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Improving Achievement *in* Mathematics *and* Science

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Changing Our Attitude toward Mathematics and Science to Improve Achievement

By Leslie Blair, Editor

Perhaps you have seen a similar headline: "Skilled Workforce Shortage Could Cripple U.S. Economy." It sounds serious—and it is, given the importance of mathematical and scientific skills in our increasingly technological society and the United States' lackluster performance on the Trends in International Mathematics and Science Study (TIMSS) and National Assessment of Educational Progress (NAEP) scores. While NAEP assessments overall show an improvement in mathematics achievement between 1990 and 1999, computation scores actually dropped during that time. In 1999, only about half of eighth and twelfth graders could compute accurately with fractions. NAEP scores also reflect an achievement gap—just 3 percent of Black students and 4 percent of Hispanic students reach the proficient level in mathematics by the 12th grade.

In a way, we are all responsible for this poor performance. Robert Moses, in *Radical Equations: Math Literacy and Civil Rights*, observed that in our culture, "illiteracy in math is acceptable the way illiteracy in reading and writing is unacceptable. Failure is tolerated in math. . . .if you're struggling with an equation while doing your algebra homework, more likely your parent will look over your shoulder, wrinkle a brow in puzzlement, then say something like, 'I never got that stuff either.'"

It is time that all of us—educators, parents, and policymakers—begin to see mathematics as the *enabling discipline* for all of science and technology that it is and to recognize its power in providing tools for analytical thought and for concepts and language for quantitative descriptions of the world (RAND Mathematics Study Panel, 2002). We need to realize the importance of mathematics and science in the lives of all of our children, and make it possible for them to become proficient in mathematics and science.

How we do this, of course, is complex. It will mean changing the way we train teachers to teach math, requiring more than just a few courses in math for elementary education majors. And it will mean ensuring that qualified teachers are teaching math. One recent study found that more than half of our middle school mathematics teachers have neither a major nor a minor in mathematics! It also means building a strong research and development program in mathematics to find out more about effective teaching practices. At a February mathematics summit, Dr. Russ Whitehurst, director for the U.S. Department of Education's Institute of Education Sciences, acknowledged, "research in math is in its infancy compared, for example, to research on reading, and that what it provides for policy and practice is more in the way of educated guesses than strong direction."

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What Does Scientifically Based Research Mean for Schools?

By Lesley Dahlkemper

The No Child Left Behind Act has increased pressure on schools to identify programs that improve student achievement. The law requires schools to adopt new programs based on rigorous research that proves they are effective.

Supporters say requiring schools and districts to adopt such programs takes the guesswork out of what works. Detractors say the federal government's mandate is too strict and costly.

Whichever side you are on, schools that fail to see gains in student achievement will face tough consequences under No Child Left Behind (NCLB). As educators review programs with a proven track record of success, they are sifting through evidence with an eye toward research that will meet the federal government's standards.

What Qualifies?

What scientifically based research qualifies under No Child Left Behind?

Research that

- employs systematic, empirical methods that draw on observations or experimentation.
- involves rigorous data analyses that are adequate to test the stated hypotheses and justify the conclusions drawn.
- relies on measurements or observational methods that provide reliable and valid data across evaluators and observers, across multiple measurements and observations, and across studies by the same or different investigators.
- is evaluated using experimental or quasi-experimental designs in which individuals, entities, programs, or activities are assigned to different conditions and with appropriate controls to evaluate the effects of the conditions of interest, with a preference for random-assignment experiments, or other designs to the extent that those designs contain within-condition or across-condition controls.
- ensures experimental studies are presented in sufficient detail and with clarity to allow for replication or, at a minimum, offer the opportunity to build systematically on their findings.
- has been accepted by a peer-reviewed journal or approved by a panel of independent experts through a comparably rigorous, objective scientific review.

Source: U.S. Department of Education

What Qualifies as Scientifically Based Research?

The U.S. Department of Education says scientifically based research applies rigorous, systematic, and objective procedures to evaluate whether a program is effective.

Russ Whitehurst, who heads the Institute of Education Sciences of the U.S. Department of Education, says requiring schools to adopt programs backed by scientific evidence is new to education. Until now, he says too many schools have adopted programs based on hunches and anecdotes. "People want to make wiser choices," Whitehurst says. "They don't want to gamble. This generates an appetite for more information on what will work best."

The U.S. Department of Education backs research employing randomized, controlled trials that assign subjects to an experimental group or a comparison group to test a program's effectiveness—an approach commonly used in medicine, but less often in education.

Some researchers caution that randomized trials can be limiting. "A randomized study invariably simplifies the world," says professor David Berliner of Arizona State University's College of Education in Tempe. "You can only look at five or six variables at a time. In the real world, there are many more factors." Berliner argues the federal government should not promote a single method of research. "The real question is what constitutes science? What will you accept as evidence?"

Many others, like principal Scott Steckler of George Cox Elementary School in Gretna, Louisiana, worry the new mandate will prove too costly, especially when schools and states are strapped for cash. "The people promoting No Child Left Behind are of the opinion that we can do the job with the same amount of money. That's ludicrous." NCLB supporters maintain it is not necessarily more expensive to implement programs and practices rooted in scientifically based research, especially since proven programs are likely to be more effective, resulting in less waste in the long run. Steckler sees other benefits to the scientifically based research requirements, however. Such requirements "could

The real question is what constitutes science? What will you accept as evidence?

David Berliner, Arizona State University

eliminate some shady practices," he says. "I have seen programs adopted because the superintendent was well acquainted with the chief sales rep of the company."

The U.S. Department of Education has called randomized studies the "gold standard" in research and is earmarking $47 million for such trials in early reading instruction, alternative certification of teachers, English language learners, charter schools, and several other areas. While randomized trials are heavily emphasized, Whitehurst points out that this approach is one of several accepted under the law. Other research methods include quasi-experimental studies, rigorous data analysis, and observational methods. (See sidebar, "What Qualifies?")

What Programs Are Affected?

The call for scientifically based research in education casts a wide net, affecting not only academic programs, like reading and math, but efforts to curb drug use, keep schools safe, increase parental involvement, and improve professional development for teachers.

What's less clear is how aggressive educators must be to ensure that all new programs meet the tough new standards. Even the U.S. Department of Education's top researcher acknowledges there's "ambiguity" on this question.

"Most people would agree that before a state adopts a reading program, you would want a high degree of evidence showing the program is effective," Whitehurst says. "But when it comes to supplemental materials, such as workbooks, do we expect they will be as closely evaluated? Probably not."

Some states, like Arkansas and Louisiana, already require schools to adopt new programs backed by evidence. "I don't know that we'll face a lot of challenges," says principal Gerald LeBlanc of Homedale Elementary School in Harvey, Louisiana, noting that such programs are "not new to us."

While the U.S. Department of Education has outlined standards for scientifically based research, comprehensive data-collection efforts by schools, districts, and states can also count as scientifically based research.

Arkansas was one of the first states to receive federal funding for the Arkansas Reading First program under the new mandate. Ray Simon, who heads the Arkansas Department of Education and is a recent nominee for the position of assistant secretary for the Office of Elementary and Secondary Education, says the state's successful funding was in part due to the Arkansas comprehensive student achievement database. The data showed that reading scores increased and the program worked, especially in kindergarten through fourth grade. Simon says the extensive data-collection efforts met the tough standards set forth in NCLB.

"I consider that research-based," he says. "How are certain groups of children doing? Educators can find that out." Still, Simon acknowledges some schools in his state will struggle to evaluate research and data to determine if they meet the criteria set forth by the federal government. He's encouraging schools to work closely with local educational cooperatives and his agency. "There are vendors all over claiming they can do this and do that but we want to make sure the program works," he says.

Help for Educators

While supporters believe the call for rigorous research will improve the quality of learning, they wonder whether educators have the time and expertise to conduct a thorough review of research. "We do have lists of what we mean by research-based programs, but just having the time to look at them, the funds to afford them, and the buy-in from teachers will be our biggest challenges," says Imelda Guerra, a SEDL board member and the principal of Magee Elementary School in Alice, Texas.

Some district administrators are helping their principals and teachers become savvier consumers of commercial and homegrown programs. Gloria Griffin, another SEDL board member who is superintendent of the Millwood Public School District in Oklahoma City, is tapping federal dollars to give teachers more time to use data in their analysis of student work during the summer and on Saturdays. "We are using our training dollars to enhance preparation of teachers coming out of school and to help those who have been in the field a long time," she says.

At Homedale Elementary, LeBlanc has convened a team of teachers that regularly reviews research to see which newly proposed programs are scientifically proven. He encourages them to visit other schools to see if the program is really getting the results claimed by the research. Teachers also field-test the program to see if it works with the school's student population before adopting it. And the team digs up as many research studies as possible on the program, looking for contradictions.

Others are turning to consultants for help, but they acknowledge that outside expertise is often costly. "I don't expect that we are going to get to a point where the typical school principal is trained as a researcher," Whitehurst says. "But we can create a culture in schools that places an emphasis on scientifically based research and gives principals the tools to judge."

We can create a culture in schools that places an emphasis on scientifically based research and gives principals the tools to judge.

Russ Whitehurst, Institute of Education Sciences

Why Evidence Matters

An Interview with Russ Whitehurst, Director, Institute of Education Sciences, U.S. Department of Education

How is this new approach different from what schools and state education agencies have done in the past?
The conversation heretofore would have been a conversation that was driven by anecdotes or by suggestions: “If you want to find out how good this is, call superintendent so-and-so and he will tell you what a good experience he has with it in his schools.”

The way that interaction will occur a year or two from now is that the vendor will be asked by the superintendent, “What evidence do you have of the effectiveness of this program for kids like ours?” The vendor may respond, “We do have the evidence.” The superintendent may ask, “Has it been vetted by the What Works Clearinghouse?” If the answer is yes, the vendor will be told to call back in a couple of weeks and the school will check it out. If the vendor says no, they’ll be asked, “Why not?”

How do you respond to critics who say scientifically based research is not clearly defined?
Well, I think with respect to what works . . . the definitions are quite clear. We know what works through randomized trials. The missing piece—and the piece we intend to provide with the What Works Clearinghouse—is a place where practitioners can turn for impartial, carefully vetted research information.

I also think there’s confusion about when we need rigor and when we don’t and that’s the nature of the enterprise.

What advice would you give to districts and schools who want to ensure that new programs are scientifically based?
First, see if the What Works Clearinghouse has issued an evidence report in the area in which you are making a decision. I also think that people making high-level decisions about programs and practices need to become more aware about what the rules of evidence are. Districts and schools also need to develop their own measures to see if they are meeting their performance goals.

Some critics argue randomized trials take too long and are too expensive. Your reaction?
If it’s over the course of a school year, you can do it over the school year plus a summer. There’s nothing inherently time-consuming about randomized trials.

What is the expense of not knowing what works? The cost of finding out what works is small compared to making bad decisions.

Others argue the federal government is promoting a particular view of education.
I’m not sure what that means. What view? The only view it is promoting is that we need to use evidence to determine what works and why. The view of education that may be ruled out is that education is an art and it will never be more than accumulated craft wisdom. These are very pessimistic views of education.

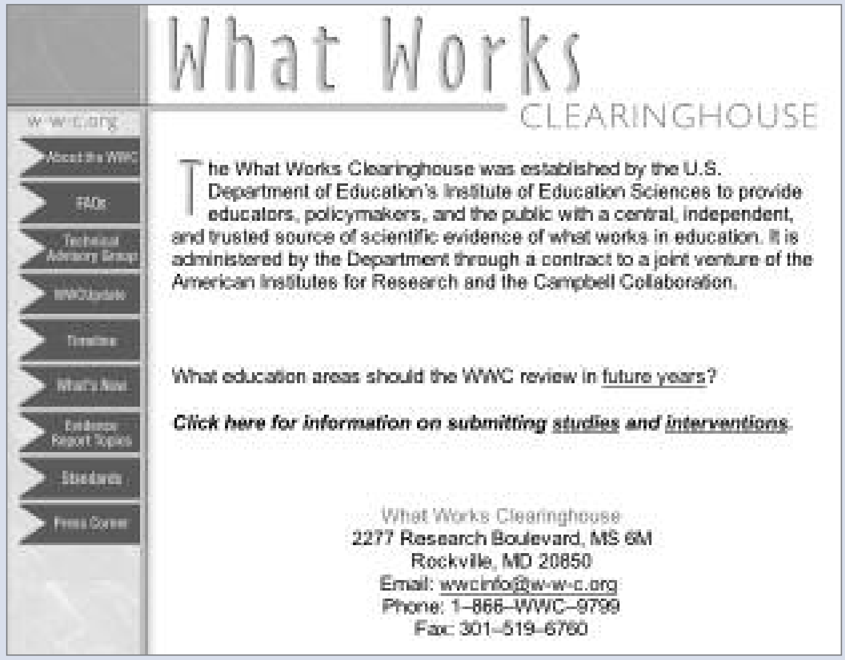
How will you enforce this provision?
The accountability provisions in No Child Left Behind are very real. Schools are held accountable for progress. When they apply for funding, applicants are required to propose programs based on evidence that a program a school is planning to implement has evidence of effectiveness.

What impact will this provision have on public schools in the long run?
The thing that drives me every morning when I wake up is that this might actually make a difference and we will start to see impressive gains. We’ll get to the point in the not too distant future where every child will be guaranteed an education that is good enough for that child’s future.

What Works Clearinghouse Priorities

The clearinghouse will conduct comprehensive research reviews in these areas:

- Interventions for beginning reading
- Curriculum-based interventions for increasing K–12 math achievement
- High school dropout prevention
- Peer-assisted learning in elementary schools
- Programs for increasing adult literacy
- Interventions to reduce delinquent, disorderly, and violent behavior in and out of school
- Interventions for elementary English language learners



What Works Clearinghouse

To help educators navigate the research on intervention strategies, the U.S. Department of Education has created the What Works Clearinghouse, which will provide an independent source of information on what works in education. That information will be based on a rigorous review of existing research.

The clearinghouse will publish evidence reports that review research evaluating the effectiveness of programs, products, practices, and policies on its Web site at www.w-w-c.org. "We're not in the business of endorsing products," says clearinghouse spokesman Steve Fleischman. "We're providing what has never existed before: a set of highly credible research review tools that will be applied consistently to judge the evidence of effectiveness across all kinds of things."

For now, the clearinghouse is focusing its work on several key areas including reading, math, dropout prevention, and school safety (see sidebar, "WWC Priorities"). Fleischman says educators can nominate topics and intervention strategies online for consideration.

The What Works Clearinghouse also offers names of individuals and organizations that can evaluate intervention strategies for states, districts, and schools, using the standards approved by the U.S. Department of Education.

For example, a large district may have the need to hire an evaluator to conduct a randomized, controlled trial of a social studies program yet to be reviewed by the clearinghouse's advisory group. Or they could tap experts to evaluate a homegrown program before it's adopted at the district or state level.

"Typically, you find a researcher by word of mouth or at a conference," Fleischman says. "But for the first time, educators will now have ready access to evaluators who make the claims that they can provide these services." He says the clearinghouse will not make judgments about the evaluators' qualifications

What's Next?

While some educators are confident they can meet the federal government's new standards, others aren't so sure. They worry that the definition of scientifically based research is too narrow, leaving behind promising practices and programs. They also question whether randomized, controlled studies can be conducted in an environment as dynamic as public education. Still others believe the emphasis on scientifically based research is good for education and long overdue.

Individuals on both sides of the debate will be watching closely to see if the mandate results in improved student learning and achievement.

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Lesley Dahlkemper is the president of Denver-based Gracie Communications, Inc., a firm specializing in K–12 education writing, communications strategy, and project management.

State Efforts Push to Leave No Child Behind in Mathematics and Science

By Geoff Camphire

Claudia Ahlstrom marvels at her state's efforts to fine-tune math and science education. As a mathematics consultant for the New Mexico Department of Education, she conducts regional workshops in techniques—portfolios, hands-on exploration, student peer review—that teachers will need to help students ace tough new tests. The state put new standards-based exams for grades 4 and 8 in place in April and will add an exam for grade 11 in November. Science standards are being updated and improved. And state legislators are weighing a three-tiered licensure system that would allow teachers to earn more by building instructional skills rather than by seeking administrative jobs.

These are just a few recent changes inspired by No Child Left Behind (NCLB), the most sweeping school reform law passed by the federal government in decades. The thrust of the legislation is, as its name suggests, to ensure that no group of students misses out on planned improvements for public education. NCLB mandates new systems of standards, tests, and policies on accountability and other areas to meet that goal.

Challenges loom large for such states as New Mexico, where nearly a quarter of students are English language learners and there are large shares of poor and minority students. But maybe that is why so many teachers, administrators, and education officials are hustling to meet the demands of the new law.

"We have a lot of organizations putting their heads together to work on math and science," says Ahlstrom, pointing out the importance of these subjects in the grand scheme of the law. "People are using it as an opportunity to shake things up." (See sidebar, "Will English Language Learners Be Left Behind?")

For Good Measure

Math and science—subjects that conjure intertwined images of theorems and formulas, calculators, and test tubes—go hand in hand in many educators' view. But they have not received equal attention under NCLB. Because most states had begun some

Five Strands of Mathematical Proficiency for Teaching

NCLB defines a highly qualified teacher as "one with a full certification, a bachelor's degree, and demonstrated competence in subject knowledge and teaching." The National Research Council's Mathematics Study Committee has taken a different approach to define quality teaching. The Committee identified five strands of mathematical proficiency necessary for successful teaching and learning of mathematics. The Committee defines teaching proficiency this way: "Proficiency in teaching is related to effectiveness: consistently helping students learn worthwhile mathematical content. Proficiency also entails versatility: being able to work effectively with a wide variety of students in different environments and across a range of mathematical content." Mathematical proficiency requires that teachers possess the following:

1. **Conceptual understanding of the core knowledge required in the practice of teaching.** One of the defining features of conceptual understanding is that knowledge must be connected so that it can be used intelligently. Teachers must make connections within and among their knowledge of mathematics, students, and pedagogy.

2. **Fluency in carrying out basic instructional routines.** Teachers who have acquired a repertoire of instructional routines can readily draw upon them as they interact with students in teaching mathematics. For example, teachers need to know how to respond to a student who gives an answer the teacher does not understand or demonstrates a serious misconception. They should know how to deal with students who lack critical prerequisite skills for the day's lessons. Research has shown that expert teachers have a large repertoire of routines—they can choose among a number of approaches for teaching a given topic or responding to a situation that arises in their classes.

3. **Strategic competence in planning effective instruction and solving problems that arise during instruction.** Strategic competence involves the analysis of instructional problems and ways of dealing with them. Teachers constantly face making decisions in planning instruction, implementing those plans, and interacting with students. Useful guidelines are seldom available for figuring out what to teach when, how to teach it, how to adapt material so that it is appropriate for a given group of students, or how much time to allow for an activity.

4. **Adaptive reasoning in justifying and explaining one's instructional practices and in reflecting on those practices so as to improve them.** Adaptive reasoning allows teachers to learn from their instruction by analyzing it and reflecting on it (e.g., the difficulties students have encountered in learning a particular topic, what the students have learned, how the students responded to particular representations, questions, and activities).

5. **Productive disposition toward mathematics, teaching, learning, and the improvements of practice.** Just as students must develop a productive disposition toward mathematics such that they believe that mathematics makes sense and they can figure it out, so too must teachers develop a similar productive disposition. Teachers should think that mathematics, their understanding of children's thinking, and their teaching practices fit together to make sense and that they themselves are capable of learning about mathematics, student mathematical thinking, and their own practice by analyzing what goes on in their classrooms. These teachers become more comfortable with mathematical ideas and ripe for a more systematic view of the subject.

Source: National Research Council. (2001). *Adding It Up: Helping Children Learn Mathematics.* Washington, D.C.: National Academy Press.

form of standards-based reform long before President Bush signed NCLB into law in January 2002, many already have met the law's initial requirements for setting standards and administering some tests in math and reading—but not in science.

Now commanding attention are NCLB deadlines in the next few years for further annual assessment in a wider range of subjects, perhaps most notably math and science. By the 2005–2006 school year, states must administer math tests to all students in grades 3–8. By 2007–2008, states must test students in science at least once in each of three grade spans: 3–5, 6–9, and 10–12.

Some officials worry that the rush to put tests in place could draw attention away from other concerns, such as NCLB demands that all students score at a "proficient" level on those tests by 2013–2014. Before then, states must demonstrate "adequate yearly progress" toward achievement goals, not only among students as a whole, but also for particular subgroups such as economically disadvantaged and minority students. Educators are still puzzled about how to meet the law's requirements, and the stakes are high. Schools that fail to hit targets year after year must offer students options—including a choice of attending other public schools or receiving supplemental services such as private tutoring, often at the district's expense. The consequences, already taking hold for schools identified as failing, will grow more severe for those that don't improve.

Meanwhile, observers say important priorities are being ignored. "There's so much focus right now on reading and math . . . science is getting squeezed out," laments Jodi Peterson, director of legislative affairs for the National Science Teachers Association (NSTA). For instance, Peterson believes that science teachers need help improving their content knowledge and ability to guide hands-on inquiry, especially at the middle school level. If schools do not start working on science curriculum, instruction, and professional development soon, it may be too late to build student skills to the levels necessary to show adequate progress down the line.

Also, the initial NCLB emphasis on math has led school systems to focus on science narrowly, as if it existed in a vacuum, complains Faimon Roberts, assistant director for science of the Louisiana Systemic Initiatives Program. But effective professional development in science can explore mathematical content and skills in rich, real-world contexts. The opportunity for teachers to combine the two subjects often is missed in the rush to stress mathematics, he says. (See "Grade-by-Grade Testing Policies in Math and Science.")

Grade-by-Grade Testing Policies in Math and Science

Education Week's Quality Counts 2003 survey of current assessment policies shows uneven coverage of these core subjects, particularly science, among southwestern states.

	Arkansas	Louisiana	New Mexico	Oklahoma	Texas
Grade 1	-	-	-	-	-
Grade 2	-	-	-	-	-
Grade 3	-	MS	MS	M	M
Grade 4	M	MS	M	-	M
Grade 5	MS	MS	MS	MS	MS
Grade 6	M	MS	MS	-	M
Grade 7	MS	MS	MS	-	M
Grade 8	M	MS	M	MS	M
Grade 9	[M]	MS	MS	-	M
Grade 10	MS [M]	M	MS	[MS]	MS
Grade 11	-	S	M	-	MS
Grade 12	-	-	-	-	-

M = Math.
S = Science.
[ ] = end-of-course or other tests that can be taken at multiple points in high school (the test is listed at the first grade level in which it can be taken).

Note: Except for places where the table reflects end-of-course exams separately, if more than one test is administered in a subject at a particular grade level, the subject is noted only once. Also, the chart includes New Mexico's pilot High School Standards Assessment in grade 11.

Source: *Education Week*, Quality Counts 2003.

Teachers under the Microscope

Besides standards and tests, NCLB calls for action in other areas of education, such as rewards and sanctions for schools, school choice and transfer policies, and provision of supplemental services. But experts suggest perhaps none of these is as important for mathematics and science education as teacher quality.

Because studies consistently show that teacher quality is among the top factors that determine student success, states are being required to define criteria for quality, guarantee that teachers are trained accordingly, and evaluate their competence. NCLB states that every public school teacher must be "highly qualified"—that is, certified and proficient in his or her subject matter—by the close of the 2005-2006 school year. Already, new teachers hired with federal Title I funds must meet elevated criteria, and similar criteria are in the works for school paraprofessionals hired with Title I funds.

"All teachers have to be highly qualified—and the bar is being set higher," warns Peterson. She points out that states now are in the process of setting teacher quality criteria. "What teachers need to be aware of is how they can be involved in that process."

States are exploring many means of improving teacher quality. Arkansas has implemented a statewide mentoring initiative that pairs new teachers with experienced educators. Teacher education programs throughout Louisiana have been retooled to dovetail with the state's academic standards in math, science, and other subjects. New Mexico has come up with a shortcut to full certification for teachers holding one-year licenses and others not certified in the subjects they teach. Oklahoma has sought incentives, such as increased health insurance benefits, to help fill teaching vacancies in shortage areas, including science and math. And math instructors in Texas who earn the title "master teacher" can receive $5,000 to mentor colleagues at struggling schools. (See "Teaching Quality by State.")

But only time will tell whether these efforts can strengthen science and math education. To do so, teacher quality initiatives must counter the common pattern illuminated by the results of a recent Louisiana Department of Education study, which showed that teachers who earn high scores on professional exams tend to find jobs in high-achieving schools, not those deemed in need of assistance.

Teaching Quality by State

The Education Commission of the States (ECS) keeps a running record of states' efforts to meet NCLB mandates in various areas—from standards and assessment to accountability and assistance for schools—that shows southwestern states scrambling to meet the law's demands regarding teacher quality.

	Arkansas	Louisiana	New Mexico	Oklahoma	Texas
Highly Qualified Teachers Definition	P	N	N	P	N
Subject Matter Competence	U	N	P	P	Y
Test for New Elementary Teachers	Y	P	Y	Y	Y
Highly Qualified Teacher in Every Classroom	N	N	N	N	N
High Quality Professional Development	N	N	N	P	P

Y = Appears to be on track. P = Appears to be partially on track. N = Does not appear to be on track. U = Unclear or data not available.

Source: Education Commission of the States, NCLB Survey, February 2003.

Resources for Reform

With all that NCLB requires, it is no wonder many math and science educators are asking what resources are available to help them achieve these ambitious new goals. NCLB arrived, in fiscal 2002, with the biggest dollar increase ever in federal education spending. Moreover, in February, Congress again boosted the U.S. Department of Education's budget—by $3.2 billion, or 6.3 percent more than last year. Signaling the new priority, the department has established a five-year Mathematics and Science Initiative, kicked off with a math summit in February, to promote public awareness, strengthen teaching, and build the research base for math and science education. On the other hand, critics charge that the administration already is turning its back on reform, noting that the president budgeted $6 billion less this year in aid to disadvantaged students than NCLB called for in 2004.

NCLB's advocates are quick to defend the agenda. "It's not just a matter of resources," argues Susan Sclafani, acting assistant secretary for the U.S. Department of Education's Office of Vocational and Adult Education. "If people continue to do what they've always done, they'll get what they've always gotten."

"Sometimes we get the idea that money will solve all our problems. I'm not convinced," agrees Charles Watson, the Arkansas Department of Education's federal liaison. "We don't ever want to do away with anything; we just want to add." NCLB may do some good, Watson says, by forcing schools to face tough choices, determine the best solutions to their problems and "go back to ground zero and start over."

Sacra Nicholas points to an example in Oklahoma. "Our professional development needs to become more focused," says the executive director of the Coalition for the Advancement of Science and Mathematics Education in Oklahoma, a statewide advocacy group. "That may not mean having more funds. . . . It may mean using data differently to determine how we can use those funds."

And if educators are ready to do business differently, then NCLB will allow them, proponents say. Modifications in federal education spending and the Title I funding formula not only target support to poor students, but also provide states and districts with enhanced flexibility in using the money. They can, for example, transfer half of their funding from

Key NCLB Web Resources

U.S. Department of Education
www.nclb.gov

National Council of Teachers of Mathematics
www.nctm.org/news/articles/2002-11nb_nochild.htm

Education Commission of the States
www.ecs.org/ecsmain.asp?page=/html/issues.asp?am-1

Education Week
www.edweek.org/context/topics/issuespage.cfm?id=59

the four main federal programs—Teacher Quality, Education Technology, Safe and Drug Free Schools, and Innovative Education Programs—to explore ways of boosting student learning without seeking approval in advance.

But some see the increased flexibility as a double-edged sword. Education systems wanting to enhance teacher quality must make tough choices—for example, between professional development and hiring new teachers. "It's putting them between a rock and a hard place in some instances," says the NSTA's Peterson. Others, like Louisiana's Faimon Roberts, speculate that increased flexibility could do more harm than good if local decision makers lack the expertise to make informed choices. (See "Key NCLB Web Resources.")

Using What We Know

To encourage states and districts to spend wisely, the law stipulates that they use methods based on scientific research. Some science and math educators see such requirements as evidence that NCLB will sap local control and dictate too much of what happens in the classroom. But the law's backers say its focus on research-based practices and regular assessment will help educators use proven strategies to reach the students who need it most.

"With the data from the individual child, classroom, and school, we can better see what is working and what's not," Sclafani says. "I think people are going to be really zeroing in on the individual child's needs rather than what was taught to the whole class." This approach, she contends, is what produced the success of Texas, where Sclafani previously served as chief of staff for the Houston Independent School District's educational services.

What will such changes look like in other states in the region, such as Arkansas? "We're going to have to become less dependent on textbooks and more dependent on our own frameworks," predicts Watson. "We're making some headway, but we have a long way to go."

Oklahoma's Nicholas voices tentative hope that changes mandated by NCLB will provide the strong medicine needed to cure math and science education of longstanding ills. "That may be healthy," she says, "but it's going to be painful."

Geoff Camphire is a freelance writer based in Virginia who has written about education issues for more than 10 years. He can be reached at geoffcamphire@yahoo.com.

Will English Language Learners Be Left Behind?

School systems nationwide face many of the same challenges under NCLB, but those in the Southwest often confront the added obstacle of limited English proficiency (LEP) among a large and growing share of students.

Many southwestern educators know the familiar frustration of trying to teach subjects such as math and science to students, mostly Latinos, still struggling to master English. Impact on the achievement and long-term educational attainment of these students can be devastating. A study of census data released in February underscores the point: Only 16 percent of Hispanic high school graduates earn a four-year college degree by age 29, as compared with 37 percent of whites and 21 percent of African Americans, according to the Pew Hispanic Center.

NCLB aims to help change such statistics, but success is far from assured. The Education Commission of the States (ECS), which monitors state progress toward NCLB compliance, warns that, as of February 2003, some southwestern states are not on track to meet the law's requirements for LEP and migrant students in the following areas:

- Inclusion of LEP Students in Assessments
  Arkansas allows three years in its program before including these students.
- Assessment of English Language Proficiency
  Louisiana officials say they will implement relevant policies next year, but ECS finds no documentation to verify this.
- Inclusion of Migrant Students in Assessments
  ECS finds no New Mexico law or program explicitly establishing systems to track migrant students and ensuring their participation in state and district assessments even though statutes and regulations require participation of "all students."

Oklahoma, on the other hand, appears to be on track to meet NCLB's requirements for such students. Likewise, Texas is mostly on track, except for a component of its accountability system that allows exemptions for some LEP students, according to ECS.

To address the needs of English language learners, southwestern school systems should take advantage of the new funding flexibility that NCLB provides, says Faimon Roberts, assistant director for science of the Louisiana Systemic Initiatives Program. Title III now consolidates earlier bilingual and immigrant education programs into a formula-based state grant under certain conditions—for example, giving states and districts additional latitude in spending the money to meet their students' unique needs. The change aims mainly to raise literacy, but it's not hard to see the potentially positive impact on achievement in such subjects as science and math.

The Lesson Study Approach
Collaboration and Creativity Are Key to Teaching Mathematics Concepts

By Johanna Gilmore and Ashley Hawkins

The fifth graders filed into their classroom and arranged their desks in groups of three for their mathematics lesson. The teacher placed two Hershey's® chocolate bars, each composed of 12 little sections, on the middle person's desk in each group. The students exchanged looks of glee. Were they supposed to eat the chocolate bars? Surely the chocolate had nothing to do with math. But because of the chocolate bars, these students at Howard Perrin Elementary School in Benton, Arkansas, went home that day with a better understanding of proportional reasoning and unitizing.

Oklahoma teachers Dawn Mills, Glenda Pettus, and Lesley Zellinger prepare a lesson plan during the Teachers as Leaders Summer Academy.

They learned that a unit could be more than one thing, such as three pizzas, five pencils, or, in this case, the two candy bars on the paper plates in front of them. The teacher had removed three sections from one of the chocolate bars in each group. "How much candy do you have on that plate?" the teacher asked each of the groups. One group who looked at the candy bars as a whole answered, "1 3/4." Another group, who saw the candy bars as 24 sections said, "21/24" or "7/8." By the time all the groups had finished answering the question, the teacher had written six different numbers on the board. "How can all of these answers be right?" she asked her students. The students realized their answers didn't make sense until they labeled their numbers with units.

The Logic Behind the Lesson Study Model

Unitizing, or the cognitive assignment of a unit of measurement to a given quantity, is a component of proportional reasoning. To better teach their students unitizing and other mathematical concepts, some Perrin Elementary School fifth-grade teachers committed to yearlong SEDL professional development that began with a weeklong summer academy. These teachers created the "How Sweet It Is" math lesson, complete with chocolate bars, after participating in the Arkansas 2002 Teachers as Leaders Summer Academy in middle school mathematics. Arkansas mathematics teachers in grades 5–9 were invited to attend the academy, which was designed by SEDL's Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST). SCIMAST staff have conducted similar academies in Louisiana, Oklahoma, and Texas.

At the July 2002 Arkansas academy in Little Rock, 15 teachers from four elementary and middle schools in Benton, Little Rock, and North Little Rock gathered to learn about the lesson study process. While focusing on proportional reasoning for this process, small groups of teachers worked collaboratively to research and develop a mathematics lesson or series of lessons using research-based resources such as Susan J. Lamon's *Teaching Fractions and Ratios for Understanding* (1999).

But the main goal of the process isn't the lesson. "Lesson study is not about designing a perfect lesson. The lesson doesn't have to be original—it can pull from what's already out there," said SEDL program specialist Como Molina, who facilitates the middle school mathematics academies with program associate Maria Torres. "The key is improving instruction, and the lesson study approach addresses so many instructional issues in an economical way."

While engaging in the lesson study approach, teachers can deepen their own content knowledge, adopt effective teaching strategies, and become more reflective about their instruction. This 25-year-old model with roots in Japan is quickly gaining momentum in the United States as educators learn to adapt it to the U.S. education infrastructure, which differs from Japan's in the amount of teacher planning time among other issues.

"If implemented correctly, the lesson study model of teacher professional development can be a regular, imbedded in-house system for promoting teacher growth and improving teacher quality in schools and districts," Torres said. She and Molina began conducting Teachers as Leaders Summer Academies on middle school mathematics in 2001 to

1. deepen teachers' mathematics content understandings,
2. investigate the conceptual basis of mathematics as a tool for inquiry as well as a process for problem solving,
3. model effective instruction and assessment practices to create meaningful learning opportunities for all students, and
4. apply the teacher-designed activities in the classroom through a research lesson study approach.

Based on what they learned from the Summer 2001 academy process, which did not include on-site follow-up meetings among academy participants, Torres and Molina decided to use the Summer 2002 academies in Arkansas, Louisiana, and Oklahoma as springboards for follow-up colloquiums in several locations. These colloquiums fit into the structure of the lesson study approach, which encompasses peer comment on instruction and learning as opposed to instructor critique. The colloquiums included public classroom demonstrations of the lessons the teachers developed during the summer academy. Those attending the demonstrations reflected on the lessons' effectiveness. The teachers then modified the lessons based on this feedback and met again during the 2003 Teachers as Leaders Summer Academy to share final reflections about what they had learned during the school year.

"We worried teachers would feel like they were being judged during these demonstrations, but that has not happened," Molina said. "That's because the lesson study approach allows the focus to stay on the students and what's being taught. There has been no criticism of the teachers."

The lesson study group from Perrin Elementary School in Benton gave a public demonstration of "How Sweet It Is" in October 2002, and the lesson study group from Poplar Street Middle School in North Little Rock presented their lesson in March 2003. Just as the Perrin teachers used chocolate bars to teach proportional reasoning, Poplar Street Middle School teachers created a lesson titled "What Is the Cost of Smoking?" to teach their sixth-grade students unitizing as well as the financial cost of smoking over a lifetime. While the professional development model at the 2002 and 2003 academies was lesson study the content focus was proportional reasoning.

Why Proportional Reasoning?

Some may wonder why one mathematical concept remained the academy emphasis for two years. The Third International Mathematics and Science Study (TIMSS) showed that U.S. mathematics and science curricula "lack coherence, depth, and continuity, and cover too many topics in a superficial way." Additionally, results from the 1996 National Assessment of Educational Progress test indicated that only 1 percent of students in grade 8 and 3 percent of students in grade 12 responded correctly on both claims of the following mathematics problem:

> In 1980 the populations of Town A and Town B were 5,000 and 6,000, respectively. The 1990 populations of Town A and Town B were 8,000 and 9,000, respectively. Brian claims that from 1980 to 1990 the populations of the two towns grew by the same amount. Use mathematics to explain how Brian might have justified his claim. Darlene claims that from 1980 to 1990 the population of Town A grew more. Use mathematics to explain how Darlene might have justified her claim.

The lesson study approach addresses so many instructional issues in an economical way.

Como Molina, SEDL program specialist

"The kids are walking into these tests with a lot of whole number tendencies and absolute thinking," Molina said. "Our math standards slight the topic of absolute versus relative thinking."

Given these findings, SCIMAST staff designed the summer academies to give teachers a fresh, focused approach to developing their content knowledge.

During the first few days of the summer academies, Torres and Molina assisted teachers in constructing a knowledge base for proportionality. SCIMAST staff stressed that this concept is the capstone of elementary school arithmetic and the cornerstone of all that is to follow. Participants grappled with open-ended math problems, brainstormed, and built connections among concepts relating to proportionality, and explored the teaching of fractions and ratios in groups.

For example, one of the mathematics problems Torres and Molina presented to the teachers focused on investments.

> Janie invested $10 in a stock. After six months, it was worth $20. Julie invested $80 in a stock. After six months, it was worth $100. Who made the better investment?

In the absolute sense, Julie made the better investment since she gained more money. But in the relative sense, the answer would be Janie since she doubled her investment. Both answers are correct, Torres and Molina said, as they emphasized the need for teachers to teach both absolute and relative thinking to allow for diverse ways of understanding.

"We don't try to traumatize them with these problems," Torres said. "We just want them to see

Stanley Gaddis and Dianne Nzinga present their findings from research at the Louisiana Teachers as Leaders Summer Academy.

the different components involved in proportional reasoning." At the request of Arkansas academy participants, Torres and Molina also wove algebraic thinking into the session with problems on patterns, functions, and inverse variations to help middle school teachers prepare their students for pre-algebra.

During the academy, participants realized they needed to ask deeper questions during math lessons to improve students' relative thinking. In *Teaching Fractions and Ratios for Understanding,* Lamon encourages teachers to become conscious of the ways in which they ask questions through the following example. If Marcus has six cookies and Crystal has nine, the questions "Who has more cookies?" "How many more cookies does Crystal have than Marcus?" and "How many fewer cookies does Marcus have?" only cover additive or absolute thinking. Questions such as "How many times would you have to stack up Marcus's cookies to get a pile as high as Crystal's?" "What part of a dozen cookies does Crystal have?" and "Each child has three chocolate chip cookies. What percent of each child's cookies are chocolate chip?" require multiplicative or relative thinking, which is more important in proportional reasoning.

In addition to building the participants' knowledge of proportional reasoning, Torres and Molina showed the teachers that they could tailor a lesson to their students' interests and needs by using a drama to create more active thinking and learning in their students.

"Maria and Como conducted our academy the same way we are supposed to be teaching—the way we want to teach," said Jan Adney, a fifth-grade mathematics teacher at Perrin Elementary School. "They made us do the work, and by the end of the session, we had learned so much. I think they made us feel the way we're supposed to make the kids in our classes feel."

Supportive Collaboration and Commentary

Along with content understanding and lesson study model use, SCIMAST staff worked to promote collaboration through the Teachers as Leaders Academies. During each academy, teachers worked as teams to research and write lessons. During the two follow-up colloquiums, members of the different teams visited Perrin Elementary School and Poplar Street Middle School to see what a proportional reasoning lesson looked like in other settings with different students and different contexts.

Judy Trowell, a coordinator of math-specialist training from the Arkansas Department of Education, was the invited commentator for the Perrin colloquium and a guest for the Poplar Street colloquium. She observed how the teachers were questioning the students and how the collaborative opportunities benefited teachers in planning and refining a lesson.

"It was obvious that the questions, examples, and materials were carefully planned for the lesson," Trowell said. "Good lessons do not just happen because you open the book and read a good chapter. They happen because the teachers look at the examples, backtrack, and ask themselves, 'How do I relate this to the experiences and content background my children have?' 'Can I hold up a candy bar and get them to verbalize what they see in different ways—the different units?' That promotes rich discussions."

Trowell said that teachers don't often get the opportunity to observe each other in a friendly manner as they did in the "How Sweet It Is" and "What Is the Cost of Smoking?" colloquiums. "By having them reflect on the lessons and the kinds of questions and discussions that were going on at the students' tables, they were beginning to grapple with the bigger picture of what happens when you provide information versus when you probe thinking."

The lesson study approach also addresses how teachers tend to work in isolation. Even though differences between the student populations at Perrin Elementary School and Poplar Street Middle School made some portions of the lessons difficult to apply at both colloquium sites, many of the teachers said they were more comfortable with collaboration because of their academy work.

"It's helped me realize that working with another colleague makes lesson development much easier," said Judy Broughton, a sixth-grade mathematics teacher at Poplar Street. "If we can have some time to work together, students will benefit from it." Broughton and a colleague make time for lesson planning collaboration in the evenings after school.

Perrin Elementary principal Pam Burton, who was the invited commentator for the Poplar Street colloquium, was so impressed by the results she saw from the "How Sweet It Is" lesson that she restructured the school day to allow for more collaboration among her school's teachers. She changed the school's dismissal time and released teachers from their after-school duties so they have 40 minutes each day to work together in addition to their regular preparation time. She also substitutes for teachers who wish to observe other teachers implement new lessons in their classrooms.

"We're trying to become a professional learning community, and collaborative work is just a must," Burton said. "We've been getting our feet wet a little more every year for several years, but nothing as intense as what the math teachers did with SEDL. We had not devoted that much time to writing a lesson, testing it, and improving it together before the teachers attended the academy."

Adney and fellow Perrin fifth-grade teacher Teresa Brown worked with teachers in their grade and fourth grade to refine "How Sweet It Is."

"We feel more comfortable sharing ideas now. Instead of going into our own separate rooms, we talk more to each other and the other two fifth-grade teachers," Adney said. "We're trying to share more ideas when somebody does something good."

Adney and Brown are also sharing a report they wrote on algebraic thinking for the SCIMAST academy. During their report research, they discovered that teachers can begin developing students' skills to solve the unknown portion of algebraic equations as early as kindergarten. They plan on sharing what they've learned with the different grade-level teachers at Perrin.

Torres notes that the types of practices that teachers experience with lesson study align with many of the expectations of the five core principles of the National Board for Professional Teaching Standards: (1) teachers are committed to students and their learning, (2) teachers know the subjects they teach and how to teach those subjects to students, (3) teachers are responsible for managing and monitoring student learning, (4) teachers think systematically about their practice and learn from experience, and (5) teachers are members of learning communities. SCIMAST staff ask academy participants to consider becoming board certified as part of the leadership component of the academy, Torres said.

"Given time and other personal constraints, some of our participants will not be able to go through the national board certification process, but we hope that they all will return to their schools and lead a change in practice based on their new knowledge of content, collaboration, and expectations at both the state and national levels."

SEDL

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SCIMAST Academy Resources

SCIMAST staff distributed the following materials to participants in the Teachers as Leaders Middle School Mathematics Academy initial sessions in Arkansas, Louisiana, and Oklahoma during Summer 2002. Teachers used these resources to develop lessons for SCIMAST lesson study colloquiums in these states throughout the 2002–2003 school year. SCIMAST staff began facilitating the academy and colloquium sessions in Texas schools in July 2003.

Lamon, S. J. (1999). *Teaching Fractions and Ratios for Understanding.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lewis, C. C. (2002). *Lesson Study: A Handbook of Teacher-Led Instructional Change.* Philadelphia: Research for Better Schools.

Ma, L. (1999). *Knowing and Teaching Elementary Mathematics.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

National Board for Professional Teaching Standards. (1998). *Middle Childhood through Early Adolescence/Mathematics Standards.* Washington, DC: National Board for Professional Teaching Standards.

National Council for Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics E-Standards.* Reston, VA: National Council for Teachers of Mathematics.

National Research Council. (2002). *Adding It Up: Helping Children Learn Mathematics.* Washington, DC: National Academy Press.

Stigler, J.W., & Hiebert, J. (1999). *The Teaching Gap.* New York: The Free Press.

SCIMAST staff also used the following resources during the Teachers as Leaders Middle School Mathematics academies.

Greenes, C., & Findell, C. (1999). "Developing students' algebraic reasoning abilities." *Developing mathematical reasoning in grades K–12.* Reston, VA: National Council for Teachers of Mathematics.

Behr, M., & Hiebert, J. (1988). "Proportional reasoning." *Number concepts and operations in the middle grades.* Reston, VA: National Council for Teachers of Mathematics.

Lewis, C. C. (2000). *Can you lift 100 kilograms? The lesson research cycle* [video]. Oakland, CA: Mills College.

Other general resources for middle school mathematics curriculum development and teaching include these:

Eisenhower National Clearinghouse
www.enc.org

National Council of Teachers of Mathematics
www.nctm.org

National Science Foundation
www.nsf.gov

Northwest Regional Educational Laboratory
www.nwrel.org

Research for Better Schools
www.rbs.org/lesson_study/readings_resources.shtml

Southwest Educational Development Laboratory
www.sedl.org/scimast/teachers_as_leaders/math/ms_math.html

It's Elementary:

Introducing Algebraic Thinking Before High School

By Leslie Blair

Sitting in Mrs. Peavey's Algebra I class, I experienced algebra much like millions of other Americans—as an intensive study of the last three last three letters of the alphabet. I failed to grasp the importance of algebra—how it provides support for almost all of mathematics or to understand its power as a tool for analytical thinking. It was a course I endured to get into college.

Algebra for All

Thirty years later, algebra is not just for those who plan to attend college, but for everyone. Robert Moses, founder of the Algebra Project, says that in today's technological society, algebra has become a gatekeeper for citizenship and economic access. As the world has become more technological, the reasoning and problem solving that algebra demands are required in a variety of workplace settings. We also see evidence of the growing importance of algebra in standards and assessments. National and state assessments include algebraic skills at the eighth-grade level and many high school exit exams now test algebraic proficiency. It seems the mantra "algebra for all" has been firmly established. Johnny Lott, president of the National Council of Teachers of Mathematics (NCTM), agrees. "I think most everybody recognizes the importance of algebra. It is a question of how they introduce it and when," he says.

James Kaput, a researcher from the University of Massachusetts, Dartmouth, believes that by "algebrafying" the K–12 curriculum, we can fulfill the promise of algebra for all and eliminate "the most pernicious curricular element of today's school mathematics — late, abrupt, isolated, and superficial high school algebra courses" (Kaput, 2000). The idea isn't new. Kaput, other researchers and educators, and the NCTM have been promoting algebra as a K–12 experience, integrating algebraic thinking and reasoning throughout the mathematics curriculum.

University of Wisconsin researcher Linda Levi, who has been working on a study called the Early Algebra Project for the past eight years, emphasizes, "We're not saying you should be teaching high school algebra to elementary school children." Instead, Levi and her colleagues in the Early Algebra Project, Thomas Carpenter and Megan Loef Franke, believe teachers should engage children in learning about the general principles of mathematics as they are learning arithmetic. They say that the learning of arithmetic is often isolated from other related mathematical ideas. This deprives students of powerful ways of thinking about mathematics and can make it more difficult for students to learn algebra later on. Many students studying high school algebra don't see the procedures they use to solve equations or simplify expressions as based on the same properties that they used in arithmetic computation (Carpenter, Franke, & Levi, 2003).

The Early Algebra Research Project

The Early Algebra Research Project began in 1996 under the direction of Thomas Carpenter, director of the National Center for Improving Student Learning and Achievement in Mathematics; Megan Loef Franke, an associate professor at the University of California, Los Angeles, and director of Center X: Where Research and Practice Intersect for Urban School Professionals; and Linda Levi, associate researcher at the Wisconsin Center for Education Research. It grew out of the Cognitively Guided Instruction research program begun in 1985.

The study, which initially began in Madison, Wisconsin, involved approximately 240 elementary school students and their teachers. It found that innovative professional development and refocused mathematics instruction paved the way for elementary school children to begin to reason algebraically.

The researchers are now conducting a large-scale experimental study in Los Angeles, involving about 5,000 elementary school students and their teachers. The study is examining the effects of the teacher professional development program on students' algebraic understandings.

Levi says the researchers have collected achievement data for the students involved and will complete their analysis in 2004.

Levi explains, "Kids come to school with a very rich understanding of numbers and operations. They may still make mistakes when counting but they solve many math problems. A lot of kindergartners come in knowing that when you add zero to a number, the number doesn't change. That is a big principle in mathematics. And they can talk about it. Maybe they can't write it down or can't read it if you write it down, but they can start talking about things that they know to always be true in math." Levi adds that teachers often don't realize how powerful the patterns or generalizations that their students express can be. These expressions should be seen as opportunities for class discussions so that all of the students have access to these ideas. "As teachers, it's really our job to understand how children think about mathematics when they come to school and build on this informal understanding," she says.

Fostering Students' Thinking

According to Blanton and Kaput (2003), teachers must find ways to support algebraic thinking and create a classroom culture that values "students modeling, exploring, arguing, predicting, conjecturing, and testing their ideas, as well as practicing computational skills." They suggest that teachers "algebrafy" current curriculum materials by using existing arithmetic activities and word problems, transforming them from problems with a single numerical answer to opportunities for discovering patterns and making conjectures or generalizations about mathematical facts and relationships and justifying them. This can be as simple as encouraging children to discuss why they believe a mathematical statement or solution to a problem is correct. Blanton and Kaput suggest teachers use the following prompts as ways to extend student thinking:

- Tell me what you were thinking.
- Did you solve this in a different way?
- How do you know this is true?
- Does this always work?

In their pilot study involving 240 students, Carpenter, Franke, and Levi found that teachers have good luck beginning discussions among students and eliciting generalizations from students using true-false and open-number sentences (see examples in the sidebar "Number Sentences Used to Elicit Generalizations"). For students in upper elementary school this can lead to discussion of what is required to justify a generalization.

Number Sentences Used to Elicit Generalizations

Below are examples of number sentences teachers used to help students articulate mathematical generalizations.

EXAMPLES 78 + 0 = 78; 23 + 7 = 23*

"When you add zero to a number, you get the number you started with."

EXAMPLES 96 - 96 = 0; 74 - □ = 74

"When you subtract a number from itself, you get zero."

EXAMPLES 96 x 0 = 0; 43 x 0 = 43*

When you multiply a number times zero, you get zero.

EXAMPLES 65 x 54 = 54 x 65; 94 x 71 = 71 x □

"When multiplying two numbers, you can change the order of the numbers."

*denotes a false number sentence

Source: National Center for Improving Student Learning & Achievement in Mathematics and Science. (2000). *Building a Foundation for Learning Algebra in the Elementary Grades.*

Why Understanding Equality Matters

Children must understand that equality is a relationship that expresses the idea that two mathematical expressions hold the same value. It is important for children to understand this idea for two reasons. First, children need this understanding to think about the relationships expressed by number sentences. For example, the number sentence $7+8 = 7+7+1$ expresses a mathematical relationship that is central to arithmetic. When a child says, "I don't remember what 7 plus 8 is, but I do know that 7 plus 7 is 14 and then 1 more would make 15," he or she is explaining a very important relationship that is expressed by that number sentence. Children who understand equality will have a way of representing such arithmetic ideas; thus they will be able to communicate and further reflect on these ideas. A child who has many opportunities to express and reflect on such number sentences as $17-9 = 17-10+1$ might be able to solve more difficult problems, such as 45-18, by expressing $45-18 = 45-20+2$. This example shows the advantages of integrating the teaching of arithmetic with the teaching of algebra. By doing so, teachers can help children increase their understanding of arithmetic at the same time that they learn algebraic concepts.

A second reason that understanding equality as a relationship is important is that a lack of such understanding is one of the major stumbling blocks for students when they move from arithmetic to algebra (Kieran, 1981 & Matz, 1982). Consider, for example, the equation $4x+27 = 87$. Many would begin to solve this equation by subtracting 27 from both sides of the equal sign. Why may we do so? If the equal sign signifies a relationship between two expressions, it makes sense that if two quantities are equal, then 27 less of the first quantity must equal 27 less of the second quantity. What about children who think that the equal sign means that they should do something? What chance do they have of being able to understand the reason that subtracting 27 from both sides of an equation maintains the equality relationship? These students can only try to memorize a series of rules for solving equations. Because such rules are not embedded in understanding, students are highly likely to remember them incorrectly and not be able to apply them flexibly. For these reasons, children must understand that equality is a relationship rather than a signal to do something.

Source: Falkner, K. P., L. Levi, and T. P. Carpenter (1999). Children's understanding of equality: A foundation for algebra. *Teaching Children Mathematics, 6*(1), p. 234. Reprinted with permission from the National Council of Teachers of Mathematics.

The Notion of Equality and Relational Thinking

One of the major concepts that Carpenter, Franke, Levi, and other researchers have written a lot about is getting children to understand that the equal sign represents a relationship. At the beginning of the Early Algebra Project, participating teachers presented the following problem to their students:

$$8 + 4 = \square + 5$$

Eighty-four percent of 145 sixth-grade students gave the solution to the problem as "12." Another 14 percent gave the solution as "17." It became clear through subsequent class discussions that to these students, the equal sign meant "carry out the operation." They had not learned that the equal sign expresses a relationship between the numbers on each side of the equal sign. Levi says, "We're advocating that when teachers begin using the equal sign with children, they use it in a way that encourages an understanding of a relationship between two quantities rather than just a signal to perform the operation. Number sentences such as

6 = 6 and 8 = 7 + 1 need to be included when teachers begin introducing the equal sign."

This type of relational thinking is crucial to students who are learning algebra but it also enhances computation skills. "If you look at algebra in a more general sense," says Levi, "what you are really looking for is the major unifying principles and properties of mathematics. As soon as kids start learning how to count, and then add, subtract, multiply, and divide, they are encountering these major principles. It makes computation a lot more efficient and accurate. For example, if kids understand the distributive property, their multiplication strategies are much more efficient and accurate than if they are trying to do repeated addition over and over again." Teachers can also provide opportunities for building computation skill in the context of finding and generalizing mathematical patterns and relationships.

How do teachers know if a student is using relational thinking? Levi explains, "We eventually want children to solve a problem like 397 + 248 = 396 + t without computing. Initially children will solve this problem by adding 397 and 248 getting 645 and then figuring out what they have to add to 396 to get 645. But by the end of elementary school, I want kids to look at the whole number sentence and realize that since 397 is 1 more than 396, t has to be one more than 248. There are relationships such as this one for subtraction, multiplication, and division as well. I want children to fully understand the operations with known quantities before they start a formal study of algebra where many of the quantities are variables or unknowns."

How Do We Get Teachers to Think Algebraically?

Elementary school teachers will need professional development to integrate algebraic thinking into their classrooms, as they typically have experienced algebra much like the majority of us—as Algebra I and II in high school and college. Blanton and Kaput (2003) write, "Elementary teachers need their own experiences with a richer and more connected algebra and an understanding of how to build these opportunities for their students."

A critical component of the Early Algebra Project has been its professional development for the teachers involved in the project. The project enabled teachers to spend time together discussing mathematics and their students' thinking. One of the principals in the Early Algebra Project requested that teachers bring in examples of their students' work and discuss with her what they were learning in the project. Such support can go a long way in encouraging teacher development.

In the Classroom

"Build a Foundation for Learning Algebra"

Here are a few ways to provide a foundation for learning algebra.

Ask questions that provide a window into children's understanding of important mathematical ideas. For example, students' responses to the number sentence 9 + 6 = □ + 8 tells a great deal about their understanding of the meaning of the equal sign. Probe students' reasons for their answers. Ask students *why* they answered as they did.

Provide students opportunities to discuss and resolve different conceptions of mathematical ideas. For example, different conceptions of the equal sign that emerge from students' solutions to the open number sentence 9 + 6 = □ + 8 can provide the basis for a productive discussion.

Provide students with equations that help them understand that the equal sign represents a relation between numbers, not a signal to carry out the preceding calculation. Examples include □ = 8 + 9, 8 + 6 = 6 + □, 9 + 6 = □ + 8, Vary the format of number sentences. Include sentences in which the answer does not come right after the equal sign.

Provide students with true and false number sentences that challenge their misconceptions about the equal sign (e.g., 8 = 5 + 3, 9 = 9, 7 - 4 = 7 - 4).

Provide students problems that encourage them to make generalizations about basic number properties (see "Number Sentences to Elicit Generalizations.") When they provide an answer to one of the problems, ask them how they know their answer is correct. That often will result in their stating a generalization such as "When you subtract a number from itself, you get zero." When they do state a generalization like this, ask for example, "Is that true for all numbers?"

Have students justify generalizations they or their peers propose. Justification of generalizations requires more than providing a lot of examples (e.g., 8 x 5 = 5 x 8). By expecting children to justify their claims, you can help them gain skills in presenting mathematical arguments and proofs. Use the questions "Will that be true for all numbers?" and "How do you know that is true for all numbers?" repeatedly to encourage students to recognize that they need to justify their claims in mathematics.

Reprinted from *K–12 Mathematics & Science: Teaching Considerations* (Fall 2000), published by the National Center for Improving Student Learning & Achievement in Mathematics and Science, Wisconsin Center for Education Research, Madison, Wisconsin.

Web sites

Eisenhower National Clearinghouse (ENC)

www.enc.org

Most mathematics and science teachers are probably familiar with the ENC and its magazine, *ENC Focus*. The Web site contains all sorts of lesson plans, activities, and resources. Most materials are free and online. A search for "algebraic thinking" on www.enc.org yielded 300 suggestions.

National Council of Teachers of Mathematics

http://www.nctm.org

The Web site of the National Council of Teachers of Mathematics is geared to members of the organization, but includes a problem of the week for elementary, middle school, and high school levels as well as some lesson plans and activities that everyone may access. Also online are abstracts for recent issues of NCTM journals such as *Teaching Children Mathematics and Mathematics Teaching in High School.*

www.illuminations.nctm.org

This is the NCTM Web site focused on the NCTM Principles and Standards for School Mathematics. It contains activities, resources, and lesson plans based on the standards and includes interactive and multimedia math investigations.

www.figurethis.org

Figure This! is a Web site cosponsored by the National Council of Teachers of Mathematics, the National Action Committee for Minorities in Engineering, and Widemeyer Communications. It features mathematics challenges for families of middle school students and includes interesting problems and math facts. "Teacher's Corner" provides details on how to conduct a family math challenge at your school.

The National Center for Improving Student Learning and Achievement in Mathematics

www.wcer.wisc.edu/ncisla

Look under Teachers' Resources on this site for a section called "Building Students' Algebraic Reasoning." Here you will find articles, activities, and lesson plans to extend algebraic thinking. The Web site also includes research summaries, newsletters, and other publications.

References and Suggested Reading

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SEDL

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Correction:

In the last issue of *SEDL Letter* (Putting Reading First), in the article, "Negotiating La Frontera: Reading and the Migrant Student," we said that Pringle-Morse Elementary and Middle School is located in Amarillo, Texas. Pringle-Morse is located in Morse, Texas, nearly 90 miles north of Amarillo. We apologize for this error.

Integrating Science with English Language Development

By Okhee Lee and Mary Avalos

In a classroom where the students are predominately Hispanic, the teacher asks, "When you have a fever, what number does your mom tell you that the thermometer says?" Students call out numbers such as 38, 39, 40, 100, and 102. The teacher writes these numbers on an overhead projector. The students are puzzled by the numbers. How could they be so different? The teacher puts down a transparency of a thermometer and asked the students to look at the numbers. And they notice the 40 is about the same as 100. One student pipes up, "Oh, it's bilingual like us."

Since the early 1990s, we have been conducting research on promoting achievement and equity in science and literacy for culturally and linguistically diverse students in a large urban school district (Lee, 2002; Lee & Fradd, 1998). Currently, the research involves all teachers (more than 75) and their students (more than 2,000) from grades three through five at six elementary schools representing diverse languages and cultures, including Hispanic, Haitian, African-American, and Euro-American backgrounds.

The state in which the research is conducted implements instruction in English with ESOL students, without bilingual education. Subject-area instruction for ESOL students in their home languages is limited. At the elementary school level, the state mandates high-stakes statewide assessments in reading and mathematics from grades three through five and in writing at grade four. Statewide assessment in science is administered at the fifth-grade level as of the 2002–2003 school year, but it does not yet count toward school grades on which accountability is based.

Since science materials appropriate to the goal of our research were not readily available, we developed instructional units based on science standards documents (American Association for the Advancement of Science, 1989, 1993; National Research Council, 1996). These units include Measurement and Matter (grade 3), the Water Cycle and Weather (grade 4), and the Living Planet with a focus on the ecosystem and solar system (grade 5). Teachers participate in the revision and refinement of the units (Fradd, Lee, Sutman, & Saxton, 2002) and supplementary materials, as they offer insights about the linguistic and cultural experiences of diverse student groups, the appropriateness of the science content for elementary students, and the feasibility of implementation in elementary classrooms.

In our research, teachers attend full-day workshops on several regular school days over the course of a school year. Workshop activities are structured to encourage active involvement of all teachers—for example, by sharing questions and suggestions, and reflecting on their own beliefs and practices. Teachers also share insights about similarities and differences in the teaching and learning environments among the six schools. Initial workshops focus on familiarizing teachers with the purpose and objectives of the research and helping them gain experience in implementing specific activities and strategies with their students. Gradually, workshops involve helping teachers reflect on their own practices, assess the impact of their practices on student learning, and generate and sustain new ideas for effective practices.

We encourage principals and teachers to include English language learners (ELLs) in science instruction in their regular classrooms. Since the intervention is schoolwide and the emphasis on teaching science to ELLs is communicated to school personnel, ELLs are more likely to receive science instruction, be it in their regular classrooms or special ESOL programs. In addition, one school offers bilingual science instruction in self-contained ESOL classrooms including mostly entry-level ELLs. These students and their teachers participate in the project to an extent comparable with participation of the regular classrooms in their school.

Instruction takes place, on average, about two hours a week. Some teachers teach science as part of language arts or mathematics instruction. All teachers are provided with complete sets of materials, including teacher guides, student booklets, and science supplies (including trade books related to the science topics in the units). Despite a lull in science instruction from January through mid-March—related to preparation for the statewide assessments in reading, writing, and mathematics—most teachers complete instruction of their respective units by the end of the school year.

As a study of natural phenomena in everyday life, science offers significant learning opportunities.

Effective linguistic scaffolding by teachers is key to making school science accessible to English language learners.

What Our Research Shows about Student Learning

Our research emphasizes promoting science inquiry and English language development simultaneously. To promote science inquiry with students who may be less familiar with scientific practices, instruction moves progressively along the continuum of teacher-explicit instruction to student-initiated inquiry (Fradd & Lee, 1999). Within each instructional unit, earlier lessons are more structured, whereas later lessons are more open-ended to encourage student initiative and exploration. Later units are more complex than earlier ones in terms of both science concepts and the level of inquiry required of students.

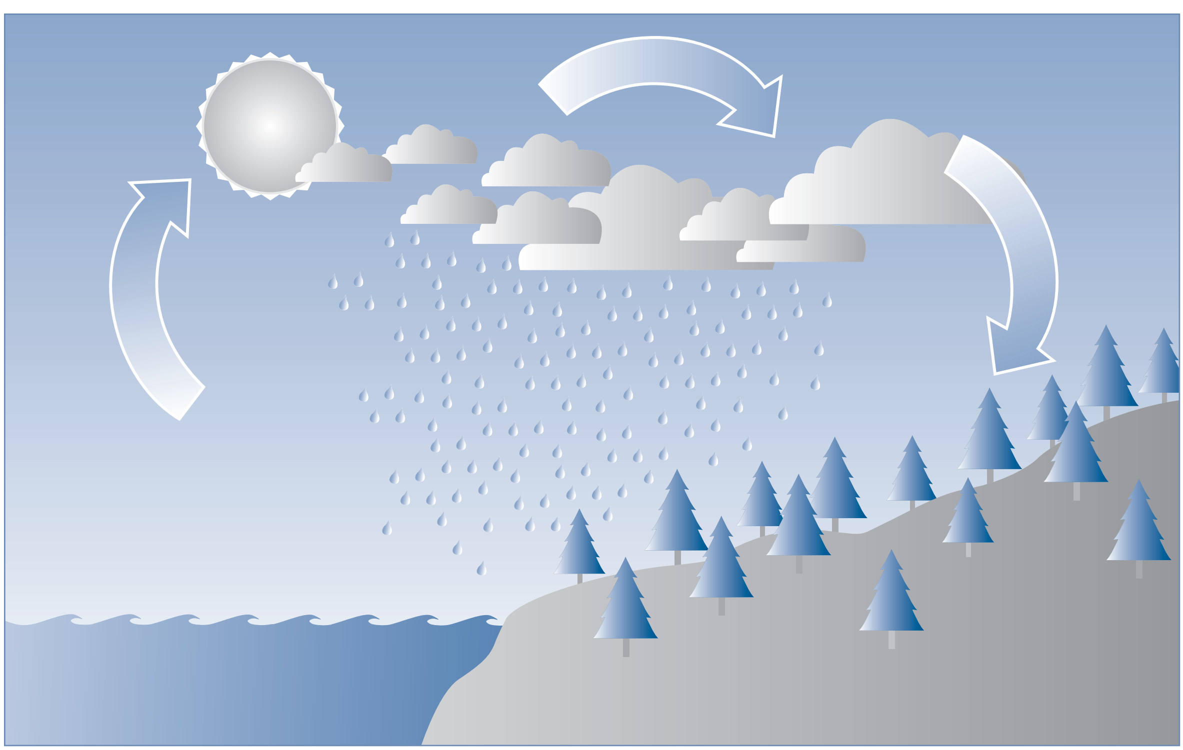
The challenge of moving along the teacher-explicit to student-exploratory continuum is further complicated for ELLs, who often must confront the demands of science learning through the vehicle of a language not yet mastered. Effective linguistic scaffolding by teachers is key to making school science accessible to ELLs, as teachers use language that matches students' levels of communicative competence in length, complexity, and abstraction, and ideally communicate at and slightly above students' level of communicative competence. Equally important is giving students structured opportunities to acquire the skills and concepts required for school science. By engaging in science inquiry with other students, ELLs develop not only their English grammar and vocabulary, but also their familiarity with the styles and genres of English appropriate to various science-related activities.

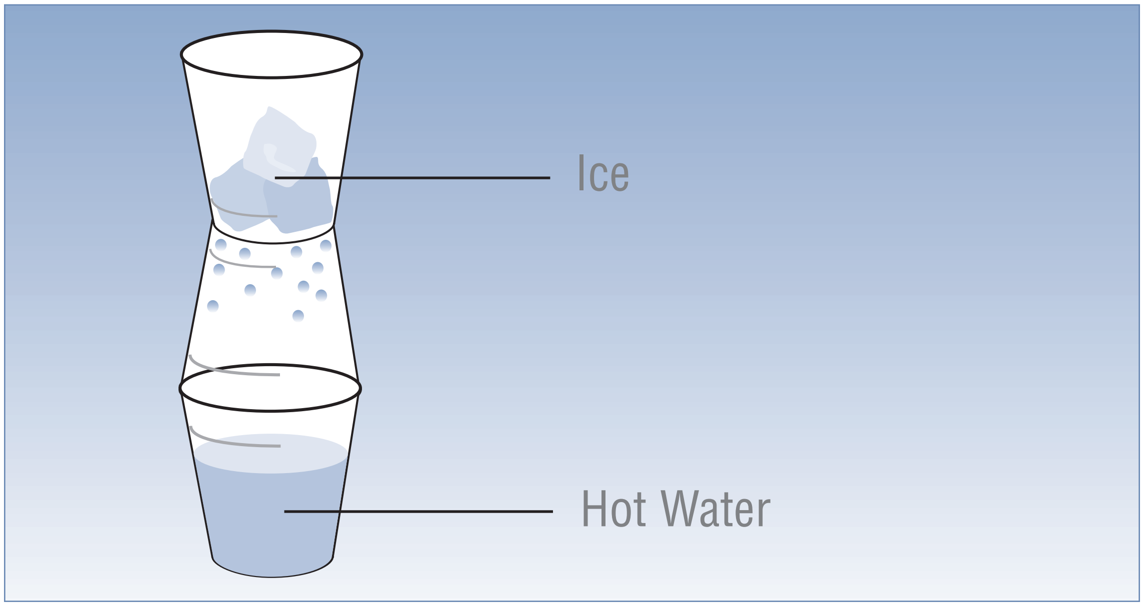
Students' science and literacy achievement is assessed using multiple instruments, including

- project-developed unit tests to measure students' knowledge of science concepts and inquiry;
- tests consisting of public-release items from the National Assessment of Educational Progress (NAEP) and the Third International Mathematics and Science Study (TIMSS),
- prompts for expository writing to measure students' levels of English proficiency and abilities to explain science concepts in writing; and
- elicitations with a small number of students as they design an experiment and write about the activity, as well as their work samples during classroom instruction.

The results indicate that students show significant improvements on all measures (Fradd et al., 2002). The elementary students in our research generally perform higher than their grade-level counterparts, and comparably or higher than middle school students, in the NAEP (national) and TIMSS (international) samples.

Below, writing samples of ELLs are presented. The water-cycle unit highlights the concept that simulations of the water cycle are models of the water cycle in nature; that the water cycle is a system with subsystems of evaporation, condensation, and precipitation; that heating and cooling cause patterns of change with water; and that the water cycle continues over and over.





A fourth-grade ELL whose home language was Spanish wrote about the water-cycle simulation activity during elicitation sessions prior to and after instruction of the unit over a two-month period (see Writing Samples 1 and 2). The pre-instruction writing showed some understanding of the concept and an emerging level of English literacy, whereas the post-instruction writing showed a comprehensive understanding of the concept and a marked improvement in English literacy.

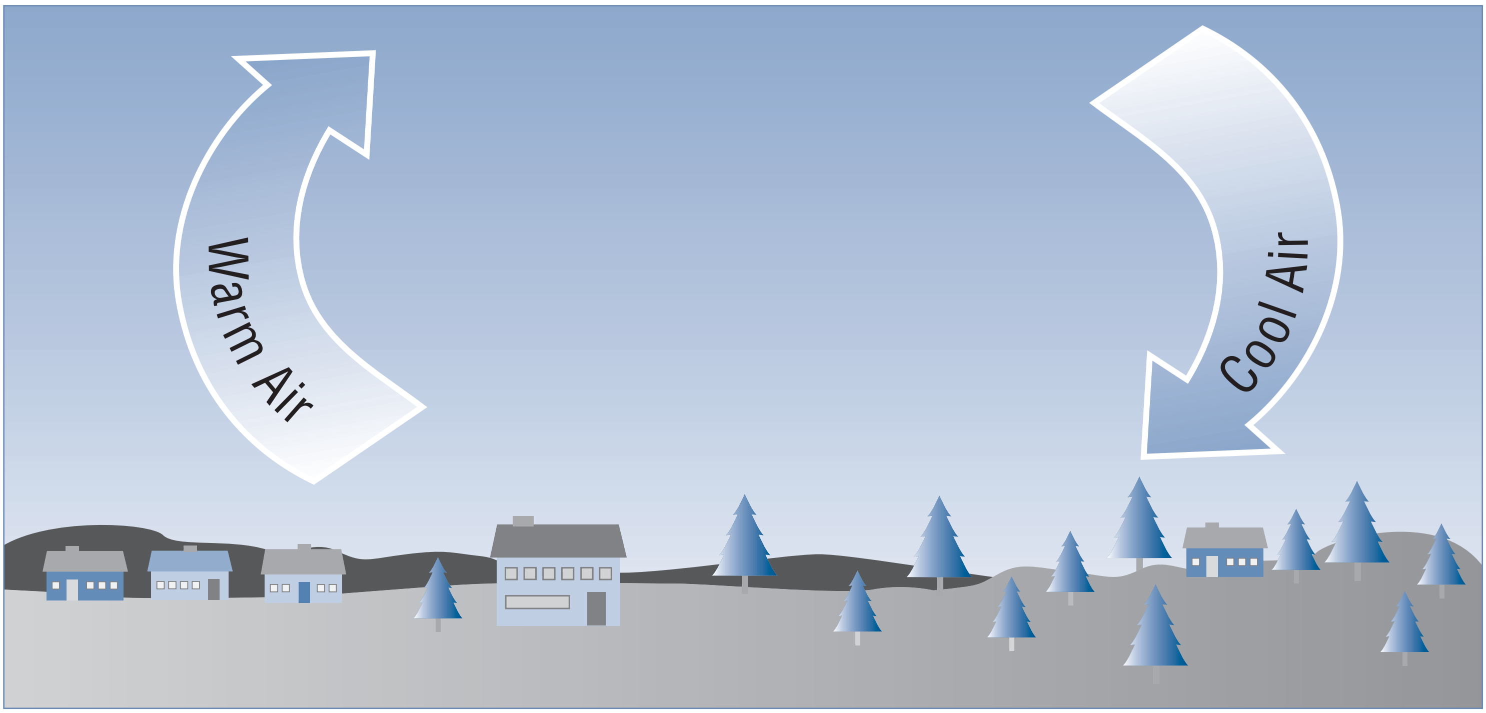
Writing Sample 1

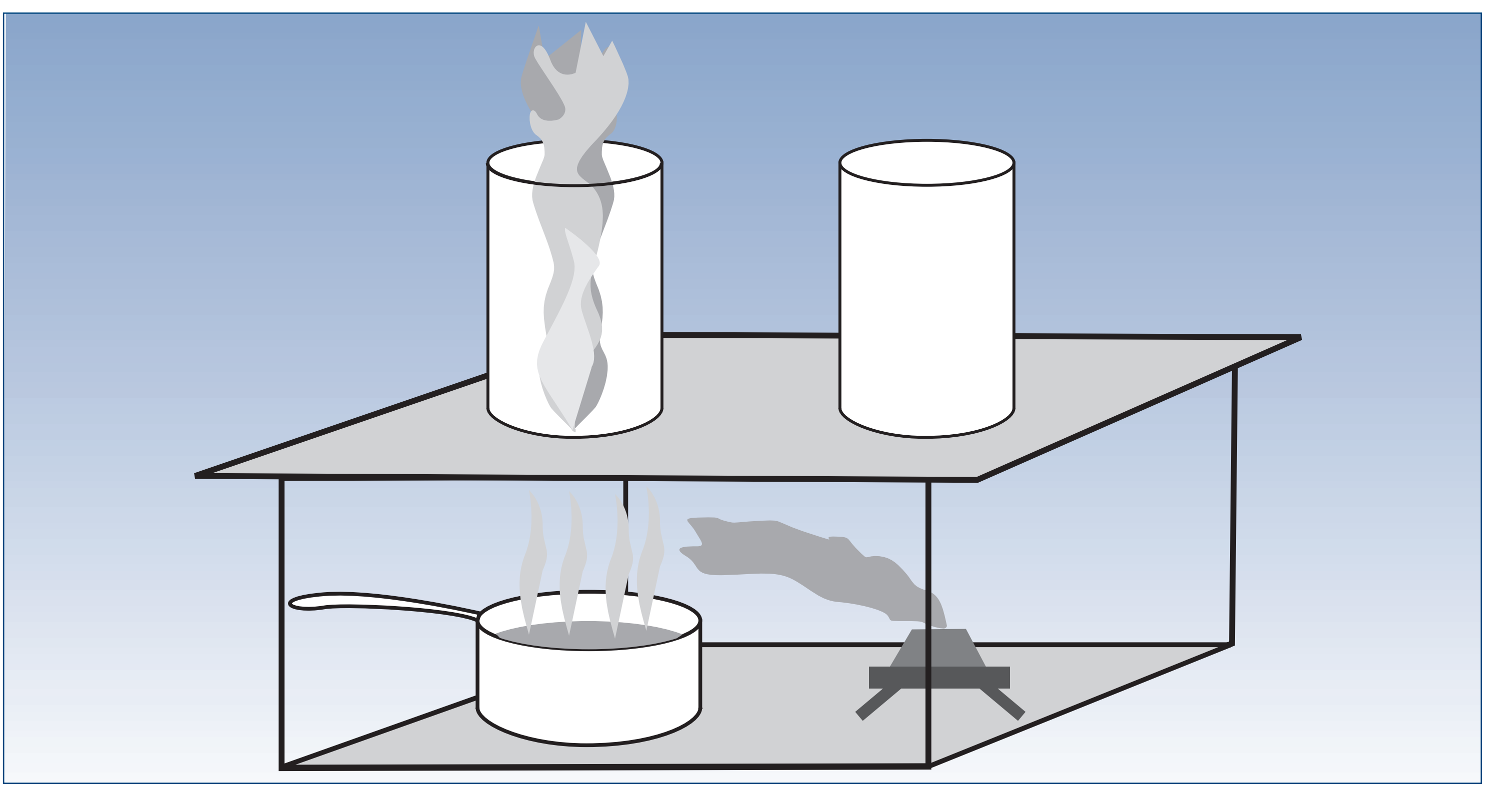
States of mater used in the water cycle
The new ways to cemulat the water cycle that evpras, condenses, and falls as rain that you need states of mater wich is solid, liqued, and gas, solid can turn to liqued as to gas as to liqued as to solid.

Writing Sample 2

What I learned about this project is that precepitation happens over and over again but in different forms like rain, snow, sheet, dew, hail. I also saw two ways I can simmlate the water cycle. One of the ways is two cups taped together and the bottom cup is warm water and ice cubes on the top cup on the outside top. The warm water evaporates and the ice cubes cool the top cup and the hot water vapor condenses as a cloud and when the cloud gets heavy it presipetates and the same thing happens to the othere experment but we use a hot plate, a glass pot, a glass lid, and water.

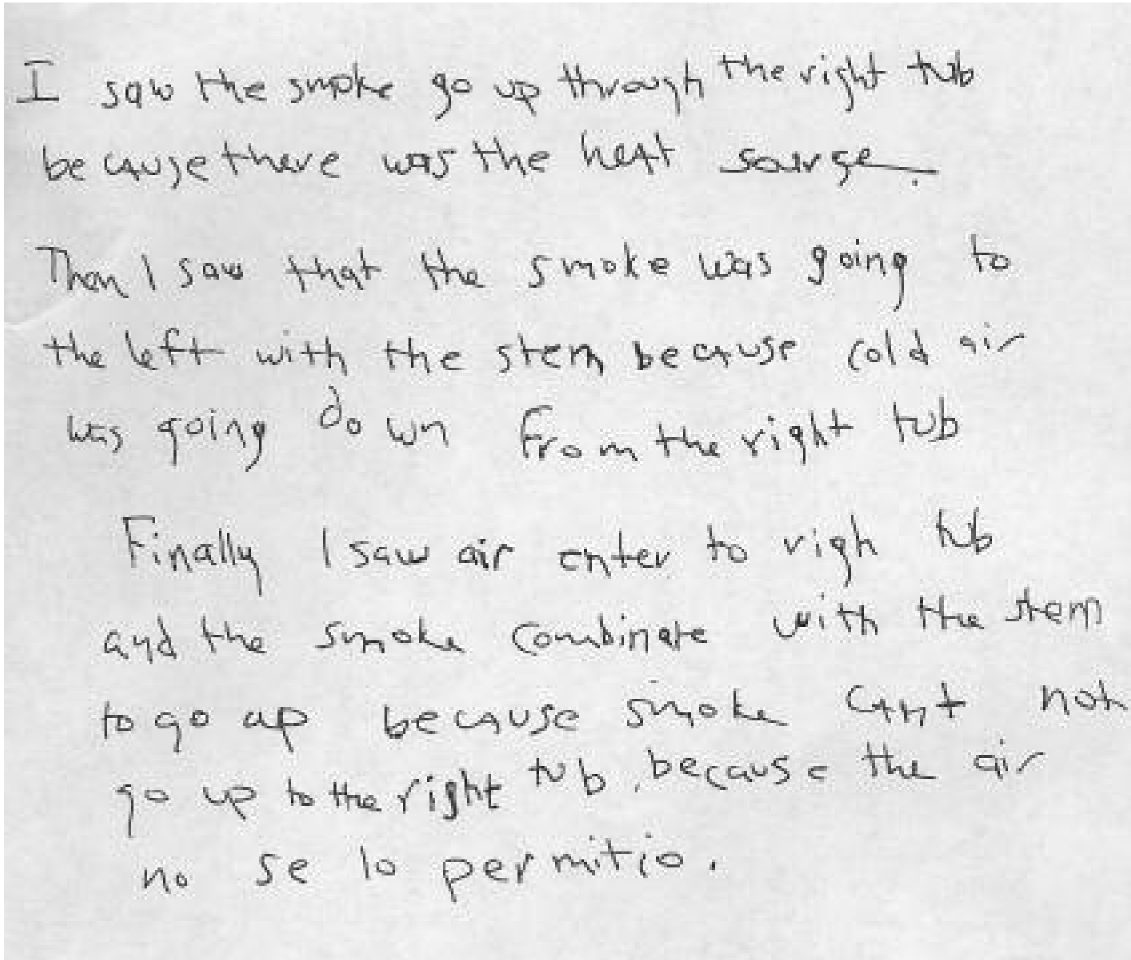
Building on the water-cycle unit, the lesson on wind in the weather unit also highlights the same big ideas that a simulation of wind (e.g., convection currents) is a model of wind in nature; that wind is a system that has subsystems of warm air rising and cool air falling; that heating and cooling cause patterns of change with air; and that the cycle continues over and over.





A fourth-grade ELL whose home language was Spanish and who had been in the United States for a short time wrote about the wind simulation activity in her workbook during class (see Writing Samples 3 and 4). Her writing showed a comprehensive understanding of the concept by accurately describing and explaining the activity through each step. The writing also showed literacy development—for example, she describes the sequence of events by using "Then" and "Finally" in the beginning of each new paragraph. The writing also showed improvement in spelling—she no longer writes, for example, "tub" for "tube," "stem" for "steam," and "combinate" for "combine." At the end of her writing, she wrote *"no se lo permitio"*—Spanish for "did not permit it."

Writing Sample 3

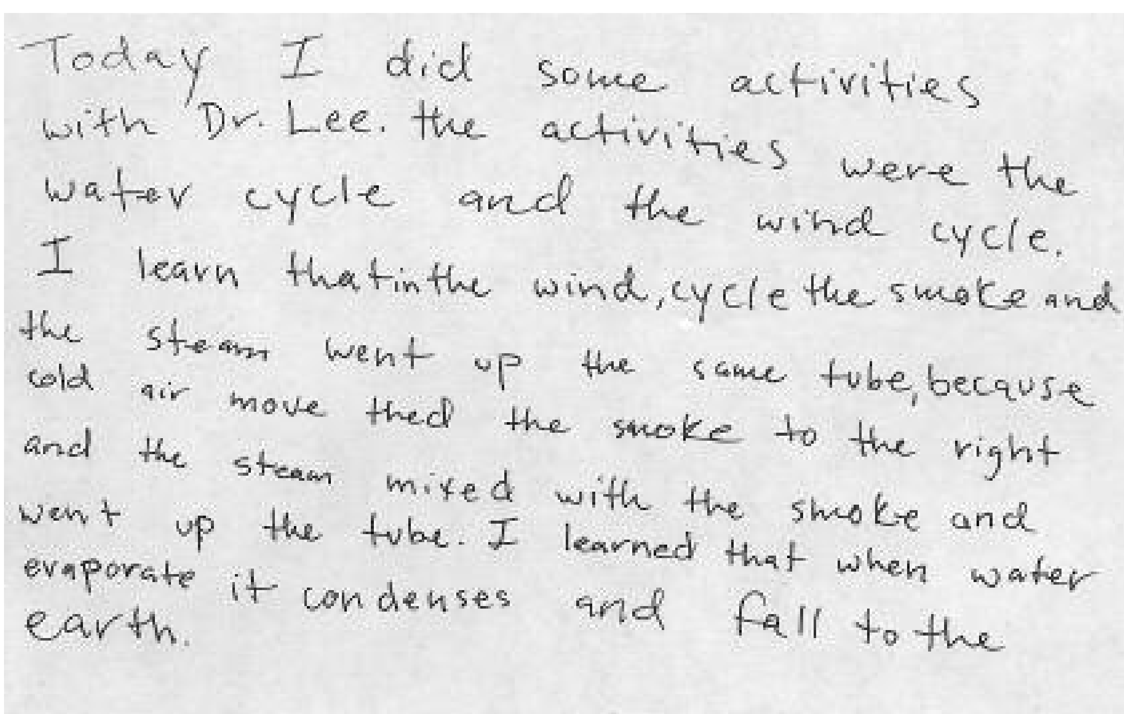

I saw the smoke go up through the right tub because there was the heat sourse.

Then I saw that the smoke was going to the left with the stem because cold air was going down from the right tub

Finally I saw air enter to righ tub and the smoke combinate with the stem to go up because smoke cant not go up to the right tub, becaus the air no se lo permitio.

Finally, a fourth-grade ELL from Haiti summarized how the water cycle and wind simulations are similar and different during an elicitation session after instruction of both the water-cycle and weather units.

Writing Sample 4


Today I did some activities with Dr. Lee. the activities were the water cycle and the wind cycle. I learn that in the wind, cycle the smoke and the steam went up the same tube, because cold air move thed the smoke to the right and the steam mixed with the smoke and went up the tube. I learned that when water evaporate it condenses and fall to the earth.

A Powerful Tool to Teach English and Language Literacy

As a study of natural phenomena in everyday life, science offers significant learning opportunities for all students. In particular, hands-on and inquiry-based science instruction provides opportunities for students to develop scientific understanding and engage in inquiry practices more actively than traditional textbook-based instruction. Science inquiry occurs when students generate questions, plan procedures, design and carry out investigations, analyze data, draw conclusions, and report findings. This type of instruction is especially promising for students from non-mainstream backgrounds, for a number of reasons:

- Hands-on activities are less dependent on formal mastery of the language of instruction and thus reduce the linguistic burden on ELLs;
- Collaborative, small-group work provides structured opportunities for developing English proficiency in the context of authentic communication about science knowledge;
- Hands-on activities based on natural phenomena are more accessible to students with limited science experience than decontextualized textbook knowledge; and
- Inquiry-based instruction provides an introduction to the scientific practices and discourse from which inner-city students are often excluded.

Summary

Although science instruction is often ignored for students from diverse languages and cultures, hands-on and inquiry-based science instruction can be a powerful tool to teach English language and literacy in the context of learning science. It is a challenge for educators to recognize both the linguistic and cultural resources ELLs bring to the learning process and the areas in which they need assistance. Teachers require professional development opportunities to develop deep and complex understandings of science and to learn pedagogical strategies in promoting English language and literacy as part of science instruction. Since educational policies for instruction and assessment in both science and ESOL/bilingual education influence classroom instruction, the support of school administrators is critically important. Eventually, ELLs understand science concepts, engage in science inquiry, and participate in science discourse, while also mastering English as a new language.

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Instructional Strategies for Developing Literacy during Science Instruction

- Read a short story or a narrative vignette to activate students' prior knowledge on a science topic.
- Use specific comprehension questions about inquiry activities or science information in expository text.
- Use a variety of language functions (e.g., describing, explaining, reporting, drawing conclusions) in the context of science inquiry.
- Have students write an expository paragraph or narrative story describing the scientific process under investigation.
- Help students record data and report results in multiple formats (oral, written, and graphic).
- Help students create Venn diagrams or concept maps using vocabulary from the science lesson.
- Incorporate trade books or literature with scientific themes into instruction.
- Engage students in whole-group, small-group, or individual reading on science topics.
- Use writing tasks as homework assignment—for example, students can write about what they did in class, then share their writings with family members and write about what they talked about with family members, and share their writings in class.

Promoting English Language Development with English Language Learners

In addition to developing general literacy with all students, teachers can provide explicit guidance to promote ELLs' English language development (Amaral, Garrison, & Klentschy, 2002; Hampton & Rodriguez, 2001; Stoddart, Pinal, Latzke, & Canaday, 2002) by using these strategies:

- Recognize the diversity of students' levels of language proficiency and adjust the language load required for their participation.
- Use multiple modes of communication and representation (verbal, gestural, written, graphic) to enhance students' understanding of science.
- Introduce key vocabulary in the beginning and encourage students to practice the vocabulary in a variety of contexts to enhance their understanding.
- Promote precision in describing and explaining objects and events—for example, give explicit attention to particular words, such as positional words (e.g., above, below, inside, outside), comparative terms (e.g., cold, colder, coldest), and affixes (e.g., /in-/ in "increase" or "inflate" as opposed to /de-/ in "decrease" or "deflate").
- Promote meaningful engagement and authentic communication through the use of narrative vignettes or expository texts related to everyday experiences.
- Use various group formations, so that students learn to work independently as well as collaboratively.

SEDL

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Changing Our Attitude toward Mathematics and Science to Improve Achievement

continued from page 2

Ensuring that all of our children become mathematically and scientifically proficient might also mean fundamental changes to the curriculum. When studying similarities and differences in eighth-grade mathematics among those nations that were high-performing on the TIMSS and the U.S., researchers found that in the U.S. many more mathematics topics are covered each year and we spend much more time reviewing material than is spent in other countries. Our curriculum continues to focus on basic computational skills through eighth grade and beyond. In the high-achieving countries, students in the middle grades had moved on to the study of algebra and geometry (Hiebert, et al., 2003).

Yes, we have a long way to go before all of our students can meet high standards in mathematics and science, but across the country, educators are changing how mathematics and science are taught. In this issue of *SEDL Letter*, we bring you two stories of how SEDL's Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teacheing is helping to change teaching and learning are changing in the SEDL region. We also focus on two issues of importance to schools and districts—how No Child Left Behind will affect mathematics and science instruction and what scientifically based research means for schools and districts and why it matters. Rounding out this issue are articles examining how algebraic thinking can be integrated into the K–8 curriculum and how science can be effective in developing language skills in English language learners.

At SEDL, we hope your first semester has been a good one, and we wish you the best for the holiday season.

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SEDL

Matter Is Everywhere
Hay materia en todos lados

Introduction and translation by Víctor J. Rodríguez

Finding ways to connect mathematics, science, and language to students' everyday lives is a challenge, especially for teachers whose students come from diverse cultural and linguistic backgrounds. And while many mathematics and science textbooks provide theoretical suggestions to connect activities to real life, the language component is missing for the most part.

SEDL's **Integrating Mathematics, Science, and Language: An Instructional Program** is a two-volume curriculum and resources guide designed to help K–3 elementary school teachers organize instructional activities to increase the learning of Hispanic primary-grade children whose first language is not English. The guide offers a curriculum plan, instructional strategies and activities, suggested teacher and student materials, and assessment procedures.

The guide is made up of units that contain overview materials and background information for the teacher, the lessons, an annotated bibliography, and a list of reference and resource materials for teachers. Preceding each complete unit in English is a Spanish version of background information for the teacher and for parents to help support student learning at home. The lesson cycle is made up of five phases: encountering the idea, exploring the idea, getting the idea, organizing the idea, and applying the idea. Language development strategies specifically related to mathematics and science processes are also incorporated into the lessons.

The following is a condensed bilingual version of a lesson from **Integrating Mathematics, Science, and Language: An Instructional Program**. The lesson, *Matter Is Everywhere,* is taken from the Unit on Matter. Teachers who use this lesson in their classroom can use the Spanish version to engage Spanish-speaking parents in supporting their children's learning at home. For more information, visit SEDL's Web site at **http://www.sedl.org/scimath/pasopartners/pdfs/matter.pdf**

Solid

Sample Lesson

Matter Is Everywhere

Big Ideas:

Everything that we see and touch is matter.

Whole Group Work

Materials:

- large chart
- bottle of perfume
- marble
- some other solid object
- cup of Kool-Aid
- ice cube
- at least three transparent glass tumblers of different sizes and shapes

Word tags:

- solid
- liquid
- gas
- shape
- form

ENCOUNTERING THE IDEA

Begin this overview lesson with a question:

What is the world made of?

Write students' ideas on a chalkboard for later use. If students do not mention air, ask if air should be on the list. What about water? What about our bodies? Ask students how some of these things are alike? Ask students what ice is. What is steam? Yes, both are water. Then ask, what is the difference between ice, water, and steam?

Liquid

Gas

EXPLORING THE IDEA

Perfume

Open the perfume bottle, set it in an open space, and ask students, "Do you smell the perfume? Why can you smell the perfume if it is far away from you? (Perfume is a liquid, but it has a smell; the smell is a vapor; a vapor is a gas; a gas can go all over the room; it doesn't stay in one place.)

Kool-Aid

Look at this cup of Kool-Aid. Is Kool-Aid matter? Is it solid or liquid? What shape is this liquid in? Now I'm going to pour it in different tumblers. What shape does it have? What can we say about a liquid? We can see it and feel it, but it doesn't have a definite shape.

Marble

Look at this marble. This is a solid. Describe it. (Hard, heavy, definite shape, can see it, feel it). What can we say about matter in the form of a solid?

Solids, Liquids, and Gases

Ask students to look around the room and list things that are either solid, liquid, or gas. Write them on a chart under the words: Solid, Liquid, or Gas.

GETTING THE IDEA

Tell students that everything we see and touch is matter. Our bodies are made of matter, the water we drink is made of matter, and so is the air around us. There is little we can see and feel that is not matter. Matter exists as a solid, a liquid, or a gas.

ORGANIZING THE IDEA

Have students write about matter in their journals—what it looks like, what it feels like. Students may draw a picture of matter. Students may make a checklist of things to look for in matter to be able to say whether it is in solid, liquid, or gas form.

APPLYING THE IDEA

Problem solving

1. What is Jello? A solid or a liquid? Can both answers be correct? Why?
2. Is temperature related to the form that water is in? Explain.
3. Do you think that the temperature of matter is related to whether it is in solid, liquid, or gas form? Why do you think that might be true?

For more activities from this lesson, consult SEDL's Web site at http://www.sedl.org/scimath/pasopartners/pdfs/matter.pdf

Lección modelo

Hay materia en todos lados

Ideas grandes:

Todo lo que vemos y tocamos es materia.

Actividad en grupo

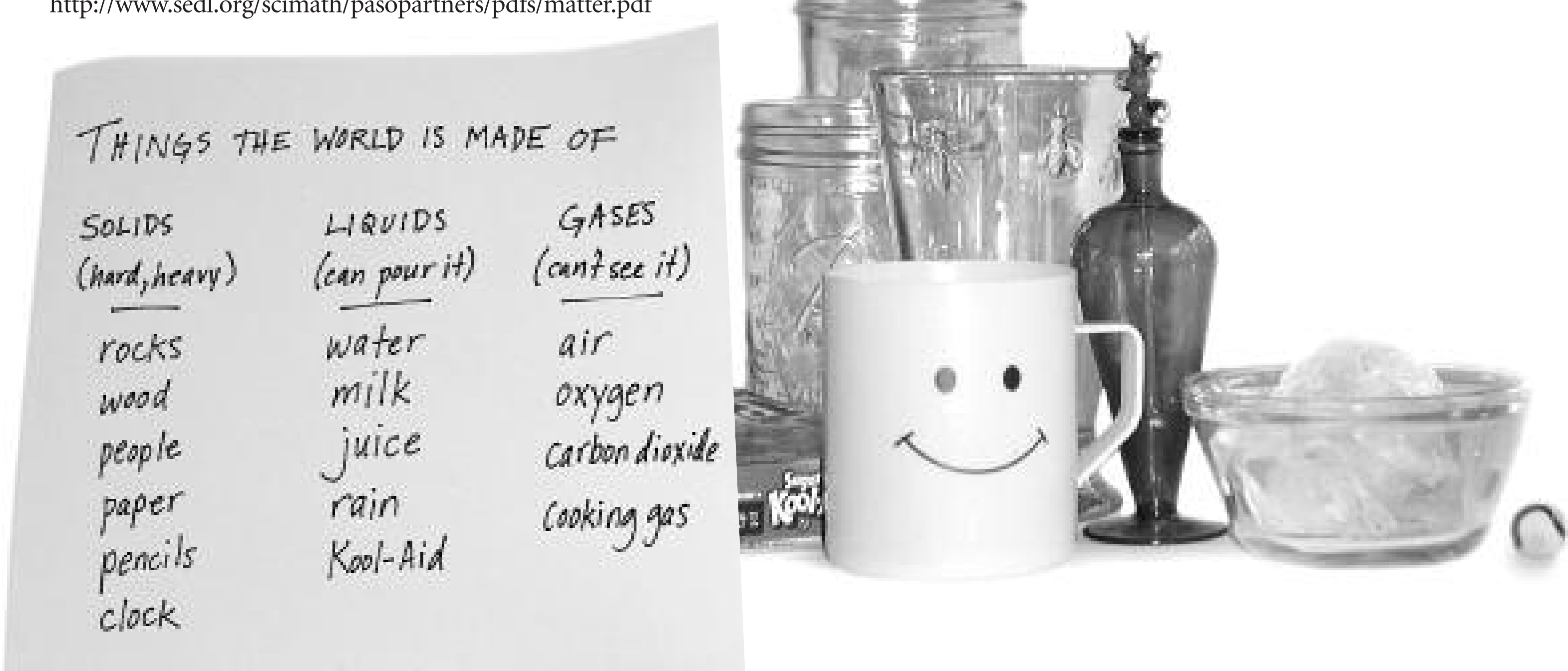
Materiales:

- cartulina grande
- botella de perfume
- canica
- algún objeto sólido
- taza de Kool-Aid
- cubo de hielo
- por lo menos tres vasos transparentes de distintos tamaños y formas

Palabras claves:

- sólido
- líquido
- gaseoso
- figura
- forma

Gases



ENCONTRAR LA IDEA

Empiece este repaso con una pregunta:

¿De qué está compuesto el mundo?

Escriba las ideas de los estudiantes en el pizarrón. Si los estudiantes no mencionan aire, pregúnteles si aire deberá encontrarse en la lista. ¿Y el agua? ¿Y nuestros cuerpos? Pregúnteles a los alumnos qué hay de similar en estas dos cosas. Pregúnteles a los alumnos lo que es el hielo. ¿Qué es vapor? Sí. Ambos son agua. Luego pregunte lo que hay de diferencia entre el hielo, agua, y vapor.

EXPLORACIÓN DE LA IDEA

Perfume
Abra la botella de perfume; colóquela en un espacio abierto y pregúnteles a los alumnos, "Huelen ustedes el perfume? ¿Cómo es que pueden oler el perfume si se encuentra tan lejos de ustedes? (El perfume es un líquido, pero tiene un olor; el olor es un vapor; el vapor es un gas; un gas puede estar disperso por toda la habitación; no se queda en un solo lugar.)

Kool-Aid
Vean esta taza de Kool-Aid. ¿El Kool-Aid es materia? ¿Es sólido o líquido? ¿Qué forma tiene este líquido? Ahora, lo vertiré en varios recipientes. ¿Qué forma adquirió ahora? ¿Qué podemos concluir acerca de un líquido? Podemos verlo y sentirlo, pero no tiene forma definitiva.

Canica
Vean esta canica. Ésta es un sólido. Descríbenla. (Dura, pesada, forma definida, podemos verla, sentirla). ¿Qué podemos concluir acerca de materias sólidas?

Sólidos, Líquidos, y Gases
Pídales a los alumnos a que vean alrededor del salón y que identifiquen cosas que sean sólidas, líquidas, o gases. Escríbelas en una cartulina bajo las palabras: sólida, líquida, o gas.

COMPRENDER LA IDEA

Dígales a los alumnos que todo lo que vemos y tocamos es materia. Nuestros cuerpos están hechos de materia, el agua que bebemos está hecho de materia, al igual que todo el aire que nos rodea. Hay muy poco de lo que podemos ver y sentir que no sea materia. La materia existe como sólido, líquido, o gas.

ORGANIZAR LA IDEA

Pídales a los alumnos que escriban acerca de la materia en sus diarios. ¿Qué características tiene la materia? Los alumnos podrían dibujar algunos ejemplos de materia. Además, podrían escribir una lista de características de la materia para determinar si su forma es sólida, líquida o gas.

APLICAR LA IDEA

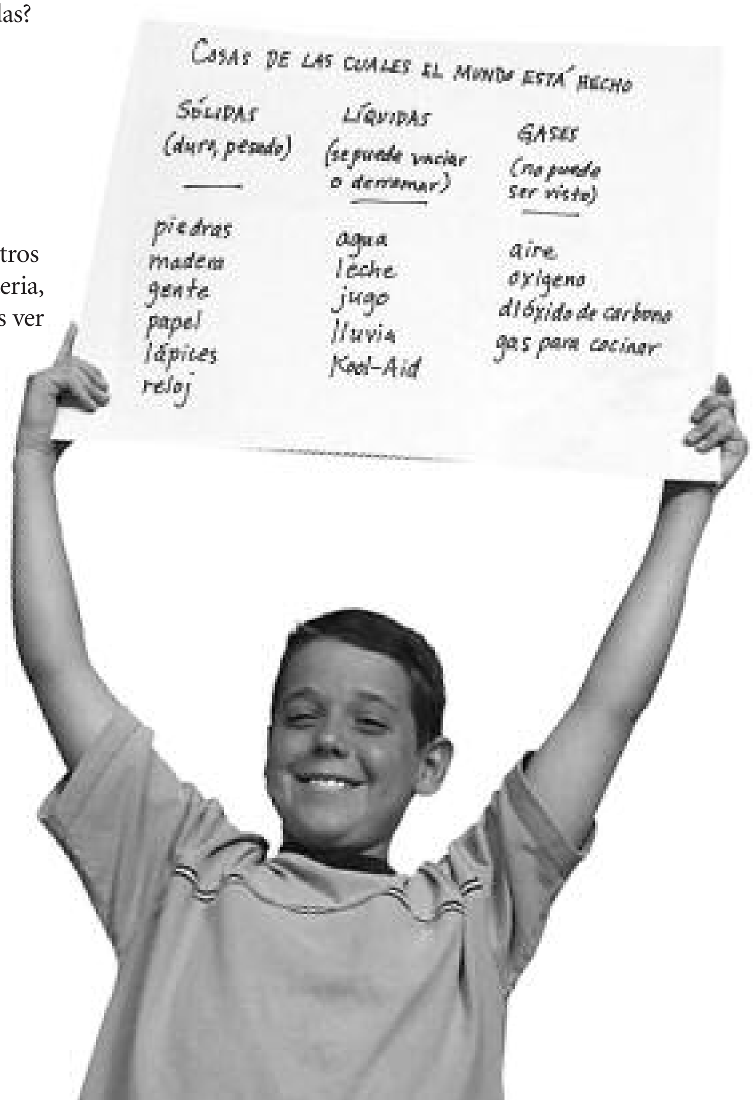
Resolución de problemas

1. ¿Qué es la gelatina, un sólido o líquido? ¿Podrían estar correctas las dos respuestas? ¿Por qué?
2. ¿Tiene que ver la temperatura ambiente con la forma en que se encuentra el agua? Explique.
3. ¿Crees tú que la temperatura ambiente afecta la forma en que toma la materia, ya sea que ésta se encuentre en forma de sólido, líquido, o gas? ¿A qué se debe esto?

Para más actividades para esta lección, consulte el sitio electrónico de SEDL http://www.sedl.org/scimath/pasopartners/pdfs/tmatter.pdf

SEDL

Víctor Rodríguez is a SEDL communications specialist. You may email Victor at vrodrigu@sedl.org.



Fossil Findings
Research in the Field Leads to Changes in the Classroom

By Johanna Gilmore

Participants in SCIMAST's Rio Grande Rift Basin Teachers as Leaders Field Science Academy found this fossil joint — the main joint in the lower leg of a fossil horse, Equus scotti. It is the equivalent of a human wrist joint. The entire leg was later reconstructed from the group's fossil finds.

The crystal clear waters of the Devils River in Texas. The biodiversity of the foothills in the Oklahoma Ozarks. The irregular limestone at the karst topography sites of Arkansas. These are all classrooms for the teachers participating in SEDL's Teachers as Leaders Field Science Academies. In another SEDL classroom, the Rio Grande Rift Basin in New Mexico, teachers not only uncovered new ways to reach their students through field research, but they also unearthed fossils dating back 3 million years.

No Ordinary Field Trip

Offered through the SEDL Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST), the summer academies are designed to teach the use of inquiry strategies and to help K–12 science teachers align content with standards and experience learning through inquiry.

In June, 14 teachers from SEDL's region returned to the Rio Grande Rift Basin—a hot, dusty site off Interstate 25 near Albuquerque—to build on the work they had done during the 2002 field science academy. Geologist Sean Connell from the New Mexico Bureau of Mines and Minerals discovered the site in 2001 while making stops at freeway outcrops. He then contacted Gary Morgan, curator of Vertebrate Paleontology at the New Mexico Museum of Natural History and Science, who began more intensive research work at the site. For this research, he collaborated with Steve Getty, a geologist and educator at Biological Sciences Curriculum Study, a nonprofit corporation in Colorado Springs.

In June 2002, Getty and SEDL program specialist Nikki Hanegan brought 16 teachers to the site to work with Morgan. Since then, the teachers—some of whom visit the site throughout the year—have had a hand in discovering more than half of the fauna uncovered at the site, including parts from cats, horses, llamas, foxes, dogs, rabbits, and rodents from 3 million years ago.

"Teachers are very visual," Getty said. "Once we got more of their eyes on the site, we learned they had a tremendous eye for picking little objects out of the outcrop. Our collection list just started growing."

Morgan and Getty believe the Rio Grande Rift Basin site is one of the richest in North America from this time period. After studying the bones and comparing them with other specimens at the museum in Albuquerque, Morgan will archive the bones to document the fauna in the central Rio Grande Rift Basin. "Such collections are valuable to geologists on a continental scale when reconstructing continental faunas," Getty said. By compiling a number of 3-million-year-old sites and comparing them with sites dating back 2 million, 5 million, and 10 million years, geologists can reconstruct a coherent picture of changes in mammalian fauna, or evolution, on a continent.

"So our knowledge and understanding of faunal succession in the fossil record relies on detailed work from hundreds and hundreds of these fossil sites," Getty said. "It's exciting when teachers can contribute to such endeavors."

Teachers as Learners

During the first Rio Grande Rift Basin academy in 2002, Getty made sure teachers—whose backgrounds vary regarding grade level, content knowledge, and experience—started on even ground. He divided the group into teams of three or four teachers each and assigned them classification and diagramming exercises to familiarize participants with the general geology of the rift. As they learned more about the site together, the teachers' anxiety levels decreased, Getty said. "We all worked together and drew from each other's strengths in both content knowledge and teaching experience."

On the first morning of the 2003 academy, Getty gauged the teachers' areas of interest, identified working teams, and assigned miniprojects for a presentation forum at the end of their five days together. While some groups did more detailed mapping of the rift basin's stratigraphy, others studied rift volcanism of around 3 million years ago, screened for and separated small mammals, or investigated the sedimentation to the east of the Rio Grande Rift into neighboring Texas. "We wanted them to do more inquiry and research on a topic of their choice," Getty said.

Dave Million, a science teacher at Las Cruces High School in Las Cruces, New Mexico, said he enjoyed the opportunity the academy provided him to be a student instead of a teacher despite the hard work in the heat alongside a highway: "You're exhausted, but your mind is recharging because you're doing first-hand exploration—you're not just reading about it or watching a video. You're actually out there doing something, and that makes it so much more personal and important to you."

Million and the other teachers studied volcanic evolution in the Rio Grande Rift Basin of the past 5 million years and worked to determine how the bones arrived at the rift-basin site. Because of the variety and number of pieces, the teachers think the area might have been a physical collection site as a result of transportation or deposition. Or it might have been a watering hole for a number of animals.

"Getting teachers to think hard about why all these bones are located at one site is one of the most pure, raw forms of inquiry," Getty said. "We discussed how the learning process involves making sense of the experiences they have as learners."

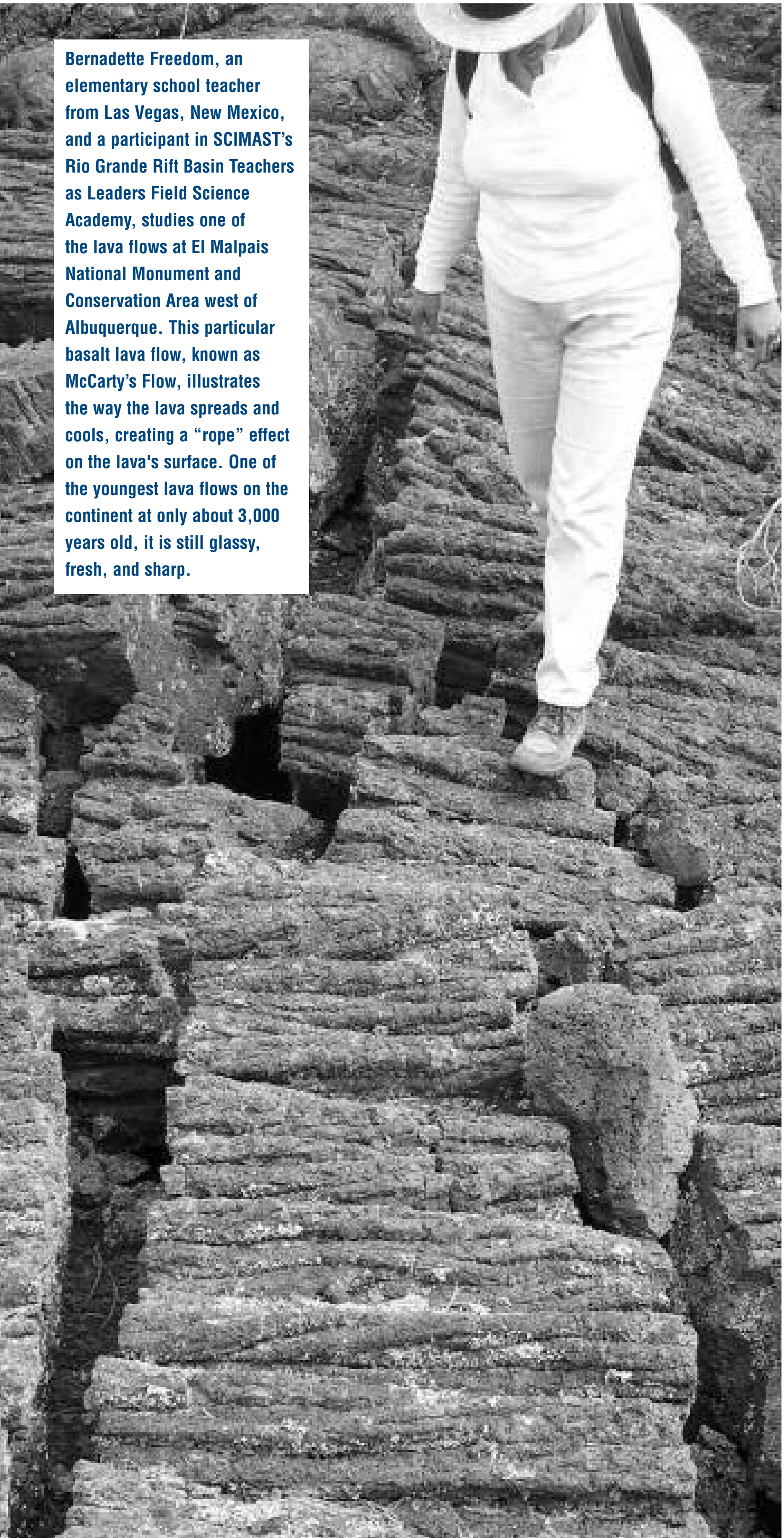
A New Way of Teaching

As the teachers are learning, they are thinking about how their students learn as well, Million said. What happens when they assign material to their students? How are students digesting this material and connecting all of the pieces of information to construct understanding? Are they using inquiry to do that?

"I've never done inquiry-based teaching before," Million said. "But I'm definitely gearing up to do it. I want to let the kids take hold of their own educations and go in the directions they want to

Found by vertebrate paleontologist Gary Morgan in April 2003, this bone belongs to a camelops, or an extinct, large herbivore in the camel family that lived in southwestern North America about 3 million years ago. Teachers as Leaders Field Science Academy participants found more fragments of the camelops leg and teeth during fieldwork in June 2002 and June 2003.

Many participants in SCIMAST's Rio Grande Rift Basin Teachers as Leaders Field Science Academy sieved and "washed" soil using this immersion tub to collect and identify bones of numerous small mammals, snakes, lizards, birds, and amphibians.



Bernadette Freedom, an elementary school teacher from Las Vegas, New Mexico, and a participant in SCIMAST's Rio Grande Rift Basin Teachers as Leaders Field Science Academy, studies one of the lava flows at El Malpais National Monument and Conservation Area west of Albuquerque. This particular basalt lava flow, known as McCarty's Flow, illustrates the way the lava spreads and cools, creating a "rope" effect on the lava's surface. One of the youngest lava flows on the continent at only about 3,000 years old, it is still glassy, fresh, and sharp.

Rio Rancho, New Mexico, high school teacher Mark Leonard, left, and vertebrate paleontologist Gary Morgan pinpoint a location where field science academy participants found several mammal bones in June 2003.

go rather than tell them where to go. It's a really hard way to teach."

Getty believes these teacher experiences are more important than creating a notebook filled with science lessons and take-home activities for academy participants. "You have to be patient. It would be much easier for me to drive people around on buses and point out sites, but I'm not sure they'd really learn anything. Doing the actual work makes them synthesize what they're learning."

Hanegan and Getty are helping academy participants teach science through experiments and fieldwork in their own backyards rather than just through textbooks. "We train the teachers to use their own natural elements instead of sending them home with fossil kits," Hanegan said. "They learn about nature in general so that they can apply their new knowledge with their students in their own environments."

Sarah Wilson, a science teacher from Eldorado High School in Albuquerque, did just that. After her first SEDL field science academy with Getty and Hanegan three years ago, Wilson began to move away from teaching geology by the book to teaching geology through New Mexico. She said with Getty's expertise in local geology and Hanegan's educational techniques, "I totally redid the class I was teaching."

Wilson's first academy featured lessons on constancy and change, which she brought home

Vertebrate paleontologist Gary Morgan, left, and Las Cruces, New Mexico, high school science teacher Dave Million hold the plastered leg of the ancient horse *Equus scotti* during fieldwork in a Rio Grande Rift Basin fossil site near Albuquerque in November 2002. Teachers and researchers participating in a SCIMAST Teachers as Leaders Field Science Academy found the 3-million-year-old leg bone in June 2002.

to Eldorado High. Instead of teaching in a linear pattern, as most scientific organisms seem to progress, "I tried to go in a more cyclical pattern with a systems approach," she said. Wilson started her lessons with something specific from New Mexico's geology to which her students could relate. From there, she worked out to a more global picture of geology.

During her first lab of the school year, Wilson takes her students outside her school building for four days to study the inactive volcanoes surrounding Albuquerque. "There are five small volcanoes easily visible to the west, and then there's a very large volcano about 100 miles west of us that they can see," she said. "They see different types of volcanic structures and results of volcanic flows that they had never noticed before."

On six weekends during the semester, Wilson takes groups of students to some of the sites she has studied during the SEDL field science academies so they can see what she has experienced. This year, she hopes to incorporate the geologic time scale in her curriculum better by discussing some of the paleontology work she did in June at the Rio Grande Rift Basin fossil site. She is also helping another geology teacher at her school take advantage of more fieldwork professional development opportunities.

Wilson said her new approach to teaching is helping students understand that geology is more than just "studying rocks." She believes that "one of the best things you can do for students is connect them to something—once they're connected, they just understand better."

Plus, sharing her experiences and the photos of her academy work with her students builds Wilson's credibility with them. "The students respect you that much more if you've done the actual work," she said. "Now I'm an expert, too."

For more information on the Teachers as Leaders Academies, visit the SCIMAST Web site at http://www.sedl.org/scimast/teachers_as_leaders/field_science/field_science.html.

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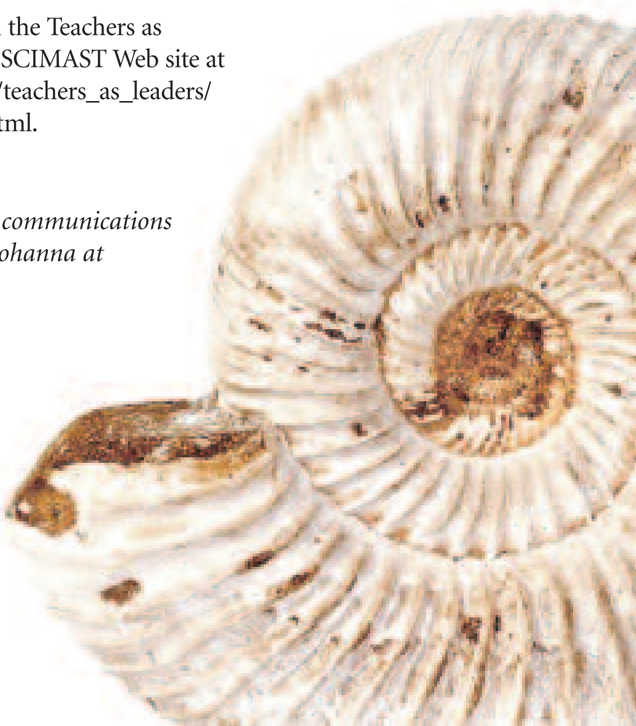

Online Mentoring Provides Support, Resources for Mathematics and Science Teachers

www.sedl.org/scimast/archives

Mathematics and science teachers in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas have a support group that is as close as their computers. SEDL's Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST) began the Mathematics and Science Online Mentoring project in 1999 to help mathematics and science teachers with classroom challenges and to provide a way for mathematics and science teachers in the region who are designated as Presidential Awardees to share their expertise.

Questions submitted to the online mentoring Web site run the gamut from "What are the best strategies for teaching mathematics to English language learners with mild disabilities?" to "What are some good resources for teaching data analysis and statistics at appropriate levels that are relevant to primary grade students?" Replies from the Presidential Awardee mentors may include personal experiences, strategies, resources, and encouragement.

The mentoring project differs from an "ask the expert" or virtual reference desk service in that the responses can result in further discussion or raise additional questions. Also, the questions are not the sort that can be answered quickly—they often pose challenges for the mentors and SCIMAST staff as well as for the teachers seeking help. In answering other teachers' questions, the mentors try to encourage teachers to closely observe their students, expand teaching strategies, and to reflect on their practice. SEDL program specialist Phillip Eaglin, who oversees the mentoring project, explains, "Encouraging reflection is most critical. We want to assist teachers in looking back to discover what did and did not work in the classrooms. By supporting and encouraging reflection, the mentors can help other teachers learn and grow professionally."

During the five years the mentoring project has been online, Eaglin says the questions have changed somewhat. Recent accountability mandates have spurred questions about high-need students, such as the following recent inquiry: "What teaching strategies do you utilize for teaching physical science (requirement of the state) to secondary kids who do not know how to read or perform simple math computations and have behavioral problems?"

The SCIMAST online mentoring project may be found online at http://www.sedl.org/scimast/archives. Visitors to the site may pose a question, browse through previously submitted questions and answers that are sorted by topic, or sign up to receive email notification of new archive submissions.

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