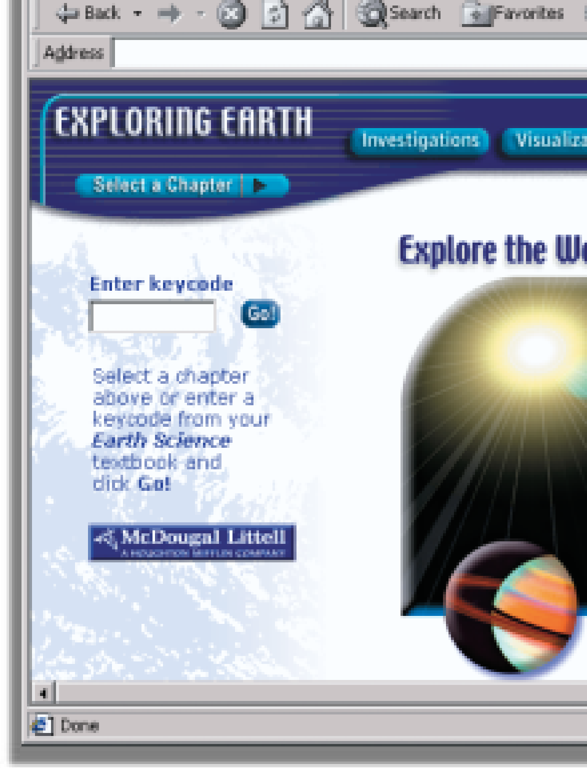
For copies of the report in PDF format or for more information on the revolution in Earth and space science education, visit the web site:
www.EarthScienceEdRevolution.org

EXPLORING EARTH

By **Martos Hoffman** and
Daniel Barstow



The World Wide Web offers an unparalleled quantity of diverse Earth science data, information, and visualizations. One need only glance at the robust web sites hosted by NASA, the USGS, or NOAA[1] to get a sense of the immense quantity of outstanding resources. Unfortunately, many Earth science teachers are not integrating this treasure trove of resources into their teaching, partly because they lack the time to locate appropriate web sites and to develop lessons that effectively integrate information from the sites. Fortunately, teachers now have Exploring Earth, a web site that brings many of these resources together for use with the *Earth Science* curriculum.

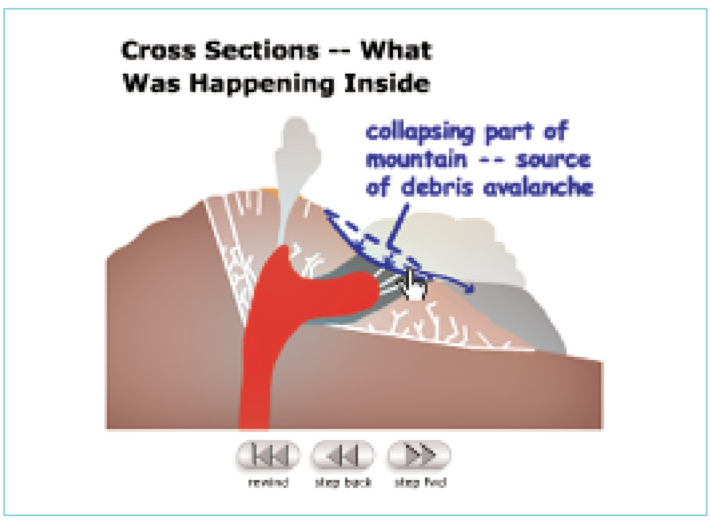


Figure 1. An advanced visualization shows a cross-sectional animated graphic of the Mt. St. Helens eruption. This can be paired and viewed simultaneously with a time-lapse photograph of the eruption. Text captions pop up as students move their mouse over different sections of the graphic.

Exploring Earth is the product of a unique partnership between TERC and McDougal Littell, the publisher of *Earth Science* by Nancy E. Spaulding and Samuel N. Namowitz. In this partnership, McDougal Littell has revised their widely used *Earth Science* textbook, and TERC has created a set of web-based visualizations and investigations that expand the curriculum.

Exploring Earth is an innovative web site that has a large set of Internet-based tools designed specifically to teach high school students about Earth system science concepts and processes through the use of engaging interactive visual materials. It includes inquiry-based investigations and visualizations of Earth system concepts as well as other technology-based resources.

The development of the Exploring Earth web site is based upon the notion that the teaching and learning of Earth science can be enhanced with web-based interactive visualization technologies. Integrating these technologies into a curriculum can reshape the context and manner that textbooks are used in the classroom. Exploring Earth is not only a new and readily available tool for Earth science educators, but is also a mechanism for changing the very way that Earth science education is practiced.

The following elements guided the development of Exploring Earth.

- Students learn best when they are able to experience Earth science through the process of inquiry, exploration, and discovery.
- Earth is best studied as a system of interconnected processes. Instead of learning many disconnected factoids, the materials, and the interactivity with these

[1]National Aeronautics and Space Administration, U.S. Geological Survey, National Oceanic & Atmospheric Administration

materials, should help develop broad understandings of system processes as well as critical reasoning and problem-solving skills.

- Earth science education is enhanced through the use of advanced visualization technologies that include abundant student interactivity.
- Integrating all of these elements into an easily accessible web-based resource provides a means for improving Earth science teaching and learning.

Features of the Exploring Earth Web Site

The core of the Exploring Earth web site consists of 79 investigations and 103 visualizations. These resources employ a wide variety of visualization and interactivity technologies. Some of the advanced visualization tools include QuickTime movies, side-by-side movies that simultaneously show a phenomenon from several different perspectives, photo-zoom slide shows, and clickable buttons that reveal different layers of data (see Figure 1). There is a suite of Shockwave and Flash-based tools students can use to draw features on diagrams, measure distances, calculate areas, plot and graph data, drag and drop geologic features onto maps, and move levers to control the progression of various animations.

The site's 37 data centers are an example of how Exploring Earth brings together the resources of the Internet. Each center focuses on a specific Earth system concept. Students can follow data center links to learn more about the impact of earthquakes in populated areas or find research on the Antarctic.

Teaching and Learning With Exploring Earth

Visualizations

Any of the Exploring Earth visualizations can be used in a variety of ways to enhance students' interest and understanding of Earth system concepts and interactions. Typically students begin with readings in the text and then follow the text references to the Exploring Earth web site, where they can extend their learning. We present several possible teaching scenarios in this article. Many other pedagogically sound approaches are possible.

In the Exploring Earth visualization, "Examine how barometric pressure changes with weather conditions," students view a QuickTime movie showing a sequence of color-enhanced GOES (Geostationary Operational Environmental Satellite) images of a major winter storm that

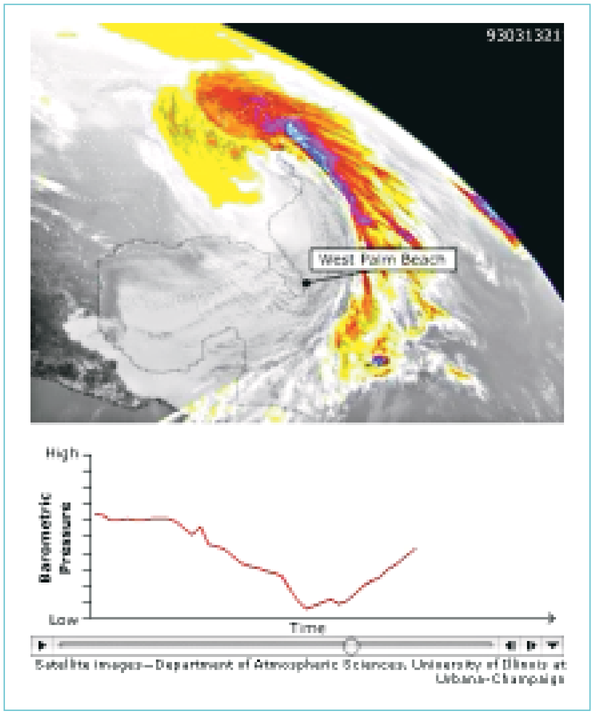


Figure 2. Image captured from the visualization movie "Examine how barometric pressure changes with weather conditions."

battered the eastern United States in 1993 (see Figure 2). As the satellite movie progresses, the barometric pressure over West Palm Beach is simultaneously plotted. Observing a graph of changing barometric pressure alongside the satellite image sequence provides students with a real-life example of this key meteorological principle.

Instead of telling students about the relationship between barometric pressure and storm systems, teachers can use this visualization movie as a mini, inquiry-style activity. Teachers ask students to view the movie several times, encouraging them to use the controls to step through the movie frame-by-frame. Students write down their observations about the relationship between the movement of the storm and barometric pressure. Next, they collaboratively develop and present to the class a unified statement of their observations. Through this simple and quick (approximately 15 minutes) process, students discover for themselves the main concept portrayed in the visual data.

This approach can also be used as a prelude to more open-ended, inquiry-based study of the visualization movie and meteorological phenomena in general. After students have completed the previous activity, they are asked to develop questions about aspects of the visualization that they do not fully understand and to identify the information needed to answer their questions. Students will raise a wide variety of issues, each of which could serve as an entry point for a more in-depth investigation. They might choose to analyze other meteorological data associated with this storm, or study the types of information that weather satellites gather and the ways that such information is used in weather forecasting. Using visualizations in this way, students can construct their own meaning and understanding of the phenomena presented.

Several other teaching scenarios can be implemented with the winter storm visualization. For example, it can be used as a way to enhance students' experience and understanding of barometric pressure changes associated with storms. Students view the visualization after they read the corresponding section of the textbook, or conversely, students view the visualization at the beginning of a lesson on barometric pressure. They might examine the visualization during the first few minutes of class as a way to transition from their previous class and begin focusing on Earth science. Viewing the visualization can be part of a homework assignment, or the visualization can be projected and used as the centerpiece of a teacher-led demonstration and discussion.

Investigations

Exploring Earth's investigations are intended to guide students through the analysis of a specific Earth science system or process. The investigations follow the same chapter and unit structure as the textbook. By design, most of these investigations employ a guided inquiry approach to teaching and learning. The vast majority of the investigations contain all of the advanced visuals, text-based resources, and interactivity tools needed to fully complete the investigation. Culminating unit investigations examine Earth system interactions via a more open-ended inquiry approach, which sometimes involves directing students to selected sets of external Web links.

The investigation "How are volcanoes related to plate tectonics?" exemplifies the interactivity as well as the guided inquiry approach to teaching that is built into the Exploring Earth investigations. It is coupled with a section of *Earth Science* that examines the relationship between volcanism and plate boundaries.

In this investigation students are initially asked to plot the location of 18 different Pacific Northwest volcanoes on a gridded map. Students do this by dragging and dropping a series of volcano icons onto the map. Students are then directed to interpret the resulting graph, and to use a drawing tool to indicate the location of plate boundaries (see Figure 3). Next, students are given the chance to check the accuracy of their prediction by viewing a map that shows the actual plate boundaries (see Figure 4). In the example given, the student sees that she incorrectly predicted that the subduction boundary corresponds to the line of Cascade Range volcanoes. After making their predictions, students are presented with an interactive three-dimensional view of the same region that can be tilted on end to view a cross-section of subsurface structure. This cross-sectional view provides a visual explanation for the spatial relationship between volcanoes and plate boundaries. As a result of this type of progression, students are able to develop an in-depth understanding of the relationship between subduction boundaries and the location of volcanoes.

Exploring Earth is an innovative new tool in the tool chest of Earth science teaching methods. Its highly visual environment is designed to enhance students' appreciation of Earth science and to move students well beyond learning Earth science as a set of disconnected factoids. Infusing these resources into McDougal Littell's textbook enables large numbers of teachers and students to make the transition to a new way of Exploring Earth.

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Visualizations created by the Exploring Earth team of developers.

Satellite image in Figure 2—Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign.

The Exploring Earth project is supported by the National Science Foundation #ESI0095684 and McDougal Littell, Inc.

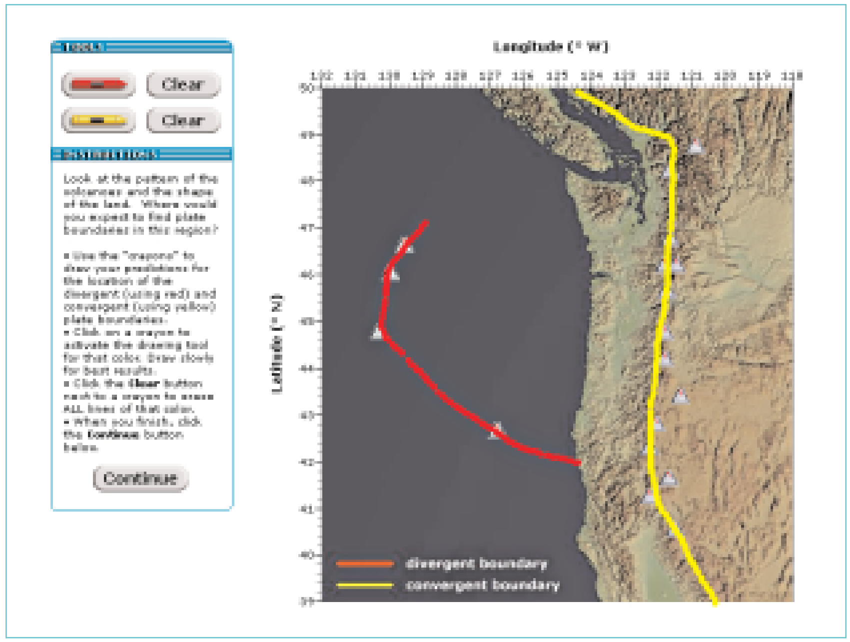


Figure 3. Drawing tool applet (left) and the location of plate boundaries as predicted by a student.

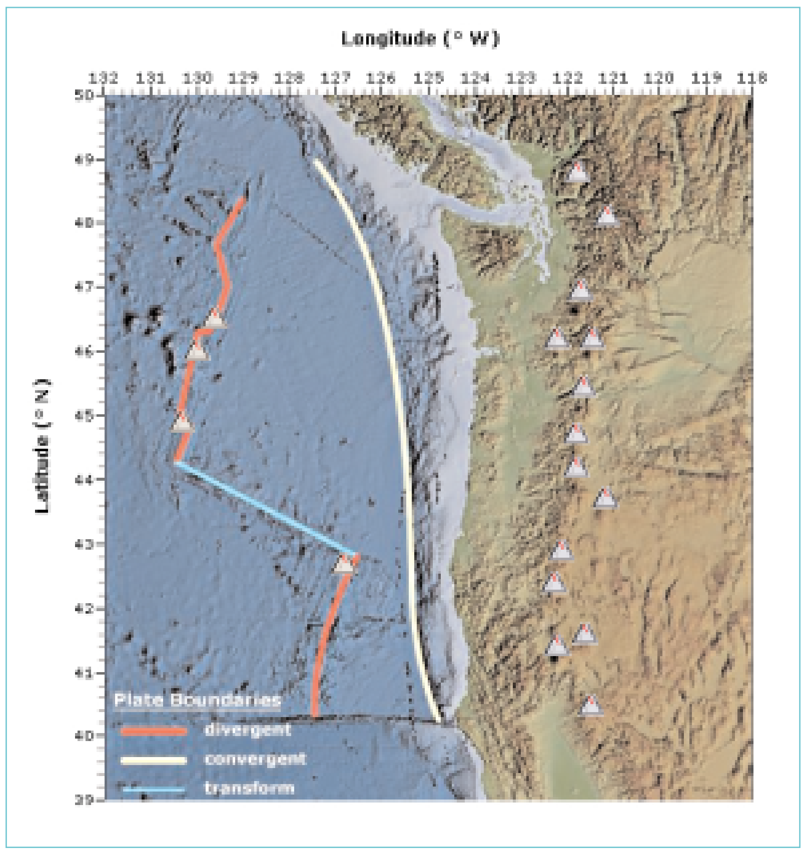
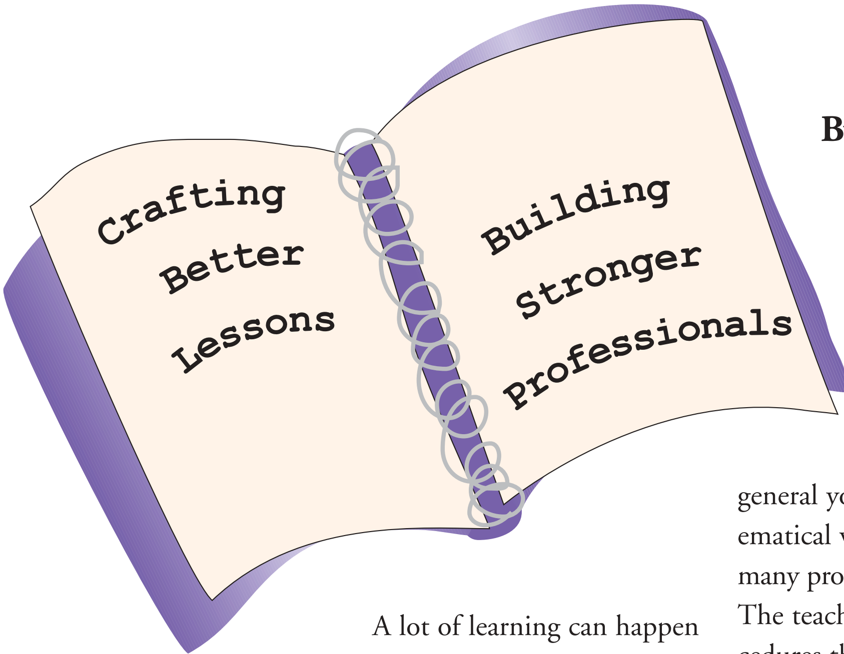


Figure 4. Actual plate boundary locations.



By **Diane E. Ready**

A lot of learning can happen when things don't proceed as planned. TERC's Joyce Tugel and a group of Sanford, Maine, elementary school science teachers experienced this educational truism when one product of educational reform (a kit for hands-on science activities) met with efforts from the Regional Alliance at TERC to introduce lesson study, a teacher-driven process for improving education. The participating school began with the notion that lesson study could provide an opportunity to train teachers to use the kits. As Tugel guided the group through the lesson study process, participants emerged with a lesson that centered more on student understanding of scientific concepts and less on how to use some good activities. In addition to crafting a better lesson, the participants carried away evidence that teachers can be the agents for improving educational practice when they harness their insights and experience in rigorous, reflective, and collaborative effort.

The Regional Alliance is working with several groups in Maine to help schools understand and apply the lesson study process highlighted in *The Teaching Gap*, by James Stigler and James Hiebert. Tugel serves as a resource to the schools as they try this gradual approach to improving both teaching and professional development. Working with Jan Goldsberry, Sanford's curriculum director, Tugel has helped pilot lesson study with a group of third- and fourth-grade teachers. She also guides reading and discussion of *The Teaching Gap* with Fellows from the Maine Governor's Academy for Science and Mathematics Education Leadership.

Closing the Gap

In *The Teaching Gap*, Stigler and Hiebert compare math teaching practices in Japan and Germany with those in the United States using data collected from the TIMSS video study.* Their analysis reveals some major differences. Tugel explains, "If you were to observe a Japanese math class, you would most likely see a great deal of time spent solving one challenging problem. And in general you would see the students doing much of the mathematical work. In the United States you would typically see many problems of the same type being practiced in one session. The teacher does most of the math work, demonstrating procedures that the students then practice."

In comparing teaching practices, Stigler and Hiebert found distinct patterns of teaching in each country. They contend that these patterns arise from a country's cultural script for teaching. Each culture shares a mental picture of what teaching is like—ideas about how students learn, the role of the teacher, and the nature of the subject being taught (p. 87). They argue that teaching is a cultural activity and that to improve teaching we must examine our cultural scripts for teaching.

One way to study these scripts is the lesson study process that Japan has been using for years. In contrast to many reforms developed by university researchers or policymakers and politicians, lesson study begins with teachers working together to examine how they teach. Tugel notes that in the United States teachers are often isolated in their classrooms, and "exceptional teachers" are seen as independent mavericks. "This is a huge stumbling block to achieving real change. Teachers are bombarded with all sorts of strategies and prescriptions for how they should teach, but they are seldom given the time to work with colleagues to develop any shared understanding of what is meant by, say, an inquiry-based or problem-solving approach to teaching. Lesson study provides the opportunity for reflective practice and collaboration, where teachers can focus on what's really helping the students understand the material. The focus is not on 'Did I implement the new strategy?' but rather 'What did I do in my teaching and how did the students respond? What did they learn?'"

*The Third International Mathematics and Science Study included a video study that compared the teaching of eighth-grade mathematics in Germany, Japan, and the United States. This was the first time ever that national samples of teachers had been videotaped teaching in their classrooms.

If you were to observe a Japanese math class...

you would see the students doing much of the mathematical work.

The Process

The lesson study process can vary. It always involves a group of teachers and may include administrators, curriculum coordinators, and others with expertise in a specific content area. Work begins with the group defining a curricular or learning goal that it finds motivating. Tugel comments that this initial step can be challenging for those not used to the process. "Teachers are often told what the goals are by the text or standards they are using. Rarely are they asked to define goals or discuss as a group what is meant by the stated goals of a particular unit, such as 'to build critical thinking skills' or 'to develop fluency in number operations.'"

Once the goal is established the group starts planning the lesson. "The term lesson can be misleading," says Tugel. "The focus is not a single classroom activity, but typically a unit that functions within the continuum of the curriculum. It builds on what has come before and prepares students for what will follow. Each lesson has its own storyline, with an introduction, expansion, and conclusion." Teachers examine everything from the possible student responses, to what materials they should have and how they should use them. What is the best way to use the blackboard to record the lesson as it progresses? What handouts and worksheets will promote and consolidate student thought? Once a lesson is drafted, one teacher offers the lesson while the others observe the class. The group then discusses their observations and refines the lesson. Another teacher will then teach the revised lesson as the group observes again. Group findings are shared, often through a written report or on videotape.

What's the Point of the Lesson?

Tugel concedes that the project in Sanford, Maine, did not offer the ideal jumping-off point for pursuing lesson study because its genesis was about how to implement specific classroom materials, not on defining an educational goal. As the teachers began discussing the goals of the science kits, their focus shifted to thinking about their goals for the unit on watersheds and the water cycle and on how and whether the kit fit those goals. Their curriculum director observed, "An afternoon spent discussing the purpose of the lesson led teachers to articulate the concepts students were to be learning. As the teachers shifted their emphasis from science activities to student understanding, they were simultaneously transforming their own professional learning."

The science kits came with a set of learning goals that the Sanford teachers could have readily accepted. Instead, lesson study allowed the teachers to define their own goals for the students and to examine how and whether using the kits would help them meet those goals. The teachers wanted the students to make connections between the natural events happening in the world around them and the classroom activities that modeled those events. By achieving this goal, the teachers believed that they would be building the foundation for more science learning. Students would see the importance of modeling and lab investigations for exploring major questions about Earth's environment and systems. Tugel emphasizes that by taking a step back to focus on the point of the lesson, "the teachers could then find ways that their students might use the kit to generate questions and more fully engage the science concepts."

Kids Can Say the Darndest Things

During the lesson planning process, teachers collaborate on how they think students will respond at different points in the lesson. After teachers give the lesson, they discuss how students did respond and modify the lesson to address unanticipated responses or inadequate teacher prompts. This planning step prepares teachers to guide students back to constructive exploration. Tugel explains, "Cognitive studies show that kids often share similar misconceptions that can take them off track. The Sanford teachers spent a lot of time determining what questions the kids might ask and what questions they [the teachers] might ask their students."

Teachers are in a unique position to anticipate and evaluate how their students may respond to certain material. This

I am absolutely terrified of holding my teaching up for inspection...

but I am so adamant that it is the only way to achieve excellence.

step not only helps teachers target the lesson more precisely to student needs, but also produces a "script" of possible scenarios for the lesson. With a script for support, teachers do not need to be so relentlessly fast on their feet when a class takes a disorienting turn. As Tugel points out, "It helps the teachers who need some support as they develop their pedagogy. It also helps to have a master teacher involved in the process to offer suggestions on how to redirect students in various situations." A teacher in the group commented, "Anticipating student reactions to parts of the lesson was an interesting aspect of the process. I have begun to do that more in order to minimize student misconceptions."

Time to Reflect Creates Unique Ownership Opportunities

With lesson study, the Sanford teachers are taking ownership of their teaching. Using the kits no longer means just following someone else's teaching strategies, but forming and testing your own best strategies. The teachers' planning and testing have changed the way they use the kits. For example, the day before the students begin doing one of the kit activities, the teachers ask the students to list everything they know or want to know about the water cycle. The teachers find that this helps them guide instruction the following day. Tugel asserts, "These changes couldn't come about without the teachers collaborating on the lesson."

Opening Classroom Doors

Through collaboration and shared reflection, lesson study can open closed classroom doors to change the culture of teaching in the United States. Instead of isolated teachers struggling to interpret and implement reforms that land on their desks as finished products, teachers can build their practice together within schools and across districts. The use of videotaping in addition to written records helps teachers see nuances in implementation that a written curriculum can't provide.

Tugel observes that close scrutiny, through collegial discussion, observation, even videotaping, can be intimidating. "In most U.S. classrooms, observation is generally reserved for opportunities to judge, like when it's time for recertification or evaluation for tenure. But teachers are willing to risk the scrutiny of their colleagues in pursuit of becoming better teachers and building a better profession." As evidence she offers comments from the online study group she leads. One participant remarks, "I am absolutely terrified of holding my teaching up for inspection…but I am so adamant that it is the only way to achieve excellence." Another reflects, "What an amazing opportunity I have before myself if I can be honest enough to see where the way I teach is not consistent with what I believe is at the heart of effective teaching."

One teacher describes her experience with videotaping her own lessons. "Sometimes it is painful to watch yourself, but as they say, no pain, no gain." She suggests that a key to productive use of observation is to "make sure that the atmosphere is one of support and collaboration, rather than criticism. I would want to do this the first time with a group of teachers that I already have a good relationship with."

Professional Development Potential Invites Increased Interest

Just as lesson study builds teaching best practices in a gradual way, interest in lesson study is slowly and steadily building in the United States. Through her work with the Regional Alliance, Tugel sees lesson study taking hold as more resources for implementing it become available. She promises that anyone who visits one of the many schools pursuing lesson study will see lively, engaged groups of learners. The fact that it can proceed on site and be scheduled around the school calendar appeals to many seeking new approaches to professional development options. She strongly suggests beginning an exploration of lesson study by reading *The Teaching Gap*. "Once teachers and administrators read the book, they are knocking at the door and asking a lot of questions."

Tugel notes, "Lesson study incorporates much of what we are learning about effective professional development. Students and learning are at the core. By engaging teachers in an ongoing, site-based initiative that focuses on student thinking, teachers can improve their knowledge and skills in a collaborative learning community." She cautions that the process requires a concerted time commitment and a willingness to challenge deeply rooted expectations about how a classroom should work. "It is not a quick fix—if you try it you can't expect that test scores will suddenly improve across the board."

A frequently heard criticism of the process is that you only get one or two improved lessons. While the immediate product is a better lesson, the process allows teachers to improve their teaching methods and share that knowledge. The lasting effects can be the development of a professional culture that has the means to continuously improve its practice.

Lesson study incorporates much of what we are learning about effective professional development. Students and learning are at the core.

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The Maine Governor's Academy for Science and Mathematics Education Leadership is an initiative of the Maine Mathematics and Science Alliance, www.mmsa.org.

The Regional Alliance is the Northeast and Islands Eisenhower Regional Consortium for Mathematics and Science Education. It is part of the national network of Eisenhower Regional Consortia and Clearinghouse.

The Regional Alliance is funded by the U.S. Department of Education #R139A000013.

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To learn more about lesson study….

Visit the web site of the Lesson Study Research Group at Teachers College/Columbia University, www.tc.edu/lessonstudy. With funding from the National Science Foundation, the research group is working to contribute to a better understanding of lesson study in the United States.

The Spring/Summer issue of *RBS Currents* is all about lesson study. The publication from the Mid-Atlantic Eisenhower Regional Consortium is online at www.rbs.org/currents.

The Northwest Regional Educational Laboratory has devoted an issue of the *Northwest Teacher* (Volume 2, Number 2, 2001) to lesson study. Available online at www.nwrel.org/msec/nwteacher/.

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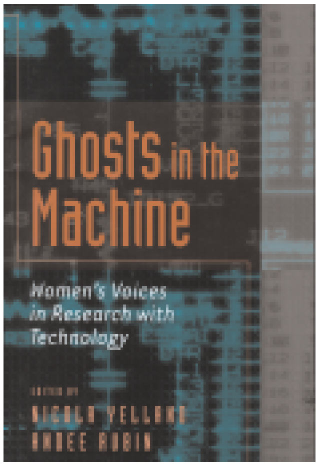
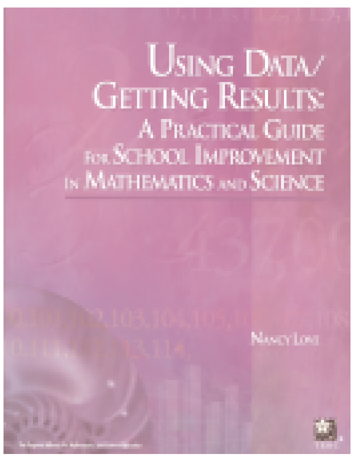


Ghosts in the Machine: Women's Voices in Research with Technology examines the complex relationships between gender and information and communication technologies (ICT). Written by women in four countries on three continents, the book was co-edited by TERC Senior Research Scientist Andee Rubin and Nicola Yelland of the RMIT University in Melbourne, Australia. *Ghosts in the Machine* discusses the educational, social, artistic, and political implications of a feminine voice in the design of technology. The research presented explores the "gendering of technology" and, in doing so, describes the Internet, computer games, computer-based design and construction environments, and digital art from a perspective that emphasizes these media's social context.

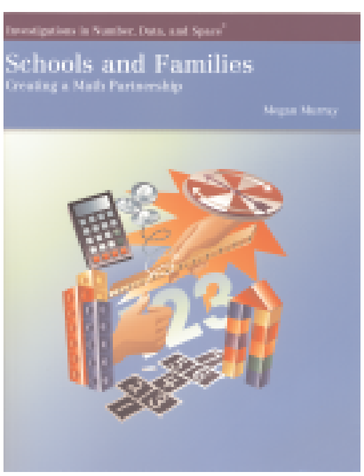
Peter Lang Publishing, Inc. 800-770-5264. (ISBN: 0-8204-4911-3)



Using Data/Getting Results, written by Nancy Love, contains practical strategies and ideas to help administrators, teachers, and community members become active inquirers into how best to improve learning for all students. This new resource details the guidelines, tools, and skills needed to take advantage of the potential for using data as a catalyst for change.

Using Data/Getting Results focuses on using data to investigate student learning; curriculum, instruction, and assessment practices; and equity. The guidebook combines practical tools with a conceptual framework. Data and planning tools, targeted to 12 problem areas, are supplemented with real-life vignettes of districts grappling successfully with reform.

Christopher-Gordon Publishers. 800-934-8322. (ISBN: 1-929024-33-9)



Schools and Families: Creating a Math Partnership, by Megan Murray, is a guide to help teachers and administrators answer the question, "How do we engage parents as partners in improving mathematics learning?" Although written specifically to support schools using the *Investigations in Number, Data, and Space®* curriculum, much of this book will be useful for all educators wanting to communicate with parents about how and why mathematics learning and teaching are changing.

Content addresses barriers to creating effective partnerships, and strategies for overcoming them; hosting math events; homework; and helping parents see the math in their children's work. The second section offers the perspective of teachers, administrators, and parent leaders on establishing effective home-school relationships.

Scott Foresman. 800-552-2259. (ISBN: 0-328-01881-3)

New Projects

Boston University Preparing Tomorrow's Teachers with Technology (PT3)

The PT3 project helps Boston University's School of Education methods faculty support their students (preservice teachers) as they create standards-based, technology-integrated units of instruction to use during their practice teaching in K–12 classrooms. BU methods faculty receive professional development to improve their technology-integration skills. TERC is the external evaluator for this project. Funded by Boston University through a grant from the U.S. Department of Education.

Media and American Democracy Evaluation

TERC is evaluating the Media and American Democracy program at Harvard University's Graduate School of Education. This week-long summer institute has served approximately 500 secondary English, history, social studies, humanities, and journalism educators. The program seeks to improve student media literacy by deepening participants' understanding of the concepts and ideas related to the use of electronic and print media in our democratic political process, and by promoting the integration of the latest ideas and research on this topic into participants' instructional practice. Funded by the Knight Foundation.

Dissemination of Expert Panel/ Ed Technology Framework

This project is disseminating the important thinking and work carried out by the U.S. Department of Education's Expert Panel on Educational Technology. The panel (which also conducted program evaluation) created a framework, criteria, and rubrics for the implementation of educational technology programs; this work is the focus of a paper written by three panelists. The paper, along with commentary papers and other related materials, will be published in the online journal *Educational Technology* in a special issue devoted to the panel's work. Funded by the Joyce Foundation.

Focus on Quality

Focus on Quality will assist educational decisionmakers, implementers, and program designers in evaluating educational technology programs. The project is leveraging the work of the Expert Panel on Educational Technology, making the work of the Panel widely available in forms that are clear and easily accessible. The project is also establishing processes for the use of the materials derived from the work of the Expert Panel. A primary goal is to engage broad segments of the educational technology community in using the materials to plan for, design, and improve educational technology programs. Funded by the Joyce Foundation.

ISS EarthKAM

TERC's involvement in the EarthKAM project has been extended with a new, five-year grant. This grant corresponds with a new era for EarthKAM, which began flying its camera on board the International Space Station in late 2001. A permanent camera on the station will allow more schools to participate, and students will have greater access to the EarthKAM camera. Funded by University of California, San Diego through a grant from NASA.

Transforming Teaching and Learning in a Digital Age

Transforming Teaching and Learning in a Digital Age is part of a large project funded by the Public Broadcasting System (PBS) to develop over a hundred online professional development modules in mathematics and technology. Each workshop module consists of six sessions of three hours each; teachers take a workshop as a cohort, with the guidance of a facilitator. The modules make extensive use of video and interactive applets. TERC is developing a module on Algebraic Thinking in grades 3–5 and another on Algebraic Thinking in grades K–2. Funded by Education Development Center through a grant from PBS.

Census Microdata in the Classroom: Phase 2

In Phase 1, the Census Microdata in the Classroom project developed Fathom Dynamic Statistics software for analyzing Census microdata. In this new phase, TERC will continue to work with developers on the classroom applications of the software, while also helping the project develop applications for analyzing multiple sources of student achievement and other school data. Funded by Key Curriculum Press through a grant from the National Science Foundation.

Search for Extraterrestrial Life Museum Exhibit

TERC is collaborating with the New York Hall of Science to create a permanent exhibit entitled The Search for Extraterrestrial Life. This exhibit examines themes at the core of TERC's Astrobiology curriculum project, such as life on Earth, planetary geology, and detecting extraterrestrial life. The exhibit includes a "Discovery Center," a space with 12 hands-on activities related to these themes. The museum's education staff will also use the Discovery Center to offer 45-minute "classes" to school groups. TERC is helping develop the Discovery Center activities and six classes. Funded by the National Science Foundation.

Symposium on the Future of School Reform

TERC's Center for Education Partnerships will host a two-day invitational conference in November, 2002, that will bring together top thinkers and practitioners from across the country to examine the past lessons, current status, and future prospects of school reform. Participants will represent: organizations focused on systemic reform, comprehensive school reform, technology, and equity; government, foundations, and other funders; private sector initiatives; and researchers, policymakers, and practitioners. Funded by TERC.

Earth Science by Design

Earth Science by Design is developing an Earth science program that will be disseminated to professional development providers nationwide. The program will enhance the ability of middle school teachers to use visualizations in teaching the big ideas in Earth science using the "Understanding by Design" approach. The program begins with a two-week teacher institute this summer and includes two mini-conferences for teachers during the school year. Funded by the National Science Foundation.

They Have Their Own Thoughts

This project will examine how computational literacy and cultural funds of knowledge interact in children's learning of ideas in math, science, and literacy. It involves two strands of research: 1) a case study of an urban classroom where students of color are supported in successful learning by a veteran second-grade teacher with socio-political commitments to teaching, and 2) a classroom-based design experiment investigating the role of cultural identity and experience in children's learning as they work with programmable media. Funded by the American Educational Research Association and the U.S. Department of Education.

NEWS NEWS NEWS NEWS

TERC's Focus on Quality (FoQ) project announces that the May issue of *Educational Technology* contains a special section designed to engage educators in conversation about quality in educational technology programs. The section includes an article authored by Jere Confrey, Nora Sabelli, and Karen Sheingold, and five responses from key people in the field. The article extends and elaborates on the framework first developed by the Expert Panel on Educational Technology, convened by the U.S. Department of Education. FoQ, funded by the Joyce Foundation, is disseminating this framework and creating partnerships with which to develop tools that embody the framework. The impact of initiatives using the framework will also be investigated.

The special section will be posted on the Web, at http://quality.terc.edu.

Former TERC President and CEO Barbara Sampson is off to Cyprus to deliver a talk titled "Does Technology Matter? Creating Appropriate Applications for Teaching and Learning" at a conference sponsored by the U.S. Agency for International Development. Participants at the May conference—whose focus is the application of educational technologies in grades K–12—will be Greek and Turkish Cypriots on the island of Cyprus.

Resources By TERC

Ecology Curriculum

This year-long curriculum teaches high school students to think about science concepts and practice as they explore carbon, energy, and water within an evolutionary framework. The standards-based curriculum includes a teacher's guide and three modules:

The **Teacher's Guide** presents key concepts, discussion questions and class sequences, and tips on group work and general logistics. Includes student assessment and teacher materials for evaluating student work. The **Evolution** module explores how evolution works by examining the natural selection of finches on the Galapagos Islands. **Carbon & Energy** examines movement and transfer of energy within and among parts of an ecosystem as the foundation underlying all other ecological processes. Students explore energy at different levels of ecology. In **Water**, students examine water flow and the water cycle at individual, population, habitat, and ecosystem levels.

Kendall/Hunt Publishing. 800-542-6657, www.kendallhunt.com

Science by Design

The *Science by Design* series offers a method for high school students to successfully develop and carry out product design. These teacher-tested units introduce the design process and sharpen student abilities to investigate, build, test, and evaluate similar products. All four volumes (**Construct-A-Boat**, **Construct-A-Catapult**, **Construct-A-Glove**, **Construct-A-Greenhouse**) are keyed to the National Science Education Standards, the Benchmarks for Science Literacy, and the International Technology Education Standards.

NSTA Press. 800-722-NSTA, www.nsta.org/scistore/.

The TERC community welcomes our new board members.

The TERC Board of Trustees is pleased to announce that Hubert Dyasi and Pendred Noyce have become members of the Board. Dr. Dyasi is Professor of Science Education at the City College of New York and director of the City College Workshop Center. Dr. Noyce is co-principal investigator of the Massachusetts State Systemic Initiative (PALMS) and the Massachusetts Parent Involvement Project.

Dr. Dyasi is one of the pioneers of inquiry-based science learning and has contributed to a number of publications, including *Inquiry and the Science Education Standards: A Guide for Teaching and Learning* (National Academy Press). As Director of the Workshop Center at CCNY he continues his almost 20 years of work with New York teachers, coordinating the center's preparation and professional development programs for elementary educators. Dr. Dyasi was co-principal investigator of the New York State Systemic Initiative, a program funded by the National Science Foundation to improve science and mathematics education. A native of South Africa, Dr. Dyasi has extensive international education experience as well. He received his Ph.D. from the University of Illinois.

As co-principal investigator of two statewide projects and a board member of the Boston Plan for Excellence, Dr. Noyce is deeply involved in efforts to improve Massachusetts science and mathematics education. On the national level, she helped design the Noyce Foundation, which is dedicated to the improvement of K–12 public education with a focus on mathematics, science, and literacy. She currently serves as a trustee of this and other foundations and organizations, including the Libra Foundation and the Massachusetts Business Alliance for Education. A physician as well as educator, Dr. Noyce graduated from Stanford University School of Medicine.

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Prices include shipping for US orders. Prepayment required: Send check or money order in U.S. dollars, payable to TERC. TERC Communications, 2067 Massachusetts Avenue, Cambridge, MA 02140, USA

Get Involved

Hands-On Universe

Hands-On Universe (HOU), an innovative program that uses astronomical explorations as a basis for science, mathematics, and technology education, seeks teachers to participate in an NSF-funded educational research project assessing the relative effectiveness of face-to-face courses versus distance learning courses for professional development. Earn a $350–$600 stipend and receive HOU curriculum materials (books and software). Five-day courses, one-day workshops, and online courses (moderated or self-paced) are scheduled for this summer. Academic credits are available. Teachers may register online; to register or for more information visit hou.lbl.gov.

Try Science

Register for Try Science, an online, graduate-level course designed by TERC and Lesley University for K–8 educators who would like to strengthen their science background, learn more about inquiry-based science, and align their classrooms with the National Science Education Standards.

Summer session begins May 13.

Fall semester begins September 9.

Try Science is a prerequisite for the online science education master's degree program at Lesley University. For information, contact Lesley University at 617-349-8300; 800-999-1959 ext. 8300 or science@mail.lesley.edu.

See page 1 for an article about Biology Explorations, another course in the TERC/Lesley master's program.

Earth Science by Design Program

If you teach Earth science topics in grades 6–8, you are invited to apply for the Earth Science by Design Program. Beginning with a summer institute in the Boston area August 5–16, 2002, the year-long program will work with teachers to enhance their ability to use the "Understanding by Design" approach to teach the big ideas in Earth science. Teachers will also learn effective assessment techniques and how to use digital visualizations such as satellite images and computer animations. Participation requires a strong commitment from teachers and schools to be part of a research project. In return, teachers and schools will receive strong support from this TERC project. Stipends provided. For further information, contact Harold McWilliams at harold_mcwilliams@terc.edu or 617-547-0430.

EarthKAM

Middle school educators and students are invited to learn about Earth as observed from space, through participation in NASA's EarthKAM Program. Students in EarthKAM take photographs of Earth using a camera mounted aboard the International Space Station, and they learn science, geography, mathematics, and technology by exploring the resulting images. Everyone is invited to access the Earth images, the exploration resources, and the activities available at www.earthkam.ucsd.edu. Middle school educators (grades 5–8) are invited to join the EarthKAM Community, using the simple online form.

Study of Place Field Test

Study of Place seeks middle school science teachers interested in participating in a ten-session field test for a web-delivered science and geography unit on Ocean Currents. The learning activities integrate web resources with hands-on classroom activities. The field test will take place in September 2002. Interested teachers should contact Katherine Paget at katherine_paget@terc.edu or 617-547-0430.

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