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35
years



HANDS ON!

Hands-on math and science learning

Spring 2000 Volume 23, No. 1

Lost In Space

a real science story

**"Space programs should
fail with regularity or
they are not
adventurous enough."**

*Freeman Dyson at American
Association for the Advance-
ment of Science conference,
February 2000*



By Jamie Larsen

Press pass in hand, I arrived at the Jet Propulsion Laboratory in Pasadena, California, to cover the Mars Polar Lander. I was prepared to write a story about a successful mission. With the outline firm in my head, I thought about how I would describe the excitement of seeing the first images from the south pole of Mars, then, hopefully, the reactions of mission scientists upon the discovery of subsurface water.

While waiting for word from the lander, my mind began to wander. How would this discovery shape the astrobiology curriculum my colleagues and I are developing at TERC? Perhaps, if my karma was really good, I would even witness a historic finding—the lander's robotic arm, equipped with a special camera,

scoops up a sample of Martian soil containing colonies of subsurface bacteria—life on another planet!

Unfortunately, this story was not meant to be. The Mars Polar Lander was lost! But there was still a story to be told.

As the likelihood of hearing from the lander faded, I began to reflect on the nature of science, the value of dealing with failure, and the differences between what science is and how we teach it. Observing the scientists and engineers at mission control brought on my philosophical state. I was witnessing a side of science that was more real than the distilled "success" versions that are so often presented in science texts and classes. My story would not be about success. It would be about how any endeavor

worth pursuing risks failure and how scientists learn from failure.

The Deep Space Mission

The scientists I had the privilege of observing and talking to were members of the Deep Space 2 team. Their mission was to test cutting-edge technology to demonstrate new ways of entering a planet's atmosphere, surviving impact, and collecting data. In short, it was a real world science and engineering challenge.

The Deep Space 2 probes are designed to piggyback on the Mars Polar Lander and eject as the spacecraft enters the Martian atmosphere. The probes then gather data as they scream through the Martian atmosphere at 200 meters per second. The force of impact on landing causes a special part of the probe to penetrate the surface of the planet. A section of the probe with batteries, antenna, and transceiver remains on the surface, while below the surface a special sample collection device called a penetrator drills a hole into the subsurface of

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Facing Equity: Facing Ourselves

Light Energy for Life—On Earth and Other Worlds? (an activity from TERC's astrobiology curriculum)

Where's the Balance in

Math Instruction?

by Jan Mokros and
Susan Jo Russell

Is it possible to achieve balance in a math program? Yes, but what kind of balance is best? Too often, math curricula lead children through a whirlwind tour of as many mathematical topics as possible at each grade level in an attempt to balance content areas and pedagogical approaches. Typically, elementary students using textbooks are exposed to one new math concept in class every 30 minutes. The danger of this 'having it all' kind of balance is expressed in the familiar TIMSS critique of American math curricula—they are "a mile wide and an inch deep."¹

Some educators and policymakers are advocating another type of balance that tries to answer the question, Why can't children learn how to do specific computational procedures and also learn to understand mathematics at a deep level? They seek a balance that is usually a response to a political, rather than a pedagogical problem. The Massachusetts Mathematics Curriculum Framework (draft, February 23, 2000) attempts to answer the question by balancing different philosophies of learning. In the document, the major principles of mathematics learning—problem solving, communicating, connecting, and reasoning—are right alongside standards of mastery for learning specific procedures at an early age.

For example, the proposed Framework indicates that first and second graders should learn the meanings and uses of addition and subtraction, as well as know and apply conventional algorithms for three-digit addition

and subtraction. Is this a good balance of learning concepts and procedures? Before answering, let's examine what first and second graders need to learn in order to solve addition and subtraction problems and reason about the numbers in such problems.

Try the following second-grade problem without using pencil and paper (or calculator) in whatever way makes most sense: There are 53 people on the bus altogether. There are 27 adults. The rest are children. How many are children?²

First and second grade students must be able to develop a model of the problem and understand its structure. The quantity 53 is a whole of which 27 is a part (the adults), and the task is to figure out the quantity of the other part (the children). Students who don't learn to develop a mental model often pull numbers out of the problem and apply some operation based on a rule like, "If the word 'altogether' appears in the problem you must add."

Once students understand the structure of the problem, they must examine the relationship between the numbers that are given and the number that is needed. A typical second grader with a good understanding of number relationships might solve this problem by adding up from 27:

$$\begin{array}{r} 27 + \textcircled{3} = 30 \\ 30 + \textcircled{20} = 50 \\ 50 + \textcircled{3} = 53 \\ 26 \end{array}$$

Another student might subtract 20 from 53 to get 33, then subtract 7 to get 26.

Second graders should be examining the relationship between operations: why is it that one student added and another subtracted, yet both got the correct solution?

Understanding the structure of the problem and knowing a strategy

for solving it are still not enough. Students must also develop the fluency to manipulate the numbers easily. This requires knowledge of the base ten structure of our number system and knowledge of many number relationships. The first student used multiples of ten as important landmarks in solving the problem, while the second student knew how to break up 27 into tens and ones in order to subtract more easily.

For adults, a problem like this one seems easy. But, as the previous example illustrates, there are several complex tasks that children must learn to solve such a problem competently.

Mixed Programs: A Confusing Balance

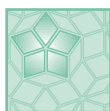
What happens if, in an effort to provide balance, a teacher gives children time to develop their own methods for solving the previous problem and then shows one subtraction algorithm and assigns many problems for the students to practice applying the algorithm? Does the teacher achieve the best of both worlds? Recent research is showing that mixed programs may be confusing to students.

In one study by Goodrow (1998), second graders whose math programs focused on building understanding of number relationships were much more accurate in solving addition / subtraction problems than children whose math programs involved a mixture of conceptual understanding and learning procedures. Goodrow concludes that "children in the mixed group almost always performed less well than children who had either a curriculum built on understanding number relationships or a curriculum built on learning procedures. This was particularly true on more difficult problems." Goodrow suggests that children in "mixed" programs may be confused about when to use a taught procedure and when to rely on one's own number sense.

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¹A *Splintered Vision*. U.S. National Research Center for the Third International Mathematics and Science Study, 1997.

²From the elementary mathematics curriculum, *Investigations in Number, Data, and Space*, Dale Seymour Publications.



HANDS ON!

From the Editor

TERC is celebrating 35 years in education. This issue of *Hands On!* provides a glimpse of how we are celebrating. The year 2000 finds us immersed in innovative work, exploring the educational possibilities offered by Earth-orbiting satellites and robotic missions to space. Two projects from TERC's Center for Earth and Space Science Education are featured here beginning on pages 4 and 11.

TERC is also celebrating its commitment to the learner by championing programs that inspire rigorous and reflective inquiry. The cover article looks at the role of inquiry in a real science challenge. The author argues that science class should offer similar opportunities to problem solve and learn from failure. *Facing Equity: Facing Ourselves*, page 8, asks educators to reflect on their own beliefs and how they affect school policies. And in our *Viewpoint*, page 2, the authors advocate that educators focus on fostering mathematical fluency rather than combine different philosophies of math instruction in an effort to solve a political problem. ✨

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Hands On! is published semi-annually by TERC, a not-for-profit education research and development organization dedicated to improving mathematics, science, and technology teaching and learning. A contribution is requested to help defray costs of publication.

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All opinions, findings, conclusions, and recommendations expressed herein are those of the authors and do not necessarily reflect the views of the funding agencies.

ISSN 0743-0221

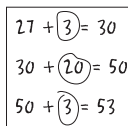
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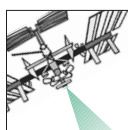
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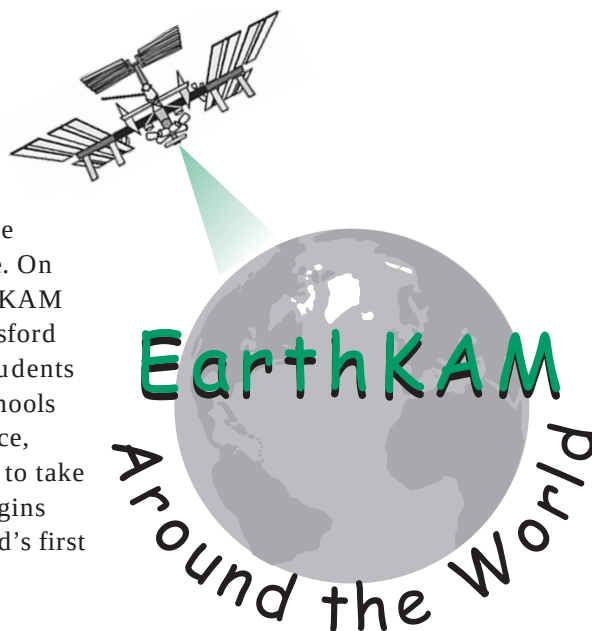
by Teon Edwards

Now delays the opening of school in Chelmsford, Massachusetts, by 90 minutes... and the Space Shuttle Endeavor orbits the Earth once. On board Endeavor flies the EarthKAM camera, waiting for the Chelmsford eighth-grade students—and students from about 80 other middle schools across the United States, France, Germany, and Japan—to tell it to take photographs of Earth. Thus begins Valentine's Day and Chelmsford's first day of taking images using the EarthKAM camera.

A power outage during the night has brought down the school's web access, so a volunteer and I scramble to get necessary Shuttle orbit information using our own computers. With that information, a group of students aligns the orbit track of the Shuttle on a map of Earth. They determine which part of Earth is in daylight and select a target—the Missouri River (Figure 1). During the fall, the students had studied the Merrimack River, which flows through their town. Now they are planning to take images of rivers around the world and expand their investigation.

Suddenly, the computer lab's web access comes on and the Chelmsford EarthKAM team kicks into high gear. First, another image of the Missouri River, next a river in North Korea, then ones in Canada (Figure 2), and so on. The students are focused and excited—picking targets, checking weather reports, debating if conditions are right to get the photograph they want, and submitting requests for photographs.

The Chelmsford middle schools are participating in EarthKAM, a NASA-sponsored education program that enables students, teachers, and now the public to learn about Earth from the unique perspective of space. Since 1996, pilot middle schools (grades 5–8) around the world have directed a digital camera on board



Shuttle missions to photograph parts of Earth. They have used the resulting images to support learning in Earth science, space science, geography, social studies, mathematics, communications, and even art. Now the program is ready to extend beyond these few pilot schools.

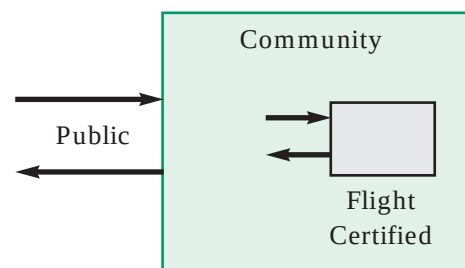
Scaling Up: Levels of Participation

Participants in EarthKAM use web-based resources to plot the Shuttle's orbit, identify targets, check cloud conditions, and forward the target's coordinates to the University of California at San Diego (UCSD), where they are reviewed and then relayed to NASA and up to the Shuttle. Within hours, the photographs are taken, downloaded into the program's data-system, and retrieved via the Web by students. The images, which currently total nearly 5,000, range from storms over the Atlantic and forest fires in Indonesia to cities, mountains, rivers, coastlines, and agricultural regions. Teachers and students analyze these images, both online and in hardcopy, to enhance their studies. Thus, efforts to scale up must address the issues of new technology, new teaching strategies, new sources of information / data, and possibly even new content.

But how does a program extend itself beyond its pilot schools? In

general, scaling up means expanding beyond the early adopters, who often are skilled in new learning strategies and technologies, to teachers with a wider range of experiences. So one important method of enabling such a scale-up is to support multiple levels of participation in the program. Multiple levels allow teachers to participate according to their skills and involvement. The challenging elements of the program are layered for teachers and students. This can be particularly important for innovative, cutting-edge projects, as many teachers may need additional support taking on an authentic, inquiry-based program such as EarthKAM.

To deal with these issues and to layer the challenges involved in the program, the EarthKAM team decided to support three levels of participation, each increasing the depth of involvement: Public, Community, and Flight Certified.



Public Level: Getting Successfully Involved

At the Public Level of EarthKAM, students, teachers, and the general public are supported in preliminary explorations of the images. Since teachers and students are often unfamiliar with images, and web access is required to obtain the images, there are innate challenges involved in participation even at this entry level. However, the EarthKAM web site and materials currently in development for the Public Level make entry into the program as easy as possible.

To begin with, there are multiple ways for Public Level visitors to become familiar with the program and with the images. A basic overview

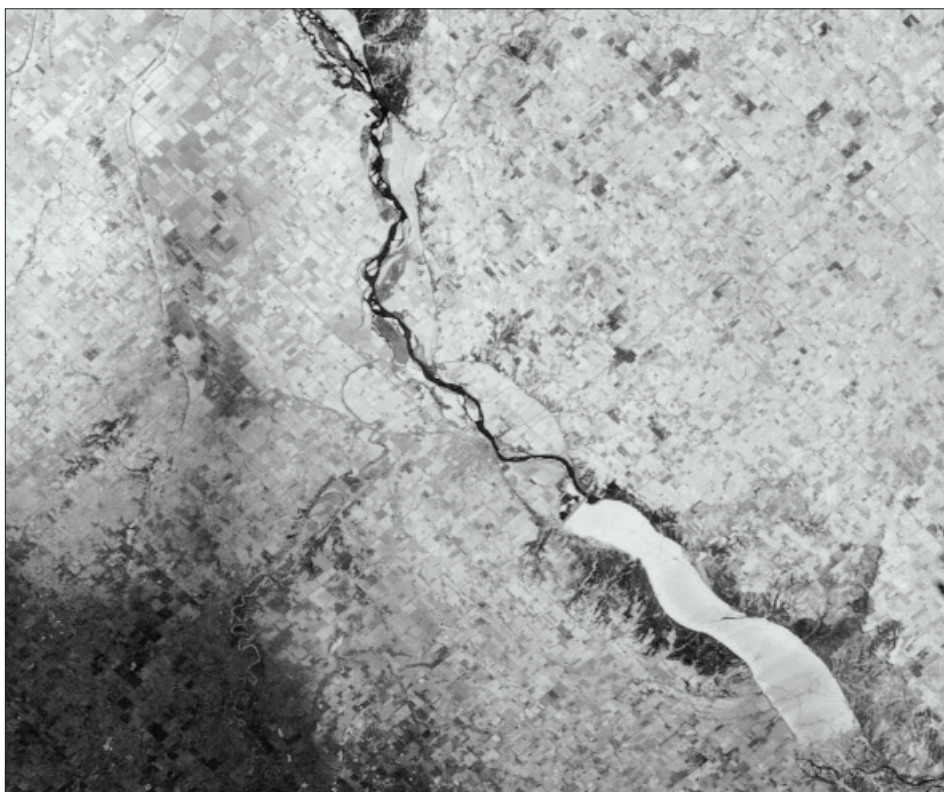


Figure 1. The image shows a dam across the Missouri River in South Dakota. Why was this dam built? Is the water used for the surrounding agriculture? How did the dam affect the rest of the river? EarthKAM image STS099.ESC03005732

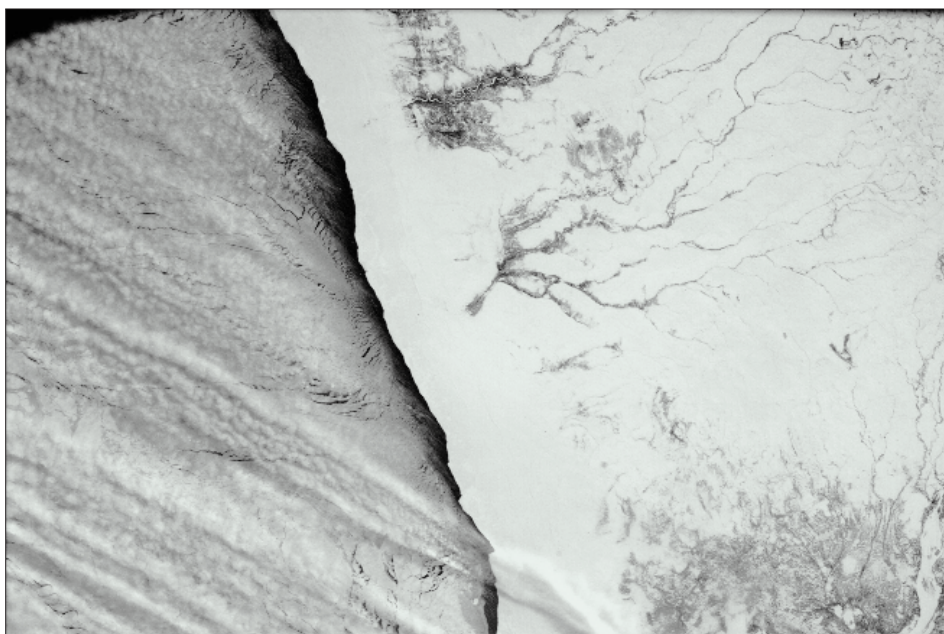


Figure 2. Hudson Bay, Canada, and nearby rivers are seen through clouds. What caused the cloud patterns? How are they related to the water? Which way was the wind blowing? Why are the areas around the rivers dark? EarthKAM image STS099.ESC.04035106

of the program, without all the nuts and bolts, is provided, as well as collections of interesting images to capture the imagination. An on-line tutorial walks participants step-by-step through the process of exploring an EarthKAM image—Getting Interested, Getting Oriented, and Getting Deeper. They are introduced to what needs to be done and understood at each step, have an opportunity to try each step themselves, and then are shown “answers” to compare with their own. For participants less comfortable with the Web, a short Exploring Images guide is available for download. In this way, they will be gently walked through what is a very new process with potentially unfamiliar data—remotely-sensed images of Earth.

Building familiarity with a project is only part of the challenge, however; new participants in a program require clear first steps to follow and easy access to all the materials they need to be successful. For EarthKAM this means changing the nature and distribution of the support materials. Previously, EarthKAM produced a single, comprehensive educator guide with good information and support, but it was too much for new participants to digest easily. For scaling up, we are dividing the material into “bite-sized” pieces, for example, (a) write-ups on EarthKAM images grouped by themes appropriate to middle school curricula, (b) procedures for a 45-minute class on introducing students to images, (c) detailed instructions on how to find and print images, and (d) fun challenges involving images written specifically for student audiences.

Also, as we scale up, almost all EarthKAM materials will be available exclusively on the Web. Some of these materials, such as the interactive tutorials, take advantage of the capabilities of the Web; others simply use the Web as a means of extensive distribution. Although this web distribution option may not be feasible for many projects, it makes sense for EarthKAM, which

already requires reliable web access for participation, and it dramatically reduces the costs and difficulties of distributing materials.

Accessibility is more than just having the materials and resources available to everyone. It is tailoring these materials and resources to help participants successfully move into the program. By supporting participation at the Public Level, we reach many more people, have a greater impact on learning, and help middle school teachers and students develop the skills they need to become more involved.

Community Level: Becoming More Involved

Successful entry into a program is important, but greater involvement is necessary to yield richer learning opportunities. Again, by layering the challenges involved in a program, teachers and students can more easily move further into it. As they develop the necessary skills and interest, new opportunities and support need to be provided.

The Public Level, a worthwhile experience in and of itself, also serves middle schools as an entryway into the Community Level, which demands more of learners in terms of image analysis, inquiry, communication, and web use. The Community Level builds upon the learning that occurs in the Public Level. Middle schools that believe they are ready for a greater commitment—and for greater rewards—can apply to join the EarthKAM Community.

At the Community Level, schools move beyond preliminary image explorations into conducting EarthKAM Investigations—explorations using EarthKAM images as a source of information and inspiration for inquiry learning about a topic appropriate to the school's curriculum. Teachers who apply to the Community Level are asked to demonstrate that they are already familiar with the EarthKAM



The author looks on as two EarthKAM students select possible areas of the Earth to photograph.

images and how to incorporate them into the classroom. Thus, the process of applying helps alert schools to the preliminary experiences and skills they will need as part of the Community.

Schools that are accepted to the Community Level are being told “You know enough about using EarthKAM images and are ready for greater involvement. You can become part of a community of educators, students, scientists, and others who use EarthKAM images as powerful educational tools.” Participation at this level involves more in-depth exploration of images, the submission of Investigation Plans and projects online, remote communication with other teachers, students, and scientists, and submission of image requests to schools at the Flight Certified Level. Thus, there is a progression of what is being asked of the teachers and students. And as more is asked, more support is provided.

The support takes several forms. The communications that happen within the Community can be a challenge, but they are also a means of support. As the teachers talk, they learn from and support each other. Also, the EarthKAM team—educators, scientists, and specialists—is part of the Community. The team runs online

workshops, hosts chat sessions, responds to questions, and develops new support pieces as the Community finds gaps or identifies unanticipated opportunities.

Professional development is a vital part of any scaling-up effort. As more teachers join a program, less and less personal support can be provided. At the same time, a greater number will be neither early adopters nor comfortable with authentic, inquiry-based programs such as EarthKAM. Therefore, more support is needed just when support becomes more difficult to provide.

The time and labor limitations of in-person workshops mean that we need alternatives. The EarthKAM team is designing workshop materials for use by all, in an effort to further enable teacher training and professional development. These materials are the preparations, procedures, and support pieces needed to conduct workshops on exploring EarthKAM images, planning an EarthKAM Investigation, and so forth. They will be available to everyone, including NASA education specialists, science coordinators, experienced EarthKAM teachers, and local support institutions, such as universities or businesses. In many ways, the

challenge of providing professional development is the challenge of scaling up.

Flight Certified Level: Taking Charge

With deeper involvement in a program comes increased responsibilities and opportunities. In order to succeed, a scale-up must incorporate self-supporting mechanisms into its design to achieve as much sustainability as possible.

As a final step in the progression of involvement in EarthKAM, middle schools at the Community Level are able to qualify for the Flight Certified Level. Having worked with images and conducted investigations, these schools can now take on leadership roles, helping to support all the other schools at the Community Level. The experienced teachers are used as resources; they act as mentors, making successful participation in a growing Community Level possible.

And as a motivator to engage very busy teachers in these additional responsibilities, participation at the Flight Certified Level means direct participation in NASA space missions! This involvement requires even more extensive use of the Web and the learning of new targeting skills, but Flight Certified schools have the opportunity to take their own images of Earth!

Moreover, this exciting opportunity will soon be accessible to many more schools when EarthKAM relocates its camera from the Space Shuttle to the International Space Station. This move offers six reliable “missions” a year with four days of targeting in each mission. In the past, EarthKAM flew approximately one Shuttle mission a year, with up to 100 schools participating in a mission. So at the very minimum, with six “missions,” EarthKAM can support 600 schools per year at the Flight Certified Level. And while the realities of the camera, web servers, ground crew, and so forth do limit the number of schools that can participate, 100 schools per mission is undoubtedly conservative. The EarthKAM team anticipates that hundreds of schools will be able to participate directly at the Flight Certified Level and thousands more indirectly at the Community Level.

Scaling up is not necessarily about making all aspects of a program accessible for everyone. Instead, the task is to be very clear about the challenges—and benefits—involved with each aspect to enable thoughtful and successful participation. For EarthKAM, this translates into supporting three levels of participation and being very clear about the requirements and rewards of each level. Participation is scaffolded in such a way as to make the program successful regardless of the level of involvement. The idea is

to provide multiple levels for program participation, layering the challenging elements to help students and teachers be successful and move forward.

Will Scaling Up Work?

The EarthKAM team is thinking and planning large, envisioning thousands upon thousands of schools participating from all around the world. But will this scale-up work? Honestly, we do not know. We know the challenges we face and have plans for tackling them, but we will learn of problems with our plans and of new challenges only as we move forward. Just as the space program moves forward by setting clear goals and fine-tuning their initiatives, so too will we need to fine-tune the EarthKAM program as we strive to reach our goal of large-scale implementation.

How does a program that succeeded with a handful of schools reshape itself to address its real audience—as many students and schools around the world as possible? With great care... and great boldness. ✨

Teon Edwards is a curriculum developer for several projects in the Center for Earth and Space Science Education (CESSE) at TERC. For EarthKAM, she coordinates the investigation process, supports schools, and is preparing educator guides. teon_edwards@terc.edu

EarthKAM is funded by NASA, contract # NCC5-257. The EarthKAM team is lead by the University of California at San Diego (UCSD) and includes NASA Field Centers (especially the Johnson Space Center and the Jet Propulsion Laboratory) and CESSE at TERC.

Get Involved...

Join EarthKAM

NASA EarthKAM is now open to new participants. At the core of the program is a spectacular collection of digital images of Earth; these images were taken by select middle schools using the World Wide Web to control a camera flown on the Space Shuttle. Everyone is invited to access these images and the learning resources available at www.earthkam.ucsd.edu. And middle school (grade 5–8) educators are invited to join the EarthKAM Community—a community of educators, students, scientists, and others who explore EarthKAM images as powerful educational tools.



FACING EQUITY: FACING OURSELVES

By Fred E. Gross

school faculty in a dialogue about equity.

This is no easy task. In workshops I facilitate, I ask educators to define equity. Often after what appears to be a quick start, educators have difficulty agreeing on a definition. Initial responses include thinking about all students, equal opportunities for all students, and equal access to course work for all students. Probing further, I ask

what *all students* and the term *equal* means. The discussion usually becomes more entangled as participants debate whether there is a difference between equal and equitable. For some, equitable means the same practices, while for others the emphasis is that the practices are fair for each student.

Do we believe our own definitions?

Although workshop participants cannot agree on a definition of equity, they usually agree that their behaviors and actions are equitable. When asked to affirm or deny the statements, “I treat everyone the same” and “I don’t see color in my classroom,” most participants nod in agreement.

Current research reveals the very different ways educators treat groups of students. For example: “Teachers initiated significantly more mathematics interactions with males than females” (Fennema & Peterson as cited in Grayson & Martin, 1997, p. 24), “When they gave correct answers, males were praised more frequently than females” (Good & Brophy as cited in Grayson & Martin, 1997, p. 25).

When I present these and other research findings, educators are often surprised, question their accuracy, and assume that the research is not relevant to what is happening at their school.

Workshop participants may say that they treat every student the same, but further questioning typically reveals

that they mean they treat students fairly. For example, one participant commented that a system of grouping or tracking students is necessary because the potential MIT student and the potential bagger at a local grocery store cannot be taught in the same class. The justification for tracking reveals how core beliefs result in schoolwide policies and procedures.

At first educators may not see the potential conflicts in their stated beliefs. In the previous example, the educator views the practice of tracking as fair and believes it supports the goal of meeting each student’s educational needs. As the dialogue continues and the group begins discussing the ways they identify those students who may or may not be college bound, participants may begin to see how their beliefs and actions conflict with their well-meaning definitions of equity.

When examining equity issues in schools, it is important to ask whether we really believe our definitions of equity. And if so, why do inequitable situations—policies, practices, and procedures—still occur in our schools? The search for answers takes a willingness to look deeply at our personal beliefs.

Facing what we really believe

The deeper conversation about equity is often avoided because many people are uncomfortable with disagreement, especially if it is loud and passionate. When I ask participants to describe their initial group interactions when trying to define equity, they respond with words such as cerebral, polite, difficult, pleasant, and thought provoking. However, they acknowledge that exchanges become more intense as people express and defend their views. Participants voice their discomfort with the more passionate tone of the discussion, and some withdraw from the conversation.

Many people feel that emotions interfere with the sharing of ideas and therefore attempt to keep them out of

Why are female and minority students not taking courses in mathematics and science? Lucretia Crocker, an educational reformer and former member of the Boston (Massachusetts) school committee asked this question nearly 100 years ago. Her question persists.

Given the current cries for accountability in education, it would seem reasonable to question why certain groups of students are not performing well in math and science. States and districts are investing heavily in standardized testing to measure student achievement and to determine how well schools are educating students. Despite this effort, are we really examining whether we are accountable to all students? When we look at performance data do we ask, are all students making improvements? Schools typically report their aggregate data which do not tell the whole story. When we begin to disaggregate the data, we may find that while the average scores have gone up, there are groups of students whose scores are declining.

What are we doing to cause inequitable outcomes? Are we creating policies and programs based solely on assumptions about certain groups of students and their potential to learn? One way to uncover underlying assumptions and beliefs is to engage

the conversation. They rely on more intellectual and less emotional approaches to the dialogue. This is not always the best course of action.

New research and insights on the role of emotions are destroying popular assumptions that emotions cloud logic. Damasio (1994) observes that ‘an important [and erroneous] aspect of the rationalist conception is that to obtain the best results, emotions must be kept out. Rational processing must be unencumbered by passion.’ Emotions, says Damasio, are actually indispensable to rational decision-making. (Hargreaves & Fullan, 1998, p. 52)

When conversations occur in which an individual or a group of people is either purposefully or accidentally left out, emotions will surface. Talking about equity is an emotional experience. A friend and former colleague, Manuel J. Fernandez, offers this caution, “Don’t confuse passion for anger.”

There is a price to pay when we choose to gloss over or avoid uncomfortable or revealing conversations. The high price can be found in school communities where stereotypes with negative implications are unjustly placed upon students and certain voices are not heard.

In her work with college-age students, Dr. Jean Wu has documented how certain groups of students describe the way their racial identity shapes their school experiences. She identifies themes that come from students’ reflections on their middle and high school years. White European American students commented that there was an absence of race in their lives. Black / African American students remarked that they were always seen as inferior and not welcomed. Latino / a students felt “alien” and lost between black and white. Asian students remarked that they were viewed as the enemy and confused

with Asians overseas. Native American students felt absent altogether. Many students felt they were not represented in the curriculum.

The consequence for not beginning the dialogue is identified further by Dr. Beverly Daniel-Tatum in her work on anti-racism. “As a society, we pay a price for our silence. Unchallenged personal, cultural, and institutional racism results in the loss of human potential, lowered productivity, and a rising tide of fear and violence in our society” (1997, p. 200).

Passion and emotion are the vehicles that help individuals identify their beliefs and prejudices. In turn, *feeling* the beliefs is a doorway towards greater self-examination and change in thinking and practice.

Starting the dialogue

The best way to deal with what’s out there is to move toward the danger. (Hargreaves & Fullan, 1998, p. 67)

What then are some methods for promoting an in-depth dialogue about equity? Here are two strategies that illustrate ways to create a more meaningful exchange.

One activity focuses on stereotypes wittingly and unwittingly promulgated in the classroom. Around the room, a facilitator hangs labels for a type of student—Hispanic female, special education, active male, overweight—and asks participants to write their reactions on stickie notes and place them around the labels. The whole group reviews the collection of comments.

The reactions from a session with nearly 200 educators revealed many assumptions and beliefs that affect how students are treated.

- Hispanic females were often viewed for their physical features and social life rather than for their intelligence.
- Asian students were all seen as smart and grouped together. There

was little understanding of the difference between Asian-American students and students from Asia.

- Black males were noticed for their brawn and not their brains.
- Active boys were identified as having an attention deficit disorder, yet, when questioned, not a single participant said they had the training to make such a diagnosis.
- Doctors’ daughters were stereotyped as spoiled, rich, academically driven and entitled.
- Overweight students were viewed as lazy and full of excuses.

In this activity, it is important to allow the emotion or passion to flow out and to acknowledge and not invalidate the feelings of each individual. In one instance, a woman was describing her perspective about girls’ experiences in school and what those experiences meant to her. A male participant jumped on the description, stating that it was “wrong!” As the facilitator, I asked him how he knew that he was right and, more importantly, what were the consequences of his invalidating the experiences of another person. This raised the level of anxiety and emotion and was a chance to demonstrate to the group the importance of working through issues rather than avoiding them.

The opportunity to discuss their beliefs was cathartic. Although many participants may not have been proud of their comments, it took courage for them to acknowledge their real feelings associated with stereotypes. The process helped participants acknowledge the feelings of their colleagues who deal with labels and negative stereotypes every day.

A second activity clarifies opinions or positions. I push participants not to settle for their initial responses but to question and examine their thoughts and beliefs. I pose the fol-

lowing statement to the group and ask for their reactions: Teachers have white, middle class behaviors and goals in mind when they think of their ideal student.

In one session, the group had the following responses:

While you wouldn't want to, you buy in.

The middle class is the middle class. Why are we using "white?"

Teachers have skills that they want to impose on others. We don't have teachers who can't do these things well—reading, literacy—so they don't know what to do with those who don't do these things well.

They are such narrow skills that we value—they lack diversity. Sometimes even as a woman—a white middle class person, but a woman—I can't succeed in the skills.

I wanted to see if all voices were heard and had the same view, so I asked the people of color in the group to give their reactions to the statement. This is what they revealed to the entire group:

They (teachers) need to be educated—walk the talk, seeing is believing.

I wholeheartedly agree that there is an ideal student and rarely is that student the person that's sitting in certain classes.

... And when it is it's because that person has absorbed all the white, middle class values. Or can display them in that setting.

I come back to diversity, being able to understand the need for all children to be different and not mirror one standard. A person, even though different, can aspire to very high goals and expectations.

I think its also validating what children and faculty of color have to say and not making the white view the only one with value.

The responses showed a different experience. By not asking all participants or constituents for their reactions, we limit our understanding of the underlying complexities of equity. When you ask a constituency for their

views, the group as a whole is forced to listen and acknowledge different perspectives.

Once these beliefs or impressions become public, the important work is to identify where they come from and how they are affecting student achievement. The work is not risk free! Examining deeply held personal beliefs and acknowledging them is where we face equity. As one recent workshop participant acknowledged, "This equity work, it is about our personal beliefs!"

Proceed with care

Facilitating an emotional dialogue is complex and difficult. It requires patience, perseverance, and excellent communication skills in order to ensure that everyone is heard and that the group adheres to agreed upon goals.

When the group dynamic intensifies, ask the participants to clarify their statements and reflect on how a particular idea, thought, or belief affects them. The following questions can help keep the group focused.

- What would that point be like for other members of the group?
- How many of you agree or disagree with that statement? Why?
- What do you think that point would be like for your students?
- What does that mean to you?
- How does that feel to you?
- Do others in the group feel the same way?

Group rules create a safer environment for examining feelings and beliefs. Participants must own their behaviors and opinions. Therefore, when stating beliefs or offering opinions, each member should use an "I" statement, for example, "I feel this way, because..." or "I disagree because...." These statements show ownership and respect for others in a group.

Participants should also use their own personal stories and not the stories

of other people. In this way, they are involved in the conversation on a more personal level. To encourage full participation, people should sit in a circle, so that they can see each other clearly. Don't let anyone sit behind another person.

"Equity is about making the invisible, visible."—Mj Terry, a math and equity specialist

Engaging school faculty in a dialogue about equity is difficult, but necessary if we are to identify the beliefs that are shaping many school policies and practices. Policies cannot be based on false assumptions. Educators must confront their personal beliefs and examine how they are affecting students' lives and student performance. As James Baldwin wrote so succinctly, "Not everything that is faced can be changed. But nothing can be changed until it is faced." ✨

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LIGHT ENERGY for LIFE — On Earth and Other Worlds?

Part of the mission of TERC's Center for Earth and Space Science Education is to transform science education from "reading about science" into an engaging process in which students "do science" by investigating the world around them. As part of this effort, TERC seeks out questions and fields of study that engage students' interest in science and provide opportunities to experience science as scientists do—not as a set of accumulated facts but as a dynamic and, at times, confusing and amorphous set of speculations. Faced with intriguing and relevant questions, students can become the scientists themselves.

TERC and NASA are developing a curriculum that asks middle and high school students to consider some very profound and exciting questions: Is there life elsewhere in the universe? What is life's future on Earth and beyond? How did life originate on the Earth? In this emerging field of astrobiology, the search for life on other worlds, students have a fertile

domain in which to struggle with fundamental questions of scientific knowledge. They can observe and experience how a knowledge base evolves through the addition of new data and the emergence of new means of understanding data. They can learn about, explore, and participate in the real processes of science research and discovery.

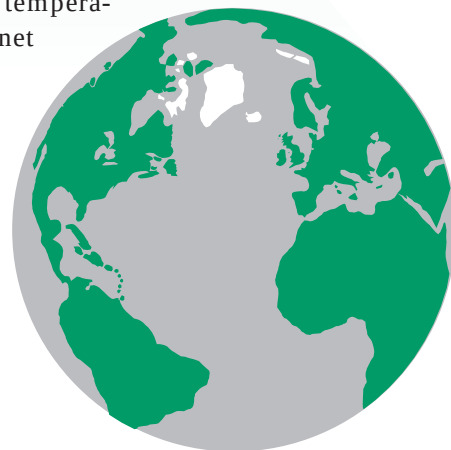
Looking for Pilot and Field Test Teachers

TERC is looking for middle and high school teachers to review, pilot, and field test materials from **Astrobiology: The Search for Life on Other Worlds** in the Spring and Fall of 2000. This is a unique opportunity for teachers to help shape and inform an innovative, interdisciplinary curriculum. TERC values the experience and input of thoughtful practitioners and will provide stipends for participants. Opportunities include pilot testing the Habitable Worlds module and other sequences from the curriculum (March-May 2000), field testing complete units (September-December 2000), and reviewing and providing feedback on units (March-December 2000). If you are interested in participating as a pilot test or field test teacher or as a reviewer, contact brian_conroy@terc.edu.

Astrobiology: The Search for Life on Other Worlds, a full-year high school course, allows students to explore diverse concepts in chemistry, physics, biology, Earth and space science, and engineering through a series of inquiry-based activities. Topics integrated throughout the course include the structure of the universe, the geologic history of planets, the chemical foundations and nature of life, biological diversity, and the use of remote-sensing instrumentation. Students develop research skills including modeling, setting up experiments, testing hypotheses, making systematic field observations, and doing image and data analysis.

The activity on the next page, Light Energy for Life, illustrates how this curriculum helps students experience the connections among physics, chemistry, biology, and astronomy. It is taken from the Habitable Worlds unit of the curriculum, which asks the question, what makes a planet or moon a good home for life? Students investigate why there is life on Earth yet no life on its nearest neighbor, the moon. Examining this question enables students to explore the roles of atmosphere, temperature, water, energy, and chemical building blocks in making a planet suitable for life.

Light Energy for Life focuses on a key factor important to habitability, an energy source. Students investigate a specific type of energy, light, and how it is important to some forms of life. They design and test an experiment to demonstrate how the proximity of a light source affects photosynthesis and discuss how their results reflect on the importance of a planet or moon's distance from the Sun.



LIGHT ENERGY

This activity demonstrates how, in a context such as astrobiology, a familiar and even traditional activity can generate questions not typically raised in a conventional course. This new context also helps students see how their classroom experience can connect them to one of the most intriguing endeavors of our time, the search for extraterrestrial life.

Materials

For each student team:

One sprig of Elodea

Test tube

Test tube rack or way to support test tube

Water (pond or dechlorinated water)

Light source (50-watt plant light is best)

Student Background Sheet (page 14)

Time

One 55-minute class period

Figure 1—Cut the stem near the bottom and crush it a bit. Place the plant with the stem up in a test tube and cover it with water.



Introducing the Activity

Being on a planet the right distance from the Sun is important to organisms. Students will demonstrate this idea by designing an experiment that shows how important to photosynthetic organisms. Students will investigate the rate of photosynthesis in a common water plant found in aquariums. Oxygen is generated by photosynthesis and is coming off of the plant. The students' experiments should show that the greater the light source, the more oxygen (bubbles) is generated. Students should be familiar with light (how the intensity of light varies relative to distance from a light source).

Before You Begin

Before class begins, set up a test tube of Elodea plants with a light source (s). Observe that bubbles are given off. You will use this demonstration to begin the activity and light intensity.

Decide how you will divide your class into small teams to design and run the experiment. Each team should have a sprig of Elodea, test tube, test tube rack, water, and light source.

Procedure

1. Photocopy and distribute the Student Background Sheet. Ask students to think about how important to an organism that uses light for energy. Try to draw out as much as you can regarding what they know about photosynthesis and how light intensity affects the process.
2. Show students the Elodea demonstration at the front of the class. They should observe bubbles coming off the plant to the light source and photosynthesis reaction.
3. Divide the class into small teams that will work together to design their experiment.
4. Outline the challenge for students—to design an experiment that will show the importance of light intensity to photosynthetic organisms. Demonstrate how to vary light intensity and discuss some ways that they can vary light intensity. The most obvious way is to move from the light source, though some creative kids may start to consider blocking light.
5. Ask each team to create a hypothesis, or possible explanation, that they can test. Have them write their hypothesis as an “if...then...” statement.
6. Remind students to write down the procedure, or step-by-step instructions for their experiment and testing their hypothesis. They should also create a data table.
7. Once you are confident that they understand the process, let them design their experiment.
8. When the teams have completed their tests, have them graph their results. Use the results to support their answers to the following discussion questions.

Thinking About It

1. Did you prove or disprove your hypothesis?
Students' hypothesis should be something like, "If the light source is closer to the Elodea, intensity will be greater, then the rate of photosynthesis should increase, and I will see more bubbles." Proving or disproving their hypothesis will depend on their experimental set-up.
2. How does intensity of the light source effect the rate of photosynthesis?
Students should observe that the closer the light is to the plant the more bubbles they should see. The more bubbles, the faster the rate of photosynthesis. You can have students attempt to quantify the amount of oxygen produced by encouraging them to modify their experiment to trap the oxygen and determine its volume.
3. Since the surface of the Earth is a set distance from the Sun, and therefore intensity won't vary according to the inverse square law, are there other ways that the intensity of light energy might change?
Intensity can change due to filtering or blocking of light by the atmosphere or water.
4. Do your findings on how light intensity can effect Elodea provide any insights into the possibility of photosynthetic organisms on other worlds in our solar system?
Worlds that are farther away from the Sun than the Earth may receive too little light to power photosynthesis.
5. The moon is about as close to the Sun as the Earth is, and therefore the intensity of light should be similar. Would you expect to find organisms that depend on photosynthesis on the moon? Explain your answer.
If light intensity was the only factor that influenced habitability one might expect photosynthetic life. But the lack of liquid water and atmosphere are greater limiting factors than the intensity of light.
6. Why does Elodea make glucose?
Elodea converts light energy into chemical energy that can be used by the plant's cells.

This activity is part of a chapter on Energy and Essential Elements. Students will go on to examine chemical sources of energy, respiration processes, and the relationship between respiration and photosynthesis. The chapter also investigates how energy relates to the essential elements that are required by life on earth. If you would like more materials to continue the explorations begun in this activity, email brian_conroy@terc.edu.

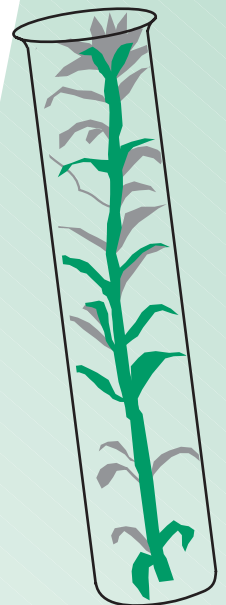
For more information about the *Astrobiology* curriculum, or to preview other materials and activities, visit astrobio.terc.edu or write to jeff_lockwood@terc.edu.

Student Background Sheet

After water, an energy source and certain essential elements are likely the most important factors that influence success or failure of life on a planet. Why is this? In one sense, the answer is simple. A successful organism is one that gathers enough energy and raw materials to allow it to grow and reproduce. Think about some of the organisms that live on the surface of the Earth. What energy sources do they depend on that help them to be successful? Your understanding of life on Earth begins to let you ask questions about what other worlds have to offer in terms of energy that may make them habitable. For example, how many different sources of energy does life take advantage of on Earth? Which of these energy sources do you think are most likely to be present and available to support life on another world?

Using Light Energy

Being the right distance from the Sun may be important if you are an organism that depends on light for your life processes. Review what you know about the inverse square law of light (the intensity of light on an object varies relative to the distance of that object from the light source). Is the intensity of light from the Sun really that important to an organism that uses light as an energy source? In this activity you will design an experiment to find out. Your experiment will look at the rate of production of a product of photosynthesis as a measure of the effect of varying light intensity.



Photosynthesis



Photosynthesis is the process by which plants and some microscopic organisms use energy from the sun to make their own food. Glucose, a type of sugar, is the food that is made in photosynthesis, while oxygen is a byproduct that is released as a gas into the environment.

Try Science Online!



**A new inquiry-
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educators**

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the Lesley/TERC program, visit
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For registration information, contact
Donna Robillard at 617-349-8202
or drobilla@mail.lesley.edu

Program staff: Susan Doubler,
Linda Grisham, Nathan Kimball
and June Siple

A glass of ice water sits on the desktop. Normal enough, or is it? Participants of Try Science, a new online science education course, discover the glass holds many secrets and provides insights into the consequences of global warming. This graduate level course for K–8 teachers is the result of a partnership between Lesley College and TERC and was developed with funding from the U.S. Department of Education Fund for the Improvement of Postsecondary Education (FIPSE).

Aligned with the national science standards, this course:

- ◆ **supports professional learning through a combination of offline and online activity,**
- ◆ **provides rich science content and the experience of inquiry learning, and**
- ◆ **supports teachers in integrating science processes, new curricular strategies, and web-based technologies into their science teaching.**

Try Science participants build deep understanding of key science concepts by using hands-on investigations as a context for online discussions with colleagues. The course helps participants to develop and try out a model of practical and effective inquiry-based science teaching in their own classrooms. Based on their experiences and discussions in the virtual environment, participants develop strategies for furthering their students' understanding of science through investigation.

Participants' science learning starts with investigations of buoyancy, density, phase change, and the transfer of energy studied in a desktop laboratory of a glass of ice water. As they are learning fundamental concepts together, participants apply their knowledge to constructing an informed opinion to an important and timely scientific and social question: What are the effects of global warming on ice in the polar regions? Course participants examine polar ice data, relating what they've learned from their own "desktop oceans." They have access to the latest ideas and research via the Internet and meet scientists online who are engaged in polar ice research.

Teachers develop new understanding of investigation-based science and teaching as they focus on their own inquiry and science knowledge and debate understandings with colleagues. Dr. Linda Grisham, science faculty member at Lesley and co-author of the FIPSE grant, says, "Together in this course we investigate phenomena that researchers still find puzzling. Our objective is for teachers to experience the pleasure that comes from using science to understand natural phenomena." Adds her co-author, TERC project director Dr. Susan Doubler, "An inquiry-based approach is central to the course. This approach honors questions, yet requires participants to build explanations using central concepts identified in the national science standards."

Trying ideas in the classroom and sharing suggestions with other professionals easily becomes part of the coursework. In the final sessions, teachers plan inquiry-based lessons aligned with their school program and try these in the classroom, sharing and discussing their outcomes with other course participants.

Try Science is the first course in a new master's degree program under consideration by the Lesley College Board of Trustees. The College and TERC are co-developing the proposed comprehensive program in science education for K–8 teachers, curriculum specialists, and instructional resource persons.

Lost in Space

(continued from page 1)

Mars. The drill is designed to pull in a sample of Martian soil (less than 100 milligrams) and deposit it into a small cup. The cup, once sealed, is heated in order to turn any water ice in the soil into vapor. A laser is then directed at the vapor. Information from the laser analysis together with thermal conductivity information about the soil surrounding the penetrator provides scientists with the data needed to shed light on the structure and chemical make-up of the soil.

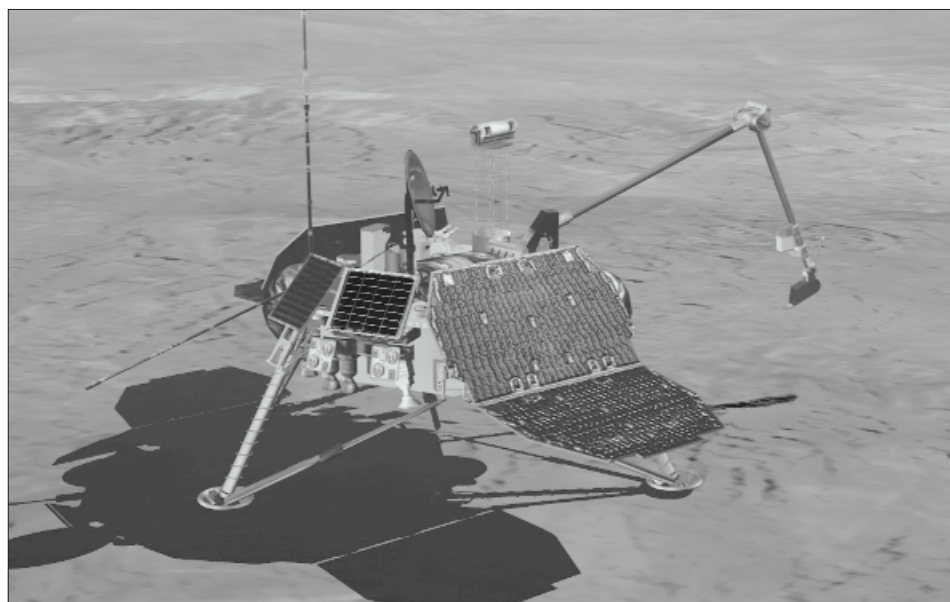
Finally, the probe sends the data to the Mars Global Surveyor, which relays the information back to Earth to the Malin Science Center (the group that handles all the image data from the Surveyor). From there the data are sent to the Jet Propulsion Laboratory where the Deep Space 2 team eagerly awaits the news.



Dr. Gavit with microprobe. “The fact that kids are watching what we are doing keeps me going.”

The Nature of Science

While waiting for the first signals and data to come in, I had the chance



The Mars Polar Lander with a robotic arm to dig trenches to collect soil samples. The composition of the soil could reveal clues to past climatic conditions.

to talk with two members of the Deep Space 2 team—Dr. Sarah Gavit, an engineer and project leader, and Dr. Suzanne Smrekar, project scientist. Their excitement and love for what they were doing was evident from the way they described the mission, the time and effort they had expended, and their hopes that the mission would significantly contribute to our knowledge of Mars. To get further insight into what brought these women to this moment, I asked them my “standard” inspiration question: “What excited you about pursuing science when you were younger?”

The answers to this question have always been important as they help me focus on what motivates kids to love science. These experiences are the essence of what I want to capture and recreate in the curriculum I design.

Without hesitating, Dr. Gavit responded, “When I was eight years old, watching the Apollo 11 mission and Neil Armstrong stepping out onto the moon!” She knew then that she wanted to explore space. That moment fed her desire to pursue science and engineering and brought her to this moment in time when she would contribute to our understanding of space. She added “Knowing kids are

watching what we are doing keeps me going.” Clearly she was hoping the day would be a defining moment for some child in the same way July 20, 1969, was for her.

For Dr. Smrekar, inspiration did not come from a historic moment, but from her first research project. She knew she wanted to be a scientist “when I realized I could figure out how things worked...to make a real discovery by doing an experiment.” Until that project, all the facts she had been memorizing in high school didn’t mean much. Experiential, hands-on learning had a significant influence on her life. Her desire to become a scientist was the result of a classroom experience that took her out of the textbook, beyond grades and tests, and into the realm of inquiry and discovery.

From these interviews, I was hooked. I had the same feeling I get when I work with students who are motivated and committed to a science investigation—when I see them engage and fall in love with science. I saw these two women not as the engineer and scientist of the moment, but as the two kids they had been. Young students learning that the nature of science is discovering for yourself the wonder and power of collecting data and using

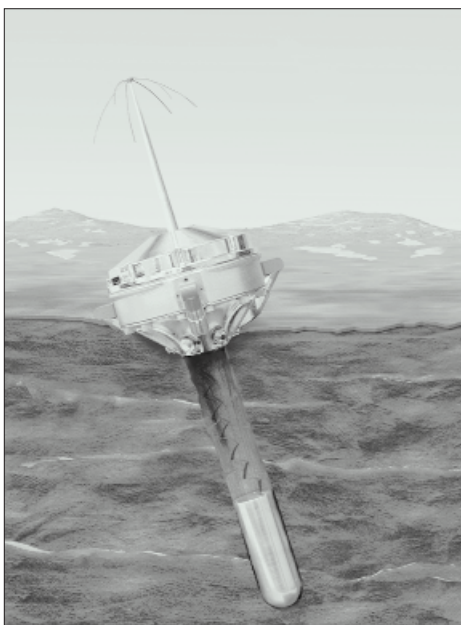
these data to explain your piece of the world. I was ready to watch and celebrate as these two women realized their childhood dreams.

And then the bad news started to come in.

Dealing With Failure

At a scheduled press conference we expected to get the first information sent by the lander. We were supposed to learn where the spacecraft set down, where the Deep Space 2 probes impacted and penetrated the surface, and when we would get pictures and significant data from the lander and probes.

The time to hear from the lander passed. I watched as the faces of the scientists and engineers lost the look of anticipation and registered concern. After 20 minutes of searching for a signal, they told us that no word at this time was not “unexpected” and that several things could have happened to delay first contact. The next attempt to contact the lander would be several hours later. I left the press-room feeling optimistic that the first data would be coming in soon.



Deep Space 2's twin microprobes were designed to smash into Mars, penetrate the ground, and conduct experiments to test for the presence of water ice in the soil.



Prototypes and final Deep Space 2 microprobe. The challenge of designing the microprobe reflects what good hands-on curriculum should be—applying science concepts and critical thinking skills to a relevant challenge.

Part of my optimism was fueled by the fact that there were two Deep Space 2 probes that communicated through their own telecommunication system via the Mars Global Surveyor. Many of the problem scenarios that were being considered for the lander had nothing to do with the probes. Adding to my optimism—I knew that the probes would attempt to contact the Surveyor about every two hours, while the intervals between the lander's attempts at contact would be much longer.

I eagerly attended each press conference expecting positive news. The scientists ran through “fault trees” of things that could keep the lander from “phoning home.” They approached contacting the lander in a logic-based, step-by-step manner that excluded one variable at a time. The scientists modeled critical thinking and problem-solving skills as they looked at a problem, collected all the facts known, and determined a course of action. All this took place on a stage where just a few

months before some of these scientists and engineers had lost another Mars mission due to human error.

After 24 hours the possibility that the Deep Space 2 project had failed became real. The probes' batteries could last only up to 40 hours. I began to frame a question for Dr. Gavit about what could be learned from the experience if the Deep Space 2 probes didn't establish contact. I didn't want to talk with her about this possibility, but I knew that eventually I might have to.

Still thinking of Dr. Gavit and Dr. Smrekar as students, I reflected on all the times I'd told my students that the real lessons, and some of the greatest discoveries in science, are often the result of failure. I know that this is not the view of science we usually project in our classrooms. With pressure to cover a wide range of content, we often give students the idea that science is about learning the facts and getting it right the first time. Students end up viewing science as a finite set of absolute truths, rather than a process of

continual questioning that depends as much on its failures as its successes to define what is known.

After a news conference where Dr. Gavit made it clear that it was unlikely we would hear from the probes, I realized I had to ask the question. I had to see if the perceived failure and the harsh judgements, sure to be heard if this mission were the second to fail this year, would affect Dr. Gavit's spirit. Would she still have the perspective of a student and be eager to explore and search for answers?

"Honestly, I don't see how both of the probes could have failed. I'm sure of the engineering and the design. Would I change anything about the design? At this point, no." She talked about the challenges of the landing site. An image of the probable impact zone showed that the probes could have impacted on the inside of a crater. This was more a matter of bad luck than bad design. Prior to this, best estimates had indicated the site was most likely relatively flat. The data she had did not point to a failure in design, but she wanted to see what future data would reveal. Dr. Gavit's answer assured me that her spirit had not changed. She was still applying critical thinking skills and looking for the truth of what happened. She wanted to learn from the experience.

Education Reform

It seems the mission failed. As of this writing it is not known what went wrong. The scientists and engineers are trying to sort through what they know. They have imaged the surface looking for a fragment of parachute, an impact crater, anything to help them understand the failure. They've attempted to track down weak signals that they hoped were a call for help from a badly crippled lander. Unfortunately that turned out to be a false hope. They are trying to learn, so that they can apply the lessons to the next mission. In fact, a new version of the Mars Polar Lander, with modifications

on this mission, is most likely going to be sent to Mars again.

What I learned from Dr. Gavit and Dr. Smrekar is that we need to continue to make science education more like real science. Curriculum should foster critical thinking and problem solving. Students need to inquire, experiment, and apply the information they gather to help them explain and understand their world. As teachers, we need to inspire students in the way that Dr. Gavit and Dr. Smrekar were inspired as young students.

My experience at the Jet Propulsion Laboratory brought into focus a fear I have about the consequence of some reforms that use high stakes standardized testing as the only way to improve student achievement and teacher accountability. To achieve higher scores, class time is dedicated to learning the facts and the set ways of applying those facts to solve specific problems. Giving students the experience and challenge of real world science is sacrificed when curriculum focuses on teaching to the test.

Reforms associated with improving scores on standardized tests often fail to let student and teacher revisit what is not understood. Too often they only provide a judgement of success or failure, not a grander lesson with reflection on what was learned. Other models of assessment, such as long-term experiments, exhibitions, and projects that generate data or a product for display and discussion, are more realistic. They are also more time consuming and difficult to quantify for those parents, administrators, and politicians who are looking for easy answers to complex problems. Just like figuring out what went wrong with the Mars Polar Lander and the Deep Space 2 probes, real understanding takes time. As teachers who embrace experiential and hands-on education, we recognize that our challenge is not getting our students to master the art of taking multiple

choice tests, but inspiring our students to care enough about something to risk failure. In the process their knowledge of the world—and worlds beyond—is expanded.

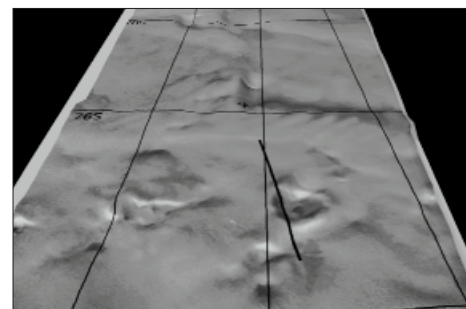
I turn to Dr. Gavit for the final word. I think she summarizes what our spirit of education should be and the type of student we should strive to create with our teaching. When she conceded that the \$28-million pair of probes were likely lost, she recalled the epitaph of Robert Falcon Scott, the polar explorer for whom one of the probes was named. She said that the spirit her team brought to the mission was: "To strive, to seek, to find, but not to yield."

This is the kind of student I would like to send out into the world. ✨

Learn more about the Mars Polar Lander and Deep Space 2 on the Web at marslander.jpl.nasa.gov/ and mars.jpl.nasa.gov/msp98/ds2/

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Images: courtesy of the Jet Propulsion Laboratory, page 1, 16, 17; courtesy of NASA/JPL/Malin Space Science Systems, page 18



The line represents the most likely impact area for the microprobes, which could have impacted on the side of this crater at an angle that would not allow their antennas to communicate with the Surveyor.

Viewpoint

(continued from page 2)

Seeking balance through mixed programs is dangerous because students can learn the steps in procedures much earlier than they can understand them. Frequently, these steps are forgotten, leading to the need to reteach the same procedures nearly every year of elementary school. Most educators know that teaching procedures without understanding doesn't work. However, the Massachusetts Mathematics Framework specifies that both must be taught in a particular window of time—without allowing for the careful development of all the elements that go into competent problem-solving.

Fluency: A New Kind of Balance

Several math curricula bring a different perspective to the idea of balanced instruction. Many of these programs, including one we have developed at TERC (*Investigations in Number, Data, and Space*), are funded by the National Science Foundation and aligned with the National Council of Mathematics Teachers curriculum standards. Our work on *Investigations* has led us to a new notion of balance that centers on the idea of fluency, and involves an interplay of three factors; efficiency, accuracy, and flexibility (Russell 2000). These factors are integral to learning all kinds of mathematical content, but we will illustrate them within the area of whole number computation. Consider this subtraction problem:

$$\begin{array}{r} 1002 \\ - 998 \\ \hline \end{array}$$

Here's the standard procedure often learned for solving it:

$$\begin{array}{r} \overset{0}{1}\overset{9}{0}\overset{9}{0}\overset{2}{2} \\ - 998 \\ \hline 4 \end{array}$$

If a fourth grade student solves the problem accurately by using this

cumbersome procedure, she is not demonstrating computational fluency. She has not made use of the obvious relationship between the two numbers in the problem. We'd like to see students (and adults) solve this problem mentally and quickly. The student should clearly see that 998 is 2 less than 1000 and that 1002 is 2 more than 1000, so the difference is 4. Such a strategy shows fluency with mathematics—a balance of efficiency, accuracy, and flexibility.

In the previous example, the numbers and their distance from each other provide a big clue about an efficient means of solving the problem. Efficient strategies are ones that can easily be applied to given types of problems after an examination of the numbers involved. They are not invented anew each time a problem is presented. Instead, fluency means developing robust strategies that work efficiently for different kinds of problems.

Accuracy depends on several aspects of the problem-solving process, among them knowledge of number facts and understanding of important number relationships (such as recognizing that 998 and 1002 are close to 1000). It also involves having a sense of the appropriate ballpark for the solution, keeping track of how one is solving the problem, and double-checking results.

Flexibility requires the knowledge of more than one approach to solving a class of problems. For second graders it is essential to know that subtraction problems can be solved either by starting with the smallest number and adding up or by starting with the biggest number and subtracting. They should also know that you can solve these problems by breaking them into sub-problems (such as $1002 - 1000$ and $998 + 2$ for the problem $1002 - 998$). Finally, a student who is mathematically flexible can always check her accuracy by solving the problem a different way, recognizing that there are many strategies for checking accuracy,

just as there are different ways of solving the problem.

Fluency can only be achieved if all three ingredients are taught and learned in concert. Focusing on fluency, rather than other forms of balance, can provide a strong sense of direction for educators. To the classroom teacher, it means that a mathematical idea isn't "covered," it is worked on over time until children have achieved efficiency, accuracy, and flexibility.

To math educators more generally, striving for mathematical fluency means that "scope and sequence" documents and Mathematics Frameworks must focus on the complexities involved in learning a mathematical idea. It is easy to say that balance is the solution, therefore we will teach procedures with understanding. If documents such as the proposed Massachusetts Mathematics Framework focus on the early mastery of procedures, we will inevitably lose the careful development of the complex, intertwined ideas about number and operations that all students should have the opportunity to learn. ✨

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- Russell, S. J. (2000, forthcoming). Developing computational literacy with whole numbers in the elementary grades. *New England Math Journal*.

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NEW Projects

Bringing Out the Algebraic Character of Arithmetic

This project is building a research basis for early algebra instruction. The research team at TERC and Tufts University is investigating how young learners express mathematical generalizations through natural language, diagrams, tables, and algebraic notation. The project documents learning issues which need to be considered in reforming early mathematics curriculum to exploit the algebraic nature of arithmetic, beginning with addition and subtraction. The classroom-based research program draws data from experimental classroom activities and clinical interviews with students. Findings will be made available in video-paper format (HTML documents with embedded video segments from classroom research) for future use by teacher education and curriculum development programs. Funded by the National Science Foundation.

Reopening the Science Door

TERC and Lesley College are developing an online science education master's degree program for elementary and middle school educators. The program, entitled Reopening the Science Door, helps participants to integrate inquiry-based science pedagogy and web-based information technologies into daily practices. Participants experience science as inquiries into the workings of the world and discover that online learning offers new opportunities for rethinking ideas about science and science in the classroom. Funded by the National Science Foundation. For more information, see page 15.

NASA Connect

Working with NASA's Marshall Space Flight Center, TERC is developing educator classroom guides to accompany two "NASA Connect" television broadcasts. The programs, for students in grades 4–8, feature the work of NASA's Space Transportation Program. The classroom guides present hands-on activities for teachers and students to carry out in conjunction with the broadcasts. Each guide features a different set of mathematical and scientific ideas to explore. Funded by NASA.

Students as Technology Leaders National Conference

In November 2000, TERC, Mass Networks Education Partnership, and Massachusetts Department of Education Youth Tech Entrepreneurs are hosting a conference to recognize outstanding student leadership and service learning models in information technology (IT). The first annual Students as Technology Leaders National Conference will encourage national awareness and accelerated implementation of service learning models that engage and motivate students, provide school technical support, promote civic good, and ensure IT workforce development. Invitees include diverse teams of students and teachers from around the country. Outcomes will include a database of exemplary student leadership programs, compilations of best practices, and IT program start-up kits. Funded by participating IT companies.

TERC Presents

AERA 2000

April, *New Orleans, LA*

Cynthia Ballenger, David Carraher, Andee Rubin

NCTM

April, *Chicago, IL*

Teresa Lara-Meloy, Ricardo Nemirovsky, Tracy Noble, Susan Jo Russell

NSTA

April, *Orlando, FL*

Jodi Asbell-Clark, Jamie Larsen, Jeff Lockwood, Chris Randall

TERC is exhibiting at NSTA. Please stop by booth #2141.

Astrobiology Science Conference

April, *Mountain View, CA*

Dan Barstow, Jamie Larsen, Jeff Lockwood

Educador 2000 Conference

May, *São Paulo, Brazil*

David Carraher

Astronomical Society of the Pacific

July, *Pasadena, CA*

Jeff Lockwood

Look for TERC's

NEW redesigned web site, coming this spring!

www.terc.edu

Resources by TERC

Available from
Dale Seymour Publications:

Developing Mathematical Ideas

Developing Mathematical Ideas is a staff development program designed to help educators think through the major ideas of K–6 mathematics and examine how children develop those ideas. The program helps teachers analyze the mathematics in a curriculum and learn how to define and select mathematical objectives for students. With increased appreciation for the complexity of student thinking, teachers become better able to ask questions that deepen children's mathematical understandings. In addition, teachers make mathematical connections for themselves.

Numbers and Operations: Building a System of Tens (Part 1); Numbers and Operations: Making Meaning for Operations (Part 2). Facilitator's Packages from \$59.95. Include Participant Casebook, Facilitator's Guide and Videotape. Components may be purchased separately.

Relearning to Teach Arithmetic

Two professional development packages, *Relearning to Teach Arithmetic: Addition and Subtraction* and *Relearning to Teach Arithmetic: Multiplication and Division* help teachers think critically about how their students develop understanding of whole number operations. Each package is designed for use by a group of teachers working together—preferably across grade levels—over several sessions. The packages provide many examples of students working on whole number computation, demonstrate how students build their understanding of the four operations, and offer shared experiences for discussion and analysis

so that teachers can consider the mathematical ideas central to understanding these operations

Addition and Subtraction package (2 videos plus guide): \$99.95; Multiplication and Division package (2 videos plus guide): \$99.95; study guide only (needed by each participant): \$8.95.

Ten-Minute Math: Activities and Games for Grades 3–5

This book is drawn from the K–5 mathematics curriculum, *Investigations in Number, Data, and Space*. In that program, suggestions for quick explorations known as “ten-minute math” are woven throughout the units to support and balance the in-depth work of each unit. In addition, the curriculum includes several math games that can be repeated often for skill-building work. This single, easy-to-access collection is a valuable resource for all teachers.

Available Spring 2000

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Earth-to-Orbit Engineering Design Challenges

This program is designed to help students in grades 6–9 learn math and science through carrying out hands-on engineering activities in their classrooms. Students are engaged in design situations similar to those faced by NASA engineers. The challenges develop the skills of careful observation, data collection and analysis, problem-solving, and communication.

Educator guides include materials for teachers, students, and parents; and provide career information and web site links for further investigation.

Thermal Protection Systems Challenge; Spacecraft Structures Challenge.

Available free of charge from the NASA Earth-to-Orbit web site, <http://eto.nasa.gov>.

Exploring Earth from Space: Lithograph Set and Instructional Materials

Exploring Earth From Space provides educators with the resources necessary to begin using space imagery in the classroom. The lithographs showcase color images of Earth taken from the Space Shuttle by astronauts and by middle-school students participating in NASA EarthKAM, a collaborative in which TERC is involved. The instructional materials include background information about the images and guidelines for teachers using them in the classroom, plus student sheets.

Available free of charge from the NASA EarthKAM web site, www.earthkam.ucsd.edu.

Global Lab: An Integrated Science Program

Global Lab is a full-year, interdisciplinary, introductory science course for grades 8–10. Using web technology, it introduces students to science as inquiry, engaging them in collaborative scientific investigations. Students choose a local “study site” for authentic, hands-on, integrated science explorations. They analyze their site from biological, physical, chemical, and geographic perspectives. The year begins with guided explorations, and culminates with extended investigations that students design and conduct themselves. The curriculum meets National Science Education Standards and major benchmarks, and was piloted over five years in 300 schools in 30 countries. The program consists of a curriculum

guide, five units (teacher's guide and optional student books), instruments and supplies, and a network membership giving each class access to the *Global Lab* web site. The web tools developed for *Global Lab* allow students and teachers to generate and edit web pages, enabling classes to publish, share, and peer review their findings just like professional scientific communities.

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Available Spring 2000

Mars Exploration Program: Is There Water on Mars? New Module!

Connect your students to the excitement and learning opportunities of NASA's mission to Mars through Mars education modules. The hands-on inquiry-based activities integrate Earth, physical, and planetary science and involve students in questions central to Mars research. The fourth module in the series, *Is There Water on Mars?*, investigates the role air pressure plays in maintaining liquid water, and students learn core physical science concepts and use them to deduce the water situation on Mars. They use evidence from their experiments as well as data and images from NASA's missions to Mars to argue whether Mars has (or ever had) surface water. Grades 9–12.

All modules include a Teacher Handbook and Student Image Set and are available free of charge from NASA's Mars Exploration Program education web site, <http://marsnt3.jpl.nasa.gov/education/>.

National Geographic Kids Network

The award-winning *NGS Kids Network* program has been revised and moved to the National Geographic Education web site. The first web-based unit is *Reduce! Reuse! Recycle!* (formerly known as *Too Much Trash?*) for grades

3–6. Additional units for elementary and middle grades will be available through 2000. The new program builds on its previous strengths by introducing web-based activities and resources that deepen and extend concepts presented in the curriculum units. New science literacy activities incorporate the language arts standards in addition to science and geography. The program will continue to use the NGS Works software and offers free participation, teachers guides, and related materials to teachers on the web site. Teachers guides, NGS software, and consumables may also be purchased for each unit as it is introduced.

For more information, visit
www.nationalgeographic.com/education.

Nortel Networks NetKnowledge Program

The *Nortel Networks NetKnowledge Program* is a four-semester networking course with curriculum and interactive hands-on projects providing students with the building blocks they need to design and manage local and wide area networks. It is designed for students in grade 11 and above to help prepare them for both employment in the networking industry and advanced studies in computer science, engineering and other related fields.

Nortel Networks

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fax (408) 495-2650
www.nortelnetworks.com/solutions/education/netknowledge/

Science by Design (formerly Design Science)

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 are keyed to the National Science Education Standards, the Benchmarks for Science Literacy, and the International Technology Education Standards.

Construct-A-Glove; Construct-A-Boat;
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Available Spring 2000.

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Using Data—Getting Results

By Nancy Love

Using Data—Getting Results: Collaborative Inquiry for Mathematics and Science Reform is designed to help school-based teams take a straightforward approach to using data as a tool for improving mathematics and science education. While the guide is tailored to math and science, the processes and tools can be applied to school reform efforts in other subject areas. The guidebook uses the process of inquiry to support change in four major areas: improving student learning; reforming curriculum, instruction, and assessment; overcoming obstacles to equity; and building critical supports, such as public support and quality professional development.

Includes a large collection of survey instruments and forms for data collection, analysis, and planning. 446 pp., \$45. Order by check or P.O. only.

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Carraher, D. & Schliemann, A.D. (2000). Lessons from everyday reasoning in mathematics education: realism versus meaningfulness. In D.H. Jonassen and S.M. Land, (Eds.); *Theoretical foundations of learning environments* (pp 173–195). Hillsdale, NJ: Erlbaum.

Carraher, D. & Schliemann, A.D. (in press). Is everyday mathematics truly relevant to mathematics education? *Journal for Research in Mathematics Education*.

Teaching Other People's Children: Learning and Literacy in a Bilingual Classroom has won the Outstanding Writing Award from the American Association of Colleges for Teacher Education. Authored by Cynthia Ballenger, staff member of the Chêche Konnen Center at TERC and literacy specialist at Graham and Parks School in Cambridge, MA, the book is a powerful account of her three years teaching Haitian children in an inner-city preschool. Ballenger writes as a teacher-researcher, exploring the literacy practices of her own students as she teaches them. The book challenges many widely held assumptions and cultural perspectives about the education of young children and the role of teachers in research and curriculum development. Available from Teachers College Press.

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Hands-On Universe Workshops

The Hands-On Universe (HOU) program is recruiting high school teachers interested in implementing the HOU educational program, in which students investigate the universe while applying tools and concepts from science, math, and technology. HOU is offering two types of professional development programs: week-long summer workshops with follow-up sessions during the school year; and distance learning sessions with self-paced study and online workshops. Teachers must have Internet and classroom computer access for the school year; must work with an evaluation team which is studying the effect of new professional development techniques; and will receive a stipend. Contact houstaff@hou.lbl.gov or visit hou.lbl.gov.

Investigations Implementation Institute

The Investigations Implementation Center is hosting an Implementation Institute, Planning for Professional Development and Leadership Development, July 17–19, 2000. It is designed for experienced teachers, staff developers, and administrators who play lead roles in supporting classroom teachers and

planning for professional development in schools and districts implementing the *Investigations in Number, Data, and Space* elementary mathematics curriculum. Participants will explore issues of implementation, review staff development materials, engage in model professional development sessions, and provide an opportunity to interact with other districts from across the country. Limited availability. Contact lorraine_brooks@terc.edu.

Investigations Workshops for Transforming Mathematics

The Education Research Collaborative at TERC offers professional development opportunities for elementary school teachers implementing the curriculum *Investigations in Number, Data, and Space*. Offered across the country, the five-day Level 1 workshops stress teachers' mathematics learning and focus on some of the roles they are assuming in classrooms as learners, researchers, mathematical leaders, and facilitators of mathematics learning. In addition, a three-day Level 2 workshop on Number and Computation is available for teachers who have already attended the Level 1 workshop or who have been using *Investigations* for at least two

years. Visit projects.terc.edu/investigations_workshops, or call Peter Swanson at TERC.

NSIP

NSIP, the NASA Student Involvement Program, is a national competition in Earth and space science for students in grades 3–12. Students use NASA resources in a series of investigations and design challenges. Competitions include Design a Mission to Mars, Watching Earth Change, Air and Space Journalism, Airplane Design Challenge, and Space Flight Opportunities. Submissions are judged by NASA scientists and educators; winners participate in a NASA-sponsored national symposium. Space Flight Opportunities finalists have their experiments launched and tested in space. Anticipated submission deadline: February 1, 2001. Contact www.nsip.net.

Online Scienceathon

Classrooms in grades K–8 are needed in early May to test one or more science challenges developed by TERC's cluster for Learning, Teaching, and School Partnerships. In this Online Scienceathon, each challenge engages students in problem solving, gathering and sharing data, using data to formulate explanations, and checking these explanations against the results of others. Contact judy_vesel@terc.edu.

For more Get Involved see page 7.



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