Hands On!

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TERC

Teachers as Educational Designers

by Harold McWilliams

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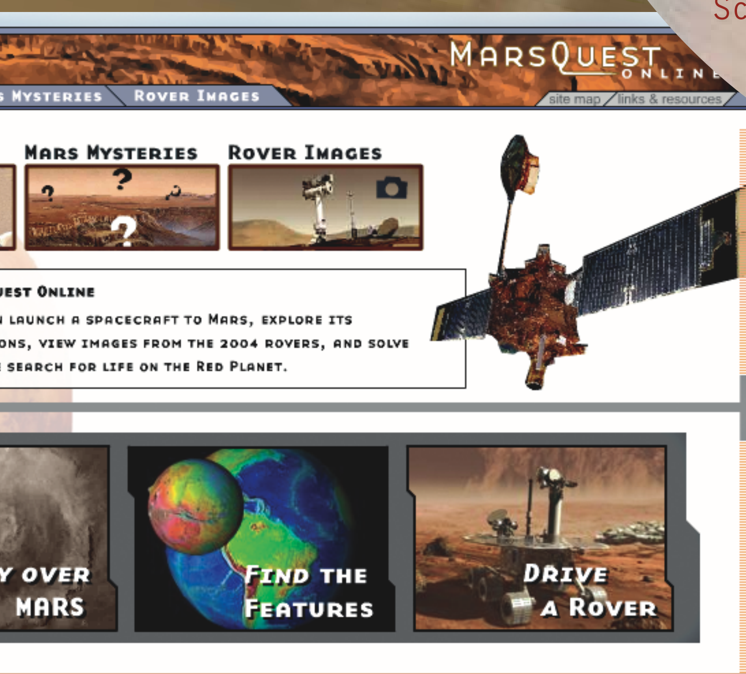
in this issue...

Be the First to Explore Mars!

The web site MarsQuest Online (www.marsquestonline.org) will allow people around the world to view interactive images returned by the Mars rovers, beginning shortly after the arrival of the rover Spirit on January 3, 2004.

The site, developed by TERC and featured in the Spring 2003 issue of Hands On!, will provide visitors with panoramic views of the Martian surface, along with background information that places the images in their proper scientific and educational context. The broadcasts are part of a collaboration between TERC, NASA's Jet Propulsion Laboratory, and the Space Science Institute. Don't miss this unique opportunity to explore our solar system!



Images courtesy NASA/JPS-Caltech

Editor's Note

Where's the science? The focus in recent years has been on improving students' math and reading skills. All this attention may be having an unfortunate impact on science as schools devote more resources to improving students' performance on math and reading tests, especially in the elementary grades.

This issue of *Hands On!* describes some of the ways TERC is working to improve the quality of science education. Our cover story details a new professional development program for middle school teachers of Earth science that is helping them acquire the skills to be educational designers. The author, Harold McWilliams, argues that teachers are already de facto designers, so why shouldn't they be empowered with the same methods as experienced designers? The skills they develop will also help them make better use of existing curricula.

In What's in a Model? (page 8), Brian Drayton encourages teachers to make the best use of the qualitative models that are so common in science curricula. His examination of models includes evaluating whether a modeling activity is conceptually valuable to students and warrants the class time needed for implementation. Good science curricula should enhance students' math and literacy skills as well. Launching Students' Curiosity (page 12) shows how one teacher has used NASA's Student Involvement Program to emphasize learning across all disciplines.

Science is and must be part of the core curriculum. TERC is working to keep the focus on improving science education.

—Kenneth Mayer, Editor

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Teachers as Educational Designers

By Harold McWilliams

"I am convinced that the ultimate reform of science education will only occur at the level of science classrooms."

Teachers working with the online unit planner at an ESBD Summer Institute

That view, clearly stated by Rodger Bybee in *Achieving Scientific Literacy* (1997), is shared by many educators who understand the critical role of teachers in implementing any curriculum or educational standard. When provided with the proper supports, teachers can change classrooms and create a robust science experience for all students. In the Earth Science by Design project at TERC, we believe that part of that support is helping teachers acquire the skills to be educational designers.

Some would argue that given everything else teachers must do, there is little time for them to design curriculum. We would contend, however, that teachers are *de facto* designers. If all classrooms and students were exactly the same, perhaps there would never be a need to adapt or modify a lesson, but we know that teachers often modify curricula to meet their students' needs. At conferences, on the Internet, and with colleagues, they look for ways to improve or augment a particular lesson or unit. Teachers do this, and we believe they can do it better if they are brought inside the design process. They should be empowered with the same theoretically based and empirically verified methods used by experienced curriculum designers.

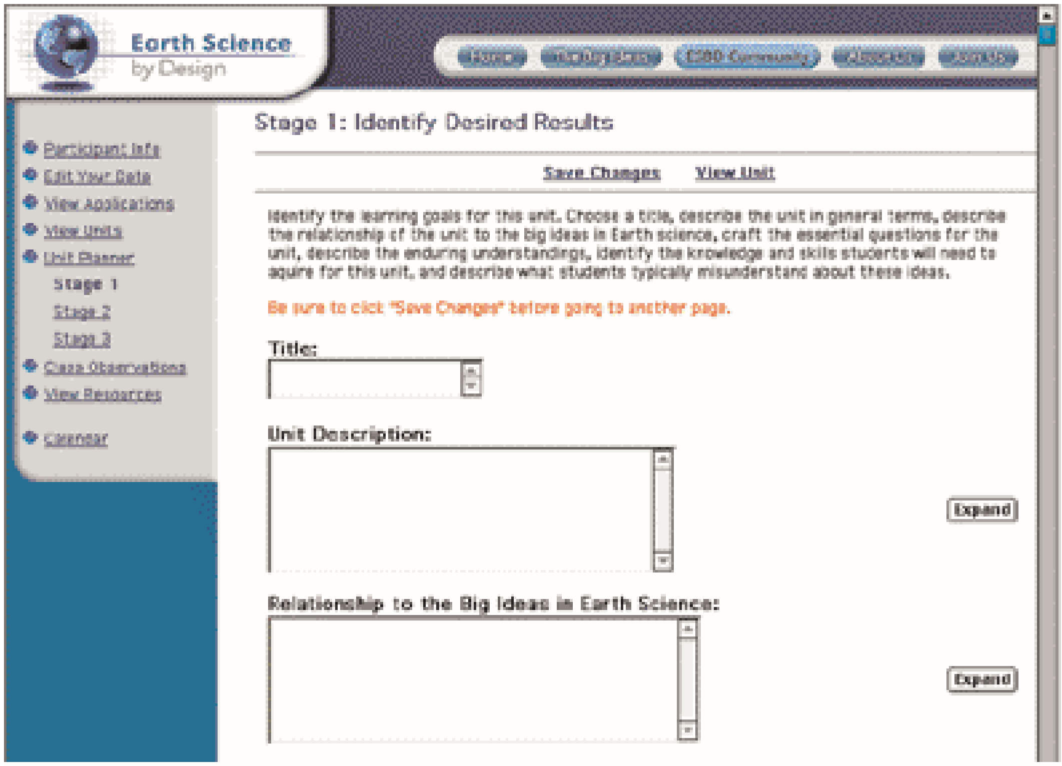
"No longer will I just look for activities that engage students. Now I have a purpose for each activity I teach."

—*ESBD Participant*

Becoming a Designer

Earth Science by Design (ESBD) is a year-long professional development program for middle school teachers who teach Earth science. The program begins with an intensive summer institute where each participant creates a curriculum unit following the Understanding by Design (UbD) framework developed by Grant Wiggins and Jay McTighe (1998). During the year they teach the unit and reflect on their implementation experiences, sharing their reflections with colleagues and project staff online and in person.

The program aims to help teachers become critical and reflective designers of learning. Participants begin by studying the Earth system science approach to Earth science so that they have a framework to organize new knowledge. They also study the UbD approach and use an online unit planner (designed for ESBD) to guide their work. They organize their unit around big ideas that capture the enduring understandings in Earth systems science. They develop essential questions to uncover these understandings and create performance assessments that motivate students to learn and allow them to demonstrate their understandings. To help the teachers design their units, the ESBD web site provides access to visualizations and other Earth science resources that teachers can weave into learning activities. During the institute, participants study how to identify visualizations and other resources that can help students develop skills and knowledge.



ESBD online unit planner

Using the Online Design Tool

During the first week of the summer institute, teachers are introduced to the UbD approach. They work in small groups to design a sample unit on the geological process known as the rock cycle using the planner as a guide. In the second week they work individually or in pairs to design the unit they will teach during the year.

The online unit planner (accessible over the Internet from any web browser) is a template that guides the teachers through the “backward design” process. A database stores what the teachers create. Only the author can change a unit’s content, but all participants can view it. In addition to being a guide, the planner is a collaborative tool for thinking about curriculum. All participants and project staff have access to each other’s units at each stage of development. We take advantage of this access to promote peer review and mentoring. Each teacher is paired with a mentor and another colleague who check in periodically to view changes and offer feedback.

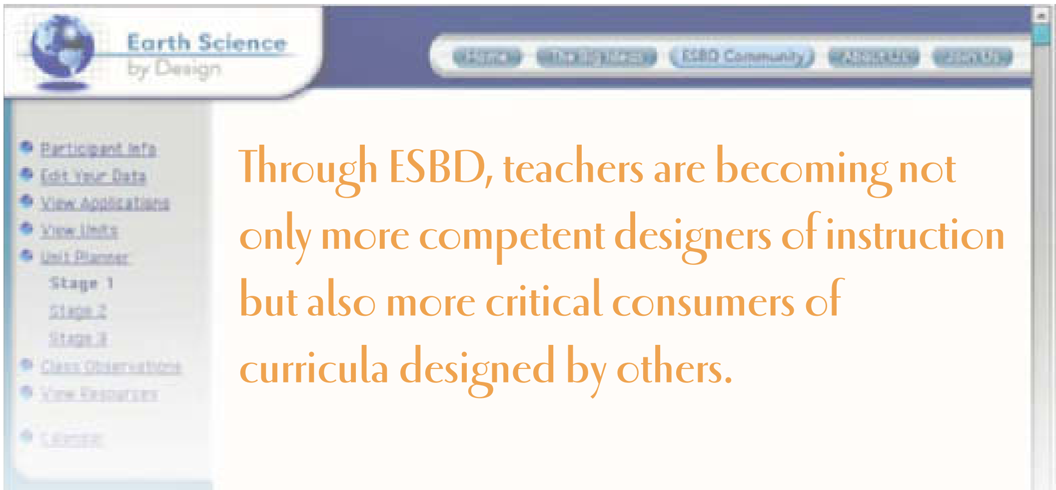
The Design Process

The unit planner lays out three stages of curriculum design, following the principles of Understanding by Design.

Stage 1–Identify Learning Goals

Stage 1 asks teachers to think hard about their goals for students. What are the enduring understandings students should learn and remember five years later? What are the essential questions that will help students arrive at these understandings? What knowledge and skills will students need in order to answer these questions? What do students typically misunderstand about these ideas?

Teachers often find this first stage to be difficult, frustrating work. They must delve into the science content in a way that allows them to determine what is essential knowledge. Their thinking cannot be superficial since they must clearly define what they want their students to understand. By establishing and recording detailed goals before thinking about activities, the teachers take the first step towards developing focused and coherent units. This process of identifying the specific skills and knowledge that students need in order to answer the essential questions helps teachers establish a



Through ESBD, teachers are becoming not only more competent designers of instruction but also more critical consumers of curricula designed by others.

clear rationale for each learning activity in the unit. After teaching the unit she designed, one teacher commented, "Because of this program I now know how to pull out the most important components first and use the Understanding by Design method to look at the bigger picture."

Stage 2—Design Assessment

An essential part of each unit is an authentic performance assessment with a rubric for evaluating student work. Grant Wiggins is fond of saying to teachers, "Think like an assessor!" Teachers must think about how they will know when students have understood. In our project, as in UbD, teachers move from setting the learning goals to designing assessments, deferring the creation or selection of learning activities for a later stage. We emphasize that each unit needs a suite of assessments which provide ample evidence that students understand the science content. For the students, the performance assessment serves both as a motivation to acquire knowledge and skills and as an opportunity to demonstrate deep and enduring understanding. The planner guides teachers through the process of constructing an authentic performance assessment. "I am so excited to be designing an authentic assessment. It has helped me to better understand what that looks like. I have done some in the past, but this one is so much more creative and clearly linked to the big idea," wrote a participant at the end of the program.

Stage 3—Plan Instruction

In Stage 3 teachers finally get to do what they usually do first—plan the learning activities. The difference, in UbD and ESBD, is that now each activity can be evaluated in terms of how it helps build understanding because the teachers have the framework to make that assessment. They have already determined the big ideas and the essential questions, identified the required knowledge and skills, and created a suite of assessments. We find that as a result of this "backward design" process teachers see activities in a whole new light. They are suddenly critical of activities that they formerly liked. No longer do they want to include activities merely because they "work well" or "are fun" or "kids like them."

The Results

For teachers, one result of their work is an Earth science unit they can teach. (These units will also be made available on the ESBD web site in a library of exemplary teacher-developed units.) An equally important outcome, we believe, is the change in teacher thinking and behavior that occurs. Teachers report that ESBD has changed how they teach in fundamental ways. And for many, the Earth system science framework has helped them organize their understanding of Earth and space science content. Reflecting on the program, one participant wrote,

> *It changed my way of teaching and designing curriculum. No longer will I just look for activities that engage students. Now I have a purpose for each activity I teach, it relates to something else. My students can see the big picture and make connections in their learning.*

Another participant comments:

> *It is a lot of work to make a unit in this way, but at the end the unit is more focused and better thought through. I feel it has been a huge help to me because it has altered my way of thinking.*

The teachers report a greater awareness of the organizing big ideas in Earth science and a heightened concern with teaching for understanding. Most report a greater appreciation for formative and performance assessments and state that they intend to use them more.

esbd.terc.edu

Ongoing Research on the ESBD Experience

As teachers design and implement ESBD units in their classrooms, project staff are mentoring and monitoring the process. The staff are studying the variables that play a role in a teacher's professional development. Through analysis of teachers' reflection responses, their written emails, their conversations with staff, and other available data, some themes are beginning to emerge. One of these is the effect of ESBD on a teacher's content knowledge and understanding. The process of structuring Earth science curriculum materials into an ESBD unit often causes teachers to rethink and deepen their content knowledge. By learning the Earth system science approach to Earth science they are seeing how to make connections among previously unrelated parts of Earth science content and are acquiring a framework within which to organize their new knowledge, a key element that distinguishes the cognitive processes of "experts" from "novices." Teachers who enter the program with self-described "weak" Earth science content knowledge leave better able to know what new knowledge they need and where to place it in a cognitive structure.

As teachers organize their curriculum through the ESBD backwards design approach, teach to the big ideas, develop assessments to motivate and check for understanding, and use powerful visualizations to teach, change can occur in their classrooms. Both students and their teachers find that they have a roadmap to deeper understanding and also a means to demonstrate that understanding through authentic performance assessments. Through ESBD, teachers are becoming not only more competent designers of instruction but also more critical consumers of curricula designed by others. They are becoming more highly qualified teachers.

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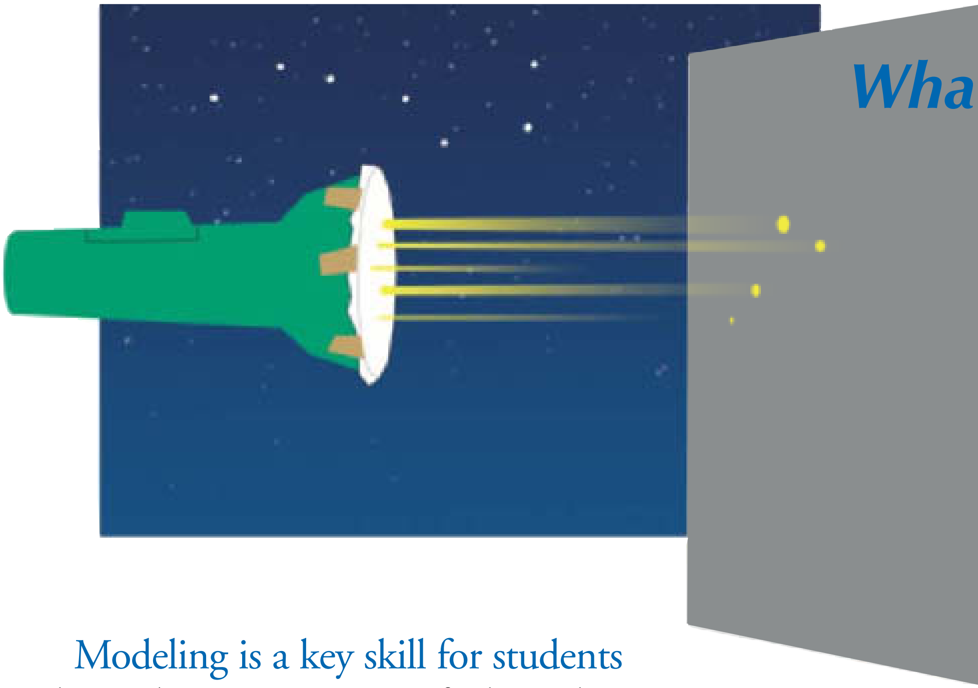
Photos (cover and page 4): Zoe Keller



What's in a Model?

By Brian Drayton

Modeling is a key skill for students to learn in their science career. It is a fundamental way that scientists make their thinking visible in a form that allows them to improve and extend their conceptualizations. The basic idea of *this* is something like *that* is one that people use all the time in daily life, but the scientific use of modeling requires learning, practice, and expertise.

TERC projects over the years have developed and researched many kinds of mathematical models or simulations for science. In this article, however, we focus on qualitative models of the sort that are widely used in textbooks and teaching to help students get a concrete grasp of a new concept. If carefully explored, such models can help students acquire the habits of mind that will support more sophisticated modeling and other kinds of scientific reasoning as their learning progresses.

Even though qualitative models are widely used as classroom activities, the *idea* of modeling as a tool to think with is rarely addressed directly in science classes or in science teacher education.[1] Still, students get an idea of what a model is every time they use one. If the teacher is aware that each model teaches something about modeling, he or she can frame an activity so that the students learn what makes a good model in addition to the lesson's science content. Students can identify a model's limitations and develop the ability to design their own models to explore or explain their understandings.

Working with scientific models in the classroom is challenging. Sometimes classroom conditions can lead to unintended results or confusion; teachers and students get distracted from the science content because they are trying so hard to make the model come out right. However, when a teacher makes time for students to explore the data as well as the design and functioning of the model, the activity becomes a powerful learning aid. It can equip students with mental tools for more powerful sense making, and help teachers make sense of their students' learning. To illustrate this, we examine the experience of Frank Fallon and his sixth-grade students as they conduct a simple modeling activity on star brightness.[2]

Modeling Star Brightness

The setup for the star brightness activity is simple: each team of four students has a flashlight, some paper, and tape. They cut the paper, tape it over the flashlight, and then poke holes of different sizes into the paper. Each team shines the flashlight on a piece of white poster board, a wall, or a similar impromptu screen. Students start at a distance and then walk towards the screen. They note the distances at which each pinhole becomes visible.

The students in Frank's class follow the setup, but the lights in the room are bright, making it difficult to discern the relative brightness of the dots. At one point Frank suggests the sort of thing the students should have seen: "This is sort of a model of a sunset" (the brighter stars being visible first and more appearing as the light fades). Before the class ends, some groups figure out what was intended; some do not.

During a debriefing the next day, Frank helps the kids consider their results, and as is his custom, he asks how things might have gone better. He acknowledges, "We didn't have all the [right] equipment [namely a dimmer switch] and so you had to work intuitively….We were looking for an answer, but since we didn't have the right equipment, you

[1] In terms of sociocultural theory, a model is a "mediational means," a tool that enables and structures learning and thinking (Wertsch, 1986). We are suggesting that the *idea* of modeling itself is also an important mediational means, but a complex one, as the rest of the article shows.

[2] This article grows out of a project in which Joni Falk and I have been studying aspects of inquiry and reform in middle school science, "The Inquiry-Based Classroom in Systemic Context," NSF/REPP 9804929.

might not have seen that the larger holes would be visible first." Here, Frank focuses on the classroom conditions and the students follow his lead in suggesting other things that "went wrong." Frank returns to the point of the activity when he creates in their imaginations a rerunning of the event as it should have been. On the basis of that imagined experience, he leads them through a typical "fill in the blank" discussion, providing a narrative with blank spaces for the kids to fill in with one-word or short answers. In the end, he states the fundamental point that brighter stars will be seen first. Frank's students spent two class periods conducting the star brightness activity. Was it worth the time and effort?

What Is a Model?

Before answering that question, let us consider some of the challenges inherent in learning and teaching with the kind of model Frank was using. How should such a model support learning?

We can say that there are two broad categories of qualitative models: *microcosms* and *analogues*. A *microcosm* is a system in which some or all of the actual phenomena being studied are at work. In essence, this is a miniaturized system. Examples might be a streamtable, an aquarium, or a simple pendulum on a stand. A little demonstration pendulum is a real pendulum; a simple food chain in an aquarium is a real food chain, but it has been pared down to a manageable size for educational purposes.

By contrast, an *analogue* model, like the one used in Frank's class, is a representation of the object or system of interest (which we can call the "target"). The model's structure and behavior are not identical to those of the target system, but are intended to elucidate or illuminate key aspects of the target system. To create the model, you choose the features of the target system you want to represent and how you want them represented based on the elements of the system you are trying to examine and understand. For example, if you want to represent a molecule, you need to decide what characteristics of the molecule you are interested in. In a common middle school representation, gum drops are used as atoms and toothpicks are the bonds. The result is a 3-D geometric representation of a molecular structure with major limitations. Different constituent molecule types might be indicated by different colors. Different kinds of bonds are not likely to be represented at all—we draw all bonds from the same box of toothpicks. In our flashlight example both the model and the target system involve light, but the relative size of the pinholes is different in important ways from stars burning and emitting energy.

Learning by Means of a Model

In many model systems defined by teachers or textbooks, the choices about what to represent, and how to represent it, have already been made. The models are designed to engage students' interest and to focus their attention on just a few features of the model (and by extension the target system) that are relevant to the curriculum. To profit from the model and take advantage of the scaffolding it provides for understanding something about the target, the students must first make sense of the model system. If you eventually want to say, "*This* (target) is like *that* (model)," you first need to get a clear picture of what *that* is.

Typically the goal of a model is not to show that a phenomenon exists, but to serve as an aid in thinking about how the phenomenon might come about or why it is the way it is. In the flashlight example, the aim is not to show that there are brighter and dimmer stars and that some are visible earlier in the night sky than others. (In fact, it is the students' basic knowledge of this phenomenon that helps them when the model runs into difficulties.) Instead, the model is a tool for thinking about what the brightness of stars might mean or tell us about the nature of stars and the universe.

Another way to put this is that a model helps the learner understand an *explanatory structure*, a story about the way things are related and the causes for the behavior that we observe. The model in our example is very simple and from it students are likely to conclude: Bigger pinholes are brighter than the small ones; therefore they are visible first. Now here is the transfer that Frank (following the lead of his curriculum kit) hopes will happen: The pinholes represent stars; the bigger pinholes should have been visible in the activity before the smaller ones. This is analogous to the fact that brighter stars are visible first in the evening sky; the model implies that brighter stars are "bigger" (they emit more light than smaller stars). By mapping the model story onto the target, students should have the beginnings of a coherent theory about apparent and absolute magnitudes, and then they can move on to other aspects of mapping the universe.[3] Frank hopes that this will be the first step in the students' understanding

[3]This "transfer" is still in many ways mysterious, even though we do it all the time. It is evidently something that is easy for humans to do, but takes learning to do rigorously, i.e., in science or math. See Brown (1989) for a helpful discussion of this problem.

that brightness tells us something about stars—but they will need to learn that brighter does not necessarily mean bigger.

New Understandings or Red Herrings

Even in this simple model there is room for ambiguity because stars of different brightness are represented as pinholes of light from the same flashlight. At this point, the students may reasonably conclude that brighter = bigger. If they have trouble with classroom conditions, such as too much light in the room, they may not even see that much. They may wonder about the fact that some of them had to walk rather close to the screen to see any pinholes at all, and therefore they may not see the difference between the big and the small; and their pinholes may not have been very different in size.

In this case, because of the simplicity of the system, and because the students have some experience of the actual night sky and know that some stars are brighter than others, Frank can verbally overcome some of the issues introduced by the inadequate setup and also mistakes in execution that the kids might have made. Some of the misconceptions introduced by the model will also be addressed in another activity the next day. Students will examine how distance from the star affects brightness by comparing the brightness of flashlights (of comparable brightness) observed from different distances in the classroom.

Discussion as the Workshop for Completing the Job

The conversation after the data collection phase of the activity is of crucial importance, both for understanding the science of the activity and for building students' understanding of modeling as a tool. This phase of the work is the most fragile and often it doesn't even take place because of time pressure, or because the teacher is not aware of the importance of this finish phase.[4]

A discussion of the model can serve several purposes. First, it can clarify the actual experiences that the students had, which may help some of them overcome problems of execution and still allow them to profit from the exercise. In our case, Frank overcame equipment problems by appealing to students' personal experience, which enabled him to conjure in their minds an imaginative picture of the actual phenomenon he wanted them to think about: "This is sort of a model of a sunset." If some teams never got the kinds of data needed to make sense of the model, others who had more success could describe how it looked to them and so, in a sense, provide a data set for their peers to use.

The discussion can also be a place where the students put into words, and reflect upon, their understanding of the model and its mapping onto the target system. If, like Frank, the teacher has in mind how the model relates to the target, he can encourage the students to reflect carefully on their experience and guide them to (or if necessary provide) the logical structure for their explanations.

The importance of class discussion in the finish phase is clear when students do not quite understand the key features of the model, or (as often happens) have alternative theories that they believe fit the facts just as well. Faced with this situation, teachers can shape the discussion, show alternative ways of arranging or interpreting the evidence, and carefully scaffold the use of new words for new concepts to help the students see how their own thoughts and observations might be put in a more powerfully explanatory context. (See Newman et al., [1989] for a fascinating exploration of this kind of co-constructive interaction.)

Finally, the discussion can be the place where the teacher and students critique the representation (the model), identifying areas where it does not work, where it is very unrealistic, oversimplified, or misleading. In our case, "brighter = bigger" is a likely provisional understanding, rooted entirely in the use of larger pinholes to admit more light. To address this, Frank has ready another activity which can help the students see how distance matters, by comparing the apparent brightness of equally strong flashlights viewed from different distances.

If the discussion reaches this level, the students gain insight into modeling as a tool and the notion that a model can be more or less serviceable for reasons that have to do with the science of the situation and the nature of the representation. Even a ten-minute brainstorming session can help by posing such questions as "OK, why is our model not like the real thing?" "Are there any ways to make it a better model of the real thing?" "Was there anything that confused you now that you think back on it?" "What new questions can we ask now?" Frank, focused on classroom logistics and pressed for time, does not quite get to this level during this class session.

[4]In our research on inquiry-based science in middle school, we found that discussing or analyzing data was far less common than collecting data; see Falk and Drayton (2001).

Conclusions

We have built a lot of thinking around a very simple example because it allows us to see some of the issues that will arise in any analogue modeling activity. Many classroom modeling situations are much more complex with many more issues obscuring both the science to be learned and the quality of the model. (Think of the use of gumdrops and toothpicks to represent a molecule.) If such issues are borne in mind, they can be used to teach specific science concepts and also some key features of the far-reaching science skill of modeling itself—model construction and interpretation. An awareness of these issues can also help teachers and students think critically about models they meet and use.

In discussions of the quality and limits of particular models, students can start to learn how to make explicit the characteristics of good explanatory analogies. They can identify the variables or characteristics to represent, choose the processes that need to be observable, and make decisions about the best way to represent these selected features.

A final consideration for the teacher is: When is a model worth the time? Because of time pressures, teachers often move on to the next activity in the textbook without considering whether the modeling activity is conceptually valuable for the students. For example, does the richness of the model (the potential conceptual or methodological complexity) justify all the set-up time? Do the students gain strategically from analyzing the model and relating it to the target? In our research in middle school classrooms, we have noted that many activities which involve model systems have essentially one point, one big idea, which like the "brighter pinholes are visible sooner" idea of Frank's model are rather straightforward for middle school students. The very conceptual simplicity of the activity may be misleading to the students when contrasted to the logistical complexity of implementation. In this case, Frank might ask himself, does it make sense to break up our exploration of brightness and distance into two, full-class periods?

Model-building is an important manifestation of hypothesizing and theory building—key components of scientific thinking. It requires the students to think analytically about the target they are trying to understand and therefore to maintain a dialogue between the phenomena and the explanations they are making of them. This process of making explicit how to employ a tool to give the most enlightening results is a fundamental operation of schooling (Weir, 1989). When a teacher, having chosen a strategically valuable activity, helps the students reflect, critique, and explore representations with each other, she helps them gain skill in seeking and articulating the "lesson at the heart of the lesson": learning both about the world and ways we make sense of it.

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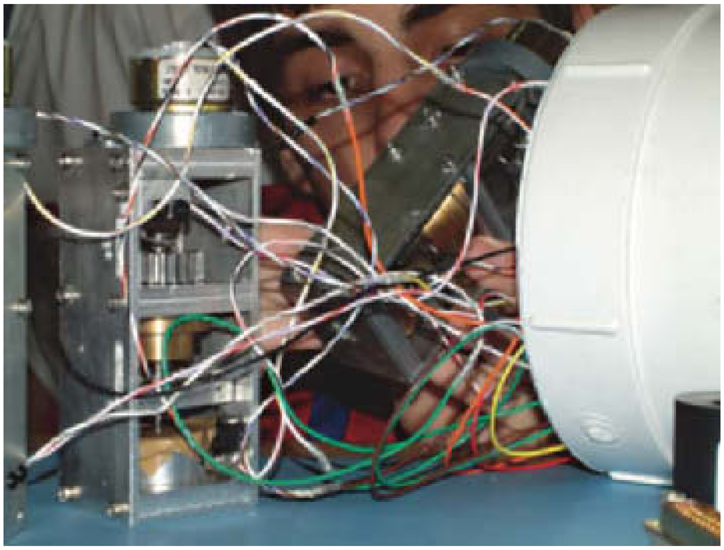
Launching Students' Curio

By **David She**

Teachers are finding that the NASA Student Involvement Program (NSIP) is an innovative opportunity to watch their students excel as they explore Earth science, Earth, and what lies beyond.

During 2002–03, more than 3500 students participated in the program's six competitions (page 13) that link K–12 students directly with NASA's exciting missions of exploration and discovery. Each competition category has a Resource Guide that provides instructional materials, judging rubrics, tips, and resources for using investigations and design challenges in the classroom. The competitions are open to any student or team of students and support national education standards for science, mathematics, technology, and geography.

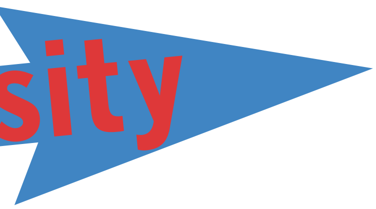


Competition winners during Flight Week at NASA's Wallops Flight Facility in Virginia.

Curt Olson, a veteran science teacher at Sauk Rapids-Rice High School (SRRHS) in Minnesota, has been working with the program for thirteen years. Olson's students have a legacy of winning NSIP competitions. In 2002–03, Olson's students placed first and second in the Science and Technology Journalism competitions and submitted a winning entry in the Space Flight Opportunities competition as well. Olson continues to sponsor entries because of the motivation the program brings out in his students. He also sees NSIP as part of his instructional "toolkit" and has come to count on the ability of the competitions to broaden students' outlook towards science.

"The educators and staff here actively work together to bridge the different disciplines in an academy approach," Olson explained. "For me, NSIP is also about empowering students and teaching advanced life skills—team work, independent work, problem solving, research, decision making, the ability to apply mathematical and scientific knowledge. Every one of those skills is fostered by NSIP. That fits well with the school's emphasis on hands-on learning across disciplines."

Olson and several other teachers at the school run a yearly activity that provides a rich context for their students' involvement in NSIP. Said Olson, "Each year, we present students with the challenge of designing the next mission for NASA. They're charged with developing a multi-faceted presentation



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NSIP National Competitions

Aerospace Technology Engineering Challenge	Grades 5-8
Science & Technology Journalism	Grades K-1, 2-4, 5-8, 9-12
My Planet, Earth	Grades K-1, 2-4
Watching Earth Change	Grades 5-8, 9-12
Design a Mission to Mars and Beyond	Grades 5-8, 9-12
Space Flight Opportunities	Grades 9-12

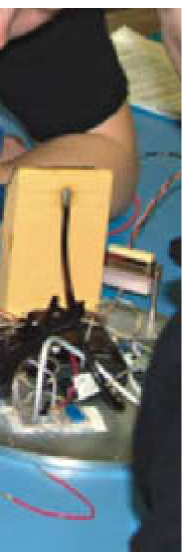
for a mock congress [a group of teachers, administrators, and former students] to get funding for their mission.

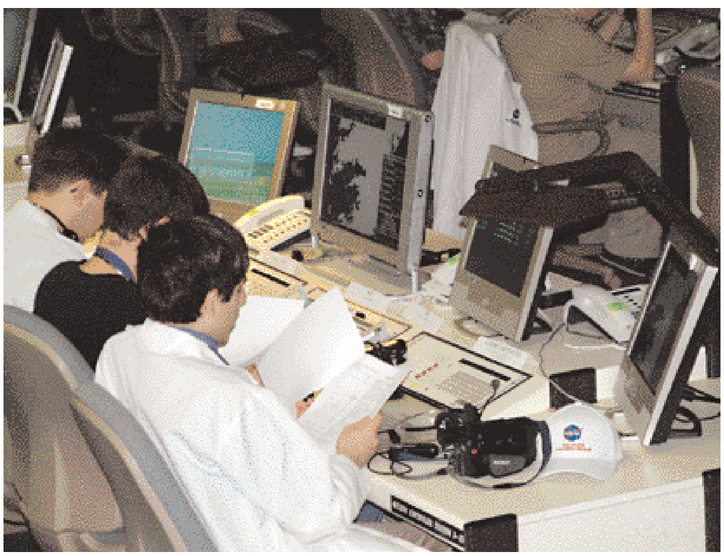
"The presentations are limited to 13 minutes and also must include a paper component. Based on their presentation, the congress decides whether or not to fund their project. Grades are directly related to whether or not congress approves the mission." This competition within the competition has been extremely effective in helping students develop NSIP entries.

"One reason we participate in NSIP is that I can cut down on lectures and let students go out and start digging for ideas on their own," Olson said. He also uses the different competitions to communicate specific messages about science, including the importance of collaboration with scientists and researchers from outside the school.

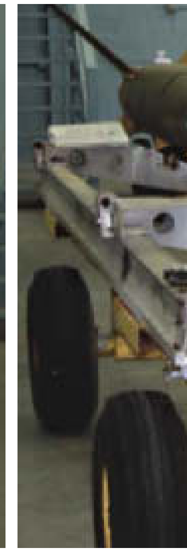
Student participation has been self-renewing.

"Many students can't imagine being a winner in a national competition. But kids see other kids winning and start to feel that they can do it too. The atmosphere in the school helps because research is such a big component of the school's overall philosophy. Kids feel comfortable going to in-school experts for help. Their participation in NSIP is piggy-backing on every single class they have here at SRRHS."





An entry from last year's competition embodies a lot of the good Olson sees in his students' participation. A team of SRRHS students submitted an entry to the Space Flight Opportunities competition, which flies winning experiments into Earth's upper atmosphere or into Earth orbit. Last year's experiment investigated what happens to an elastic container of pressurized gas as it travels from sea level conditions into space and back. (The tires of the Space Shuttle are one such container.)



TERC’s Paul Wagoner

The competition’s judging rubric outlined expectations for the project and helped the students organize their entry. Later they had to work with people from industry to solve problems they were having. Their entry won in the Space Flight Opportunities competition and therefore was launched into Earth’s upper atmosphere at NASA’s Wallops Flight Facility in Virginia.

“When they got back their data, they had to acknowledge that the experiment wasn’t successful in terms of the data they received, but the success came in going through the process of developing the entry. The process is real life stuff, not fictitious,” Olson said.

Paul Wagoner of TERC worked with Olson’s students to develop and conceptualize their gas experiment.

“They had an interesting idea and a means to investigate it,” said Wagoner. The experiment’s original focus was on what might occur if different gases were used to pressurize a container, with the intention of testing their knowledge of the ideal gas law. The data they collected instead led them to an improved understanding of rates of effusion of different gases through similar materials.

Said Wagoner, “They set out to conduct their experiment. Only after the experience could they see ways they could have done things like given more consideration to a range of possible results, or ways to have collected even more data.

“After they received their results, they realized the data showed only one part of what they intended to investigate. No one had to point these things out to them, they realized these things themselves.” We’re often given examples of scientific discovery isolated from its context. Science often develops through repeated experimentation, scientists working together to hone ideas. NSIP involves students in a process similar to real-world science, especially in the schools which work to refine their experiments over many years, often with groups of students that change as team members move on.”

For some students their participation in NSIP takes on even more significance. One of Olson’s former students and NSIP participants is now a project manager for Space Shuttle Modifications and Upgrades with NASA. Not every student who participates in NSIP goes on to work at NASA, but the benefits are just as real.

Sarah Klaphake developed a winning entry with Olson in the 2000–01 Science and Technology Journalism competitions. The five-minute video about the Moon started as a project for Olson’s multimedia class.

“My participation in Mr. Olson’s multimedia class had nothing to do with science. I was more interested in learning about video production,” said Klaphake.

Klaphake and her other three team members ended up working more than 150 hours collectively to ready their video presentation for submission. “After we started working to develop our entry, I began to appreciate the science a little bit more.” For Klaphake, NSIP participation helped reinforce her belief not so much in her science skills but rather in the life skills Olson so values in the NSIP competitions.

"I gained a lot of confidence in my skills as a storyteller from doing NSIP. That helped me realize that broadcast journalism was something that wasn't just fun, that it could be a career.

"I was able to meet professional journalists and public relations professionals. It was a great opportunity and my friends at other schools didn't have anything like it." Asked to identify the aspect of her participation in NSIP she enjoyed the most, she doesn't hesitate.

"Mr. Olson gives you so much responsibility. He leaves a really big imprint on a lot of people. That includes me." With that type of legacy, it's clear why Olson and his students continue to compete and succeed.

David Shepard is assistant editor of Hands On!. david_shepard@terc.edu

NASA Student Involvement Program is funded by NASA #NASW98010.

Photos: Ken Porter

Participation in NSIP is designed to help students:

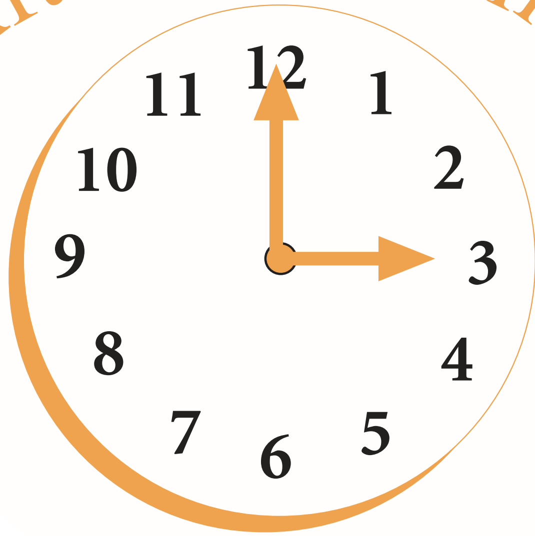
- Develop "science as inquiry" skills
- Work collaboratively as team members
- Apply computer and Internet skills
- Learn core concepts of Earth and space science
- Integrate science, mathematics, technology, and geography concepts
- Learn to communicate more clearly and effectively.

For more information on the NSIP competitions, including Entry Packets and the competition Resource Guides necessary for participation, visit www.nsip.net, email info@nsip.net, or phone 800.848.8429.

Entry deadlines for these annual competitions are in January.

See the competition rules, in the Entry Packet, for limitations and requirements for participation.

Afterschool Time



At Mellon Academy in Boston, TERC's Nick Haddad explains a mapping activity to a room of middle school girls. When challenged to find their houses and streets on one of three maps positioned around the room, the girls quickly notice that the maps have different scales. Eventually one girl points and says, "Hey, this is my street." Another girl who rarely speaks up exclaims, "And this house, this is my house!"

Mellon Academy is an afterschool program for girls run by Goodwill Industries. TERC began collaborating with the Academy to develop a short curriculum for their program. "Staff explored the idea of using satellite images of Earth as a way to bring social studies and Earth science activities into the program," comments Haddad. "We wanted to encourage the girls to investigate their surroundings and so we created a mapping unit that focused on their neighborhood. You can be really familiar with your neighborhood from the ground, but when you look at it from above, you always get a few surprises." He adds, "Using maps and data collection to get the students to explore their community seemed like a wonderful opportunity to strengthen the girls' understanding of important mathematical ideas like proportionality with the added bonus of being fun and engaging."

Haddad admits that eight afterschool sessions may not necessarily transform anyone's relationship with math, but "we wanted to do something that would capture the girls' interest and have possibilities for further exploration. Piloting the unit helped us learn more about the challenges and opportunities of working in the afterschool environment," he said.

Afterschool programs are playing an ever-increasing role in the development of today's youth. A recent survey by the Boston-based After-School for All Partnership found that Boston has nearly doubled the number of children who participate in afterschool programs since 1998, and for the first time a majority (51%) of Boston school children participate in some kind of afterschool programming.

Teachers, parents, and community leaders recognize that these afterschool programs can greatly contribute to students'

academic success. The challenge for educators is how best to use the unique strengths and resources of these programs when developing academic activities.

"The afterschool environment requires activities that are rewarding and interesting for kids, activities that require them to become more aware of their own self development," comments Carolyn Nelson of TERC. "Ideally, you keep the balance between socialization, interaction, and learning." Nelson, who has been active with several Boston area programs, sees how "Afterschool programs have connections with both community and classroom. New teaching models require everyone on board, not just teachers and administrators."

Students working in Mellon Academy's computer classroom.

Nelson's commitment to afterschool programming helped lead to a collaboration between TERC and the Somerville Community Schools Program (SCSP) in Massachusetts. SCSP received a grant to provide afterschool care that would offer creative, academic, enrichment, and recreation activities linked to the Massachusetts Learning Frameworks. SCSP administrator Susan Gross contacted Nelson because she hoped TERC could help her and her staff better integrate science into their programming. TERC's Brian Conroy led two professional development sessions in science for Gross' staff. "The less structured nature of afterschool programs provides an opportunity to engage in real science learning, the kind of learning that is happening less and less in science classrooms on the elementary level," Conroy explained. "In an afterschool setting, kids have more time to undertake extended investigations or explore concepts. They are motivated by their interest and curiosity, not by whether the material will be on the test."

The first session at SCSP was designed to assess staff needs and introduce them to what different approaches to science might look like. "We set up science centers at the workshops and showed what children could learn from different activities. We addressed how to ask questions and establish clear-cut objectives for activities," explained Conroy.

The first day gave staff a window onto different kinds of science activities, from free-form investigations to those with a clear beginning, middle, and end.

"Some staff were concerned they wouldn't know enough science," Nelson said. In part in response to this concern the focus of the workshops remained on how to interact with children as they explored science, while keeping the emphasis on fun—a high priority was placed on keeping afterschool time distinct from students' activities during the school day.

A second session provided suggestions for nature activities and challenged afterschool staff to consider extended activities that could involve students over a period of days or weeks. Staff engaged in hands-on modeling themselves, and were presented with resources for further investigations with their kids.

TERC's work with programs like Mellon Academy and the Somerville Community Schools Program is continuing to evolve. TERC staff are learning from these partnerships and exploring ways that the organization's research and development efforts can contribute to this expanding area of educational programming.

For more information about TERC's work with afterschool programs, contact communications@terc.edu.

Photos: David Shepard

EnViSci Network

Technology-Enhanced Science Education

Ask an important environmental science question—and students answer using discovery-based investigations and online research.

EnViSci Network combines hands-on investigations with online inquiry. Each unit poses a central question that involves standards-based concepts and processes.

- Teacher materials support regular classroom teachers as well as science specialists—with background information, easy procedures and directions, teaching strategies, directions for web site use, pre- and post-tests with scoring rubrics, and reproducible Student Journal student pages.

Learning Benefits:

- Integrates Internet resources and classroom instruction by providing a controlled web site where students can do research and compare their data with data from a national student network
- Builds understanding of science processes and content through hands-on activities that help students learn how to observe, measure, compile data, and analyze results
- Develops writing skills in a science context as students record predictions, observations, data, reactions, and conclusions
- Measures learning in relation to National Science Educational Standards in pre- and post-tests

Units

Grades 3–5

What's the Weather?
Is Our Rain Acid Rain?
Is Our Tap Water Just Water?
How Much Solar Energy Can We Collect?
Do We Throw Too Much Away?

Grades 6–8

Are We Getting the Oxygen We Need?
Is Our Surface Water in Danger?
How Should We Use Our Soil?
Is the Sound Too Loud?
Are Polar Regions Getting Warmer?

Unit cost: $95 plus materials
www.charlesbridge.com, 800.225.3214, fax 800.926.5775

In Print

The following is a sampling of recently published research and academic works authored or co-authored by TERC staff.

Book Chapters

"Lessons from South Africa: A Look at Reform-Based Education in a Post-Apartheid Era," by Hollee Freeman (TERC), in *In Celebration of Black History*, Vol. 7, Boston College, 2003.

"Reasoning About Data," by Clifford Konold and Traci L. Higgins (TERC), in *A Research Companion to Principles and Standards for School Mathematics*, Jeremy Kilpatrick, W. Gary Martin, and Deborah Schifter (Eds.), National Council of Teachers of Mathematics, Reston, VA, 2003.

Research Report

"The ARC Center Tri-State Student Achievement Study," by Sheila Sconiers, James McBride, Andy Isaacs, Cathy R. Kelso, and Traci L. Higgins (TERC), ARC Center at the Consortium for Mathematics and Applications (COMAP), Lexington, MA, 2003.

Papers

"Reasoning in the Presence of Variability," by James K. Hammerman (TERC) and Andee Rubin (TERC), in *Proceedings of The Third International Research Forum on Statistical Reasoning, Thinking and Literacy*, Carl Lee, (Ed.), Lincoln, NE, 2003.

"Types of Transformation in Mathematics Teacher Professional Development," by James K. Hammerman (TERC), in *Proceedings of The Fifth International Conference on Transformative Learning*, C. A. Wiessner, S. R. Meyer, N. L. Pfhal, and P. G. Neaman (Eds.), Teachers College, Columbia University, New York, 2003.

Journals and Periodicals

"Developing Meaningful Student-Teacher-Scientist Partnerships," by Tamara Shapiro Ledley (TERC), Nick Haddad (TERC), Jeff Lockwood (TERC) and David Brooks, *Journal of Geoscience Education*, Vol. 51, No. 1, pp. 91–95, 2003.

"Discourse Analysis of Web Texts: Initial Results From a Telementoring Project for Middle School Girls," by Brian Drayton (TERC) and Joni Falk (TERC), *Education, Communication, & Information*, Vol. 3, No. 1, 2003.

"Discovering Gifts in Astronomy," by Jeff Lockwood (TERC), *Mercury*, Vol. 32, No. 1, pp. 12–13, 2003.

"Energy Balance Model: Surface," by Tamara Shapiro Ledley (TERC), *Encyclopedia of Atmospheric Sciences*, pp. 747–754, 2003.

"Learning in Settings Other Than Schools," by Dennis Bartels (TERC) and George Hein (Lesley University and TERC Board member), *Educational Researcher*, August–September 2003.

"Why We Need a Structured Abstract in Education Research," by Frederick Mosteller, Bill Nave (TERC), and Edward J. Miech, *Educational Researcher*, January/February 2003.

Algebra in Early Mathematics

In previous work, the Early Algebra, Early Arithmetic research team from TERC and Tufts University have found that students ages 8–10 were able to grasp algebraic concepts generally withheld until the onset of Algebra I. This latest project investigates whether integrating algebraic concepts such as function into early mathematics can help students perform substantially better on measures of general mathematical achievement. Funded by the National Science Foundation.

ARC Center Project Renewal

The Alternatives for Rebuilding Curricula (ARC) Center Project Renewal will build on the work of the *Investigations* Implementation Center. The Center supports districts, schools and teachers working to improve student understanding of and access to mathematics through effective implementation of the *Investigations* curriculum. This project focuses on professional development and technical support for *Investigations* teachers and administrators as a way to build capacity in their schools and districts. Funded by COMAP through a grant from the National Science Foundation.

Center for the Study of Culture, Learning and Development

Traditionally, issues of cultural diversity have been peripheral in core fields concerned with understanding learning and development. A science of learning must place these issues at the center of the scientific investigation of learning and development. The goal of this project is to develop the conceptual, methodological and empirical underpinnings for the creation of a Center for the Study of Culture, Learning and Development. Funded by Northwestern University through a grant from the National Science Foundation.

Digital Video & Motion Detection Phase II

The project will develop a real-time 2-D motion detector based on a digital camera transferring the data to the computer. The system will be able to detect two objects at once and it will allow the student to choose among multiple types of data analysis. The system will be tested in mathematics and physics classes. Funded by Alberti's Window through a grant from the National Science Foundation.

DLESE Data Services

DLESE (Digital Library for Earth System Education) Data Services will identify the Earth science data needs of educators at all levels, and identify educational modules that use Earth science datasets and tools and make them accessible via DLESE. The project will hold workshops to facilitate the interaction of Earth science data providers, developers of data tools, and curriculum developers to guide the creation of effective and usable data access and analysis tools and related curricula. Funded by the National Science Foundation.

Earth to Orbit Engineering Design Challenges: Personal Satellite Assistant

TERC and NASA are creating a challenge for grades 5–9 related to the Personal Satellite Assistant (PSA), an intelligent robot being developed by NASA to assist astronauts in orbit. NASA engineers and scientists will provide career information and will interact with students about their design work. Funded by AI Signal Research through a contract from NASA.

The Earth Exposed

The Earth Exposed project introduces people to the artistic and Earth science aspects of images taken by astronauts and satellites. It will present selected Earth images at a prominent Philadelphia art gallery and develop an educational program to be used in the gallery's school outreach program, including animations, web-based resources and hands-on science and art activities about remote-sensing and Earth science concepts. Funded by the National Science Foundation.

Eye Tracking for the Study of Seeing and Imagining

Studies in eye motion provide evidence that visual perception is not instantaneous, but an exploratory process. This project is studying the crucial relationship between visual perception and imagination in mathematics learning by using a tracker to monitor an interviewee's eye movements while writing, handling objects, walking, looking at a computer screen, and imagining different aspects of motion. Funded by the National Science Foundation.

Eyes in the Sky: Applied Information Technology

Information technology (IT) provides the tools necessary to explore, model, and interact with scientific data produced by satellites orbiting Earth. This program will enable teachers and students to apply IT tools such as Geographical Information Systems (GIS) in the context of community-based science projects in order to encourage students to consider careers as technicians or researchers. Funded by the National Science Foundation.

Foundational Tools for Data Literacy—Tabletop 2

This project is revising and expanding the popular visual data analysis tool, Tabletop, with the goal of publishing a new tool and supporting materials. The project will enable students and teachers to use data meaningfully across subjects and grade levels, with the long-term goal of improving student understanding of science and mathematics through data-based inquiry. Funded by the National Science Foundation.

GDSE/RES: Women's Science Equity Online

The Women's Science Equity Online project will identify characteristics of online science courses for teachers that correlate to positive learning outcomes for women, as women are the largest users of online education. Online courses will be studied for factors leading to success by women learners of science, resulting in guidelines for online developers dealing with equity issues. Funded by the National Science Foundation.

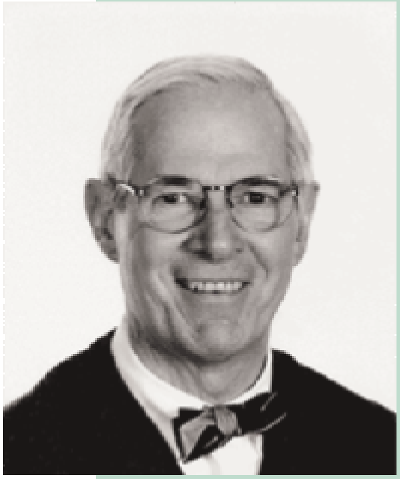


Photo courtesy of Center for Applied Special Technology

Remembering Walter Palmer

The TERC community suffered a major loss with the death of Walter Palmer, a strong supporter and friend of the organization who had served as a trustee since 1998.

Walter was a gentle man with a generous spirit and big heart. He believed passionately in education for all individuals. Through his many community involvements, he was always eager to connect people and organizations with each other in order to advance the promise of learning for all. He bridged the corporate, civic, and education communities and opened doors for many.

Everyone at TERC who worked with Walter was touched by him and enjoyed their relationship with him in a number of different ways. TERC President Dennis Bartels remembers Walter's smile at their first meeting. "It was warm, genuine, uplifting, and contagious. Even a bit mischievous. I knew instantly that I would delight in working with Walter." Dennis adds that Walter "always wanted to do more, to give more, to teach more."

We express our shared grief to Walter's wife Caroline and their family, and we celebrate Walter's outstanding contribution to education.

We will truly miss him.

New Projects (continued)

Infusing NSDL in Middle Schools

This research project will examine systemic issues and other barriers that affect the infusion of digital resources that support science and mathematics teaching and learning at the middle school level. The research will offer strategies to developers, policy makers, administrators, and teachers to promote effective implementation of the National Science Digital Library (NSDL) in schools. Funded by the National Science Foundation.

MSPnet

MSPnet will create an electronic learning community to support NSF's Math and Science Partnerships (MSPs). MSPs connect K–12 teachers and administrators with college-level faculty. MSPnet will enable MSP projects across the country to share resources, emerging research, and tools. MSPnet will also enhance dialog between geographically dispersed partnerships. An interactive web site will provide the public with increased access to the MSP program. The MSPnet web site, mspnet.org, will be available February 2004. Funded by the National Science Foundation.

Planning Conference for National Initiative for Science After School

This project will take advantage of the increasingly academic nature of the after-school community to introduce math and science activities into afterschool programs. TERC, in collaboration with the Exploratorium and the Lawrence Hall of Science, will convene a conference to bring together afterschool providers, math and science curriculum developers, and staff trainers to launch a national effort to create research-based science and math activities for the afterschool community. Funded by the National Science Foundation.

Teaching to the Big Ideas of Early Algebra

This project will design, produce, and test two professional development modules to help teachers prepare their students for formal algebra courses. The modules, on themes of generalization and functions, are part of Developing Mathematical Ideas (DMI), a series of seminars designed for elementary and middle-grade teachers of mathematics. Funded by the Education Development Center through a grant from the National Science Foundation.

Technology in Support of District-Wide Instructional Improvement

TERC will identify the key challenges inherent in using digital technologies to improve student learning; develop case studies illustrating the complexities of systemic reform in medium sized urban districts; hold a conference for foundations, national technology vendors, and district and local educators; and prepare a final conference report. Funded by the John D. and Catherine T. MacArthur Foundation.

Get Involved

Earth Exploration Toolbook

Participate in a two-hour distance-learning professional development seminar for science and technology teachers of grades 6–12. In spring 2004, participants will walk through one chapter of the Earth Exploration Toolbook (EET) and discuss ways to use Earth science datasets and tools with their students. EET is a collection in the National Science Digital Library and the Digital Library for Earth System Education. Requires use of the Internet and a phone at the same time. Attendees will receive a $60 stipend for completing the seminar and an online survey. For more information about EET, to see the Spring schedule, and to register, see www.terc.edu or serc.carleton.edu/eet.

ISS EarthKAM

Middle school students can take photos of Earth from space! Through ISS EarthKAM, a NASA-sponsored education program, students control a camera mounted on the International Space Station and study the resulting images to enhance their learning of science, geography, mathematics, and technology. There are four or more missions each year, generally in January, April, July, and November. All images and educational materials are available on the Web. Register to join the program at www.earthkam.ucsd.edu.

Lesley/TERC Try Science

Register for online graduate-level courses 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. Try Science is the prerequisite course for the online master's degree program in Science education at Lesley University.

Summer session begins May 17, 2004. Courses offered: Try Science, Biology Explorations, Earth Science

Fall Semester begins September 7, 2004. Courses offered: Try Science, Investigating Physics, Engineering

For information, contact Lesley University at www.lesley.edu/soe/science, email science@mail.lesley.edu, or call 800.999.1959 x8938.

NASA Student Involvement Program

Find rewarding opportunities for exploration and research with the NASA Student Involvement Program's K–12 competitions: My Planet Earth, Science and Technology Journalism (with the 2004–5 theme "Spinoffs—Using NASA Technology to Improve Life on Earth"), Aerospace Technology Engineering Challenge, Design a Mission to Mars and Beyond, Watching Earth Change, and Space Flight Opportunities. Students and teachers have the chance to win a variety of awards. Visit www.nsip.net, email info@nsip.net, or call 800.848.8429 for entry materials, resource guides, and additional information. Also see "Launching Students' Curiosity" on page 12.

Science for Today and Tomorrow

Science for Today and Tomorrow is seeking field test teachers for the Heredity unit (grade 6 or 7). The unit encourages students to build ideas of science content and process through hands-on and web-enhanced investigation of the question, What makes us the way we are? In so doing, students develop a qualitative understanding of genetics that serves as the basis for more molecular-based studies in high school and beyond. For more information and to apply, contact tara_robillard@terc.edu.

TERC's Dennis M. Bartels Named AAAS 2003 Fellow

TERC President Dennis M. Bartels has been awarded the distinction of American Association for the Advancement of Science (AAAS) Fellow. The award recognized Dr. Bartels' energetic leadership in systemic science education reform, informal science education, and research and development of innovative mathematics, science, and technology curricula.

Since coming to TERC in 2001, Dr. Bartels has led TERC's efforts to expand its endeavors in online learning and afterschool programming. Previously, Dr. Bartels directed educational programming at the Exploratorium, an interactive science museum, and also directed a statewide education reform initiative at the South Carolina Department of Education.

Said Dr. Bartels, "I'm extremely grateful for the recognition of AAAS and its members, not only on my own behalf but also for current and former colleagues whose work this also honors."

New Web Site

Earth Exploration Toolbook

The Earth Exploration Toolbook (EET) web site provides step-by-step instructions for using Earth science datasets and software tools in educational settings. Each chapter of the EET walks users through an example—a case study in which the user accesses data and uses analysis tools to explore issues or concepts in Earth system science. In each chapter, users produce and analyze maps, graphs, images, or other data products. Chapters and professional development opportunities available at **serc.carleton.edu/eet**.

Photo: Bruno Debas

TERC's Board of Trustees has appointed Susan Friel as its newest member.

Dr. Friel is a professor of mathematics education in the School of Education at the University of North Carolina, Chapel Hill. Previously, she served on the faculty of Lesley University and served as the first director of its Mathematics Education Center.

Dr. Friel is well known for her current work on the Connected Mathematics Project (CMP) middle school mathematics curriculum and other research and teacher education projects in mathematics education. She is currently studying what middle school students come to understand about data analysis through their use of the software program Tinkerplots in one of the CMP units.

Photo: Amelia Kunhardt

Elaine Laughlin named new Director of Development

TERC recently appointed Elaine Laughlin as Director of Development.

Laughlin has worked for more than twenty years managing programs and raising funds for Greater Boston nonprofit organizations, including WGBH and WBUR, Boston's NPR news affiliate. Laughlin also served as Executive Director for Arlington Center for the Arts, and held development and marketing positions at the Freedom Trail Foundation, the Massachusetts Cultural Alliance and Arts/Boston.

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Blueprint for Change: Revolution in Earth and Space Science Education	____	FREE	____
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Encouraging Inquiry in a Seventh-Grade Mathematics Class	____	$5.00	____
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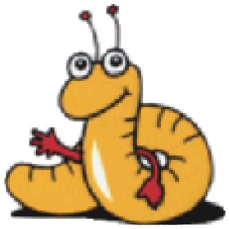
Prices include shipping for U.S. orders. Prepayment required: Send check or money order in U.S. dollars, payable to TERC. TERC Communications, 2067 Massachusetts Avenue, Cambridge, MA 02140, USA

A New Way to Do Math at Home



Funded by the National Science Foundation.

A free English/Spanish web resource offers ten activities that help parents do math with their children as a part of everyday routines such as cleaning up, sharing fairly, or getting somewhere on time. At Home with Math/Diez Actividades Cotidianas para Padres y Niños engages children in arithmetic, estimation, measurement, problem-solving, and other important math skills—in the context of ordinary home life.

At Home with Math was created in collaboration with Ceridian Performance Partners. Designed for children ages 5–11 and their parents, the activities are available in PDF format. Download the activities at **athomewithmath.terc.edu**.

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