

Hands On!

A publication for mathematics and science educators

Spring 2001 Volume 24, Number 1



in this issue...

Algebra in the Early Grades?

Re-Opening the Science Door

Collaborative Inquiry Uses Data
to Get Results

Children's Way with Words

Staying the Course

A commitment to inquiry-based learning

By Barbara C. Sampson

For more than a decade now, spokespersons for national, state, and local public policy have claimed education as their top priority. Improving it has become the mantra of good citizenship, the plea of employers, the anxiety of parents, and the exhaustion of school administrators and teachers. All this attention and yet large-scale progress seems elusive. How then should responsible educators respond?

Do we abandon principles and practices that research and experience tell us profoundly impact learning for the reason that they are not easily adopted or implemented? Do we give up our vision of a rich inquiry-based educational experience, where all children are engaged in the disciplines of science, mathematics, history, literature and the

(continued on page 18)

What's the View from the International Space Station?

with **NASA EarthKAM**
you can find out.

Access thousands of Earth images, with learning guides and activities that support classes in science, math, geography and social studies.

Join the EarthKAM Community and explore images with scientists, geographers, and other educators.

Become "Flight Certified" and your class can take its own images of Earth, directing a camera on the International Space Station.

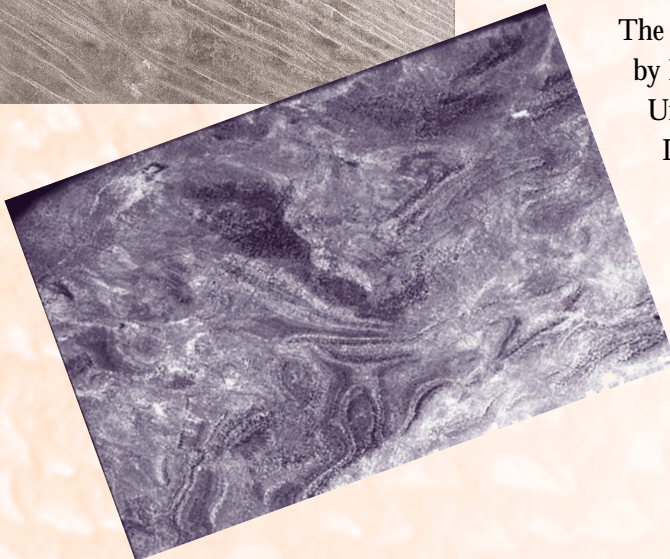
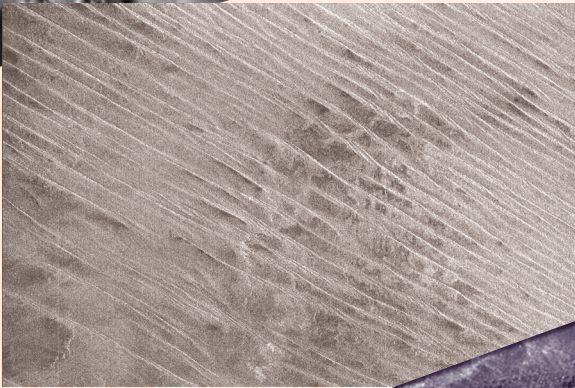
Visit the free image library

www.earthkam.ucsd.edu

Middle grade teachers (grades 5–8) use the online application in the Educator section to join the EarthKAM Community.

EarthKAM integrates Earth images with inquiry-based learning to enhance curricula in support of national and state science standards.

The EarthKAM Program is funded by NASA. Partners include the University of California at San Diego, NASA, and TERC.



Contents

“Embrace change when change holds promise for bringing us closer to our vision,” writes Barbara Sampson in this issue’s cover article *Staying the Course*. Indeed, as is evident from the cover, we are embracing change.

Hands On! was launched more than 25 years ago and has appeared twice a year in its previous format for over a decade. The very first issue stated that the publication was an “experiment,” a way to reach out to teachers with ideas and materials for improving education. Since then our readership has grown to more than 25,000, including administrators, staff developers, scientists, mathematicians, parents—people committed to improving math and science education. Over the years we have continued the experiment. *Hands On!* may have a new format, but the purpose remains the same: to offer thoughtful articles that contribute to an understanding of teaching and learning.

The format changes hopefully bring us closer to achieving our aim. The new font and layout should make it easier to read and reproduce. More sidebars have been added to offer quick reference to important resources and contacts relevant to each article. We continue our regular departments that announce new projects and resources and ways to get involved with TERC. We are also taking advantage of technology. In addition to *Hands On!* on the Web, we offer a way to subscribe online at www.terc.edu/handson.

We hope that the changes contribute to making *Hands On!* a better educational resource. We welcome your comments at ken_mayer@terc.edu.

—Kenneth Mayer, Editor

Executive Editor
Peggy M. Kapisovsky

Editor
Kenneth Mayer

Designer, Production Manager
Jane Sherrill

Editorial Assistant
Sherry Soares



1

Staying the Course

Barbara C. Sampson

Committed to a vision for learning that honors the abilities and potential of students and teachers



4

Collaborative Inquiry

Uses Data to Get Results

Diane E. Ready

How one district is implementing an approach to school improvement now detailed in a new book



8

Algebra in the Early Grades?

David Carraher, Analúcia D. Schliemann, and Bárbara M. Brizuela

Third-grade students encounter “algebraic arithmetic”

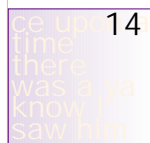


12

Re-Opening the Science Door

Susan J. Doubler, Gail Mathews-DeNatale, and Andee Rubin

Teachers pioneer a new online master’s program in science education



14

Children’s Ways With Words

National conference explores how mathematics and science education can be more responsive to poor and minority students

22 New Projects

22 Resources by TERC

24 Get Involved

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

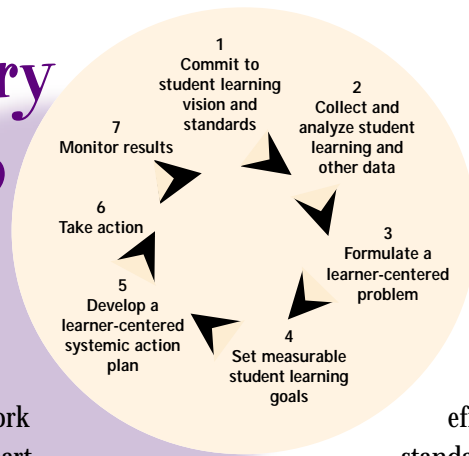
Copyright © 2001 by TERC. All rights reserved. No part of this publication may be reproduced without written permission. Contact Peggy Kapisovsky, TERC, 2067 Massachusetts Avenue, Cambridge, MA 02140, (617) 547-0430. peggy_kapisovsky@terc.edu. *Hands On!* is available at www.terc.edu.

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

ISSN 0743-0221

Collaborative Inquiry Uses Data to Get Results

By Diane E. Ready



Tuesdays in the Concord, New Hampshire, public school district are alive with academic inquiry. Groups work together, ask questions, examine assumptions, and tear apart data. This scene, however, is not playing out among students, but among teachers participating in “Data Tuesday Training Days.” Using an Eisenhower grant from the U.S. Department of Education to fund release time for professional development, Concord is training all mathematics teachers in the district to use a collaborative inquiry process to improve their programs.

The process modeled at the Concord training sessions is detailed in *Using Data /Getting Results: A Practical Guide to School Improvement in Mathematics and Science*, by Nancy Love, forthcoming from Christopher-Gordon Publishers. The book grew from Love’s work as a professional development specialist for the Regional Alliance at TERC.¹ Collaborating with a network of schools throughout the Northeast, Puerto Rico, and the Virgin Islands, the Alliance piloted many of the principles and techniques now outlined in the book. Teachers in those schools were using a process of inquiry to improve their curriculum, instruction, and assessment practices. Love and the Alliance realized that the process, which involves asking generative questions, collecting and analyzing data, examining assumptions, and formulating and testing hypotheses, could help other educators achieve their reform goals.

Data As a Tool, Not a Club

Using Data presents a rationale, guidance, and reams of practical data collection and analysis tools for school districts that want to use data to improve student learning. The author challenges conventional assumptions about what data are and how to use them in the context of educational reform. She explains, “The standards movement has shined a flashlight on improving learning for all students. However, many school reform efforts have been based on intuition and speculation, rather than on rigorous use of data, and this has led to a flurry of activity without effective ways to measure

whether students are benefiting. Over-reliance on standardized and high-stakes tests—which often lack rich information about instruction—compounds the problem.

Educators have learned to fear data because data have been used so often “as a club against schools, administrators, and teachers....For a variety of reasons, including this fear, [educators] often don’t use data for their own purposes—to diagnose problems, spark action, and improve results” (Love, 2001, p. 1.11).

Anne Wheelock further describes this practice in the forward to *Setting Our Sights: Measuring Equity in School Change*, by Ruth S. Johnson.

Indeed it is frequently “outsiders”—state officials or university researchers, for example—who first gather the data, and other “outsiders”—the local Chamber of Commerce or politicians with an ax to grind—who then use the data, often for purposes that serve neither schools nor their students well. As a result, many educators have come to think of data...[as] the stuff that bureaucrats in faraway offices use to beat up on schools. (1996, p. xxi)

Some schools, responding to pressure to increase scores on state tests, may focus their efforts on raising the scores of those students already doing well. Schools may appear to be improving, when, in fact, the needs of the lowest-performing students remain unmet. A recent study of fourth-grade reading results from the National Assessment of Educational Progress is just one example of this problem. The study found that while the scale scores for higher-performing students have increased since 1992, the gap between the highest- and lowest-performing students is widening (Donahue, Finnegan, Lutkus, Allen & Campbell, 2001). “Quick fix” methods focused on raising the average test score often leave some students behind. Increasingly, educational leaders are turning to a more rigorous collection and use of data to inform decisions and guide sustained improvements in the system so that all students attain higher levels of achievement.

¹The Regional Alliance is the Northeast and Islands Eisenhower Regional Mathematics and Science Consortium.

Creating Data Users

Love asks educators to become “data users, not just data givers.” They need to collect and analyze data to develop informed responses to student needs. In addition to standardized tests, schools need to use other measures such as local performance assessments, enrollment figures, and dropout rates. Further, using data about curriculum, instruction, and assessment practice may help educators understand underlying factors related to the student learning results.



Photo: Chris Demers

Looking Through Many Windows Improves the View

Once a number of potential data sources are identified, *Using Data* recommends “triangulation,” defined as “using multiple (two to three) independent sources of data about the same issue or problem” (Love, 2001, p 2.20). The book references researcher Richard Sagor’s analogy showing how students would use “triangulation” to investigate life in a terrarium. Students would be expected to observe from above and from each side to draw a three-dimensional understanding of the life inside. An animal hidden under a leaf or behind a rock would be overlooked if the observations were made through one window only (Love, 2001, p 2.20). So too, educators gain insight by examining questions from multiple perspectives before embarking on a path of reform.

Data from different sources may highlight issues that raise crucial follow-up questions. For instance, standardized tests showed one school that students were underperforming in geometry. While it was initially assumed that teachers needed to spend more time teaching geometry, subsequent data collection revealed that instruction time was not the problem. That pointed the school to look at differences in instructional practices to improve results. This example illustrates how “Data can get to the root cause of problems, pinpoint areas where change is most needed, and guide resource allocation” (Love, 2001, p.2.10).

Disaggregation: Looking At Each Chapter To Learn The Whole Story

Disaggregating the data is another critical step to gaining increased knowledge from the collected information. Disaggregating data involves delving more deeply into a set of results to highlight issues that pertain to individual subsets

of results, such as those for a specific grade level, gender, ethnic, or socio-economic group.

For example, the public schools in Providence, Rhode Island, looked at enrollment data as well as

standardized test scores to address poor performance in math. The enrollment data revealed that students of color were underrepresented in high-level mathematics courses. The district also looked at research showing that minority students who do not take algebra or geometry in high school are 40 to 60 percent less likely to complete college. In response, the district untracked mathematics instruction, offering the same algebra instruction to all students. After six years, the district reports failure rates much lower than before, as well as an increased enrollment in third and fourth year mathematics courses (Love, 2001, p. 7.16).

Concord Data Sessions Identify Issues

Chris Demers is the Concord-based educator who is implementing the Tuesday Data Training sessions to introduce all of Concord’s math teachers to the collaborative inquiry process. Early efforts at triangulating and disaggregating data are pointing participants in constructive directions.

Demers tells of how one group used disaggregation to learn more than aggregate scores alone could tell about sixth-grade science performance. Teachers suggested taking the results of a sixth-grade science test and pulling out questions that called for knowledge taught exclusively during sixth grade. Demers explains that by taking this extra step “they came up with some interesting, disturbing findings. Kids were progressively doing worse on the grade 6 content as they looked at tests back all the way to 1996 through to the current test in 2000....The average score [for questions covering sixth-grade content] dropped over the five years, where-

Possible Ways to Disaggregate Data

- ▼ Schools within a district
- ▼ Grade level
- ▼ Proficiency in English
- ▼ Length of time in the district
- ▼ Race
- ▼ Gender
- ▼ Quartiles
- ▼ Socioeconomic status using indicators such as students receiving free or reduced lunch or mother’s level of education
- ▼ Course-taking experience
- ▼ Amount or type of training the teacher has received
- ▼ Participation in programs such as special education, bilingual, or Title I

as the K–5 content stayed primarily level....They took that as a starting point for further inquiry.”

Time Well Spent

As the New Hampshire example illustrates, data analysis leads more often to the need for additional data collection and analysis than to immediate action. The collaborative inquiry process is a means to continuous improvement, not a sprint to short-term solutions. The process does, however, eliminate time and resources wasted when systems ask the wrong questions or take action based on faulty assumptions and incomplete knowledge.

Chris Demers calls *Using Data/Getting Results* “a natural fit” as his district strives to meet state requirements to measure a district’s actions in terms of its contributions to student learning. Rather than resisting the time commitment required to faithfully follow the process, teachers have reacted positively because using data will meet educational goals and satisfy demands for accountability.

Demers observes, “We see this [the collaborative inquiry process] as a more viable type of professional development, as opposed to offering a workshop on a new way to teach without knowing if it’s right for your school. The process also models the process we want teachers to use with their students, which helps them be better teachers when they leave the session.”

Instead of viewing data collection and use as an “add-on,” school systems are encouraged to use data to advance the work of established committees and planning groups. Teachers need to have professional learning imbedded in their jobs in the same way that most other professions have meetings and planning sessions included in the weekly workload.

Collaboration Creates Ownership and Informed Action Plans

When Chris Demers began the data use workshops in Concord, he feared teachers might reject the collaborative inquiry process, noting that teachers have been asked to jump on and off so many educational “next-big-thing” bandwagons. He found, however, that many of the teachers who were most skeptical about the utility of the process left the

workshop fired up to take the process further. Teachers welcomed the collaborative framework of *Using Data’s* approach, which diminishes the frustration that comes when change is dictated from external sources alone.

According to Demers, “The teachers like that the process values them as intrinsic to the solution. Because it is grounded in dialogue with no predetermined outcomes, the process mirrors what so many teachers want to achieve in their classrooms. As teachers delve more deeply into a question, they begin to challenge assumptions and reflect on their own personal classroom practices, and open up to different ways of looking at both problems and solutions.”

A Cycle for Perpetual Progress

In the collaborative inquiry process (see title graphic), it should be noted that five steps precede taking action and, more importantly, taking action is not the final step. A cycle emerges, which calls for constantly monitoring results to adjust to the ever-changing educational landscape. Reaction to the process, as it is being introduced in Concord, indicates that teachers and administrators appreciate the fact that the approach does not begin with loyalty to any specific curriculum or instructional

practice. Because the process uses data to *identify* problems as much as to solve them, it does not allow for data to be manipulated to justify any predetermined agenda for action.

Using Data emphasizes that the only loyalty must be to students and their learning.

No program is implemented, no action is taken unless there is good reason to believe it will help students to reach a specific learning goal, such as improving their ability to reason better in mathematics. Once action is taken, teachers, students, and parents receive frequent feedback about how well students are performing in relation to that goal. If the changes are working, everyone knows it and can celebrate its success. On the other hand, if student learning is not increasing, planners try to find out why, make mid-course corrections, or abandon the program. (Love, 2001, 1.13)

Using Data/Getting Results

Coming soon from
Christopher-Gordon Publishers

To order call 1-800-934-8322

Christopher Gordon Publishers, Inc.,
1502 Providence Highway, Suite 12,
Norwood, MA 02062

Facilitator Training for Using Data-Getting Results

August 13–15, 2001,
Newton, Massachusetts

This workshop will engage participants with the conceptual framework, processes, and practical tools from *Using Data/Getting Results: A Practical Guide for School Improvement in Mathematics and Science*. Designed for administrators, staff developers, and others responsible for leading teachers in reform initiatives, the training is the first step in a certification process that includes ongoing support from the Regional Alliance and book discounts. Contact alliance@terc.edu or see ra.terc.edu/datatraining.

While data are essential for school improvement, reports alone will not create better schools. Only by working collaboratively to use the numbers and observations can schools attain lasting progress. Love writes, “We believe that the full power of the inquiry process is unleashed when school staff work together, not in isolation, when data become a catalyst for constructive dialogue, and when school communities develop shared understandings and ownership of problems and solutions being pursued” (Love, 2001, p.1.11).

Only Time Will Tell

A long-term commitment to collecting and using data collaboratively is necessary to sustain the arc of improved student learning through political, personnel, cultural, and academic changes and trends. Twenty years ago the Glendale, Arizona, school district instituted its “Instructional Management System, a network of personnel and resources to promote curriculum alignment, district-wide assessments, and rigorous use of data as a catalyst for improvement.” Since then, Glendale student scores on a range of assessments have shown gradual but nearly continuous improvement, while drop-out rates have decreased and the relationship between achievement and socio-economic status has shrunk (Love, 2001, pp. 7.5–7.6).

The principal of Glendale Union’s Washington High School notes “I used to hear a lot of complaining about the kids...the neighborhood has gone down; their families...their attitudes....I don’t hear anything about ‘these kids’ any more.” (Love, 2001, pp. 7.5–7.6). Every year the district releases reports that provide a snapshot of each school’s performance. The data provide accountability and are the reservoir that feeds improvement. “Departments meet as teams to pore over their data, set targets for improving specific student learning outcomes and discuss what instruction strategies they will implement to reach their goal” (Love, 2001, 7.10).

The data assessments and data analysis provide a map that moves teachers closer to reaching each student. The

chairperson of the Washington High School Science Department reflects on the gains the school has made using data. “To me, the best part of this process is that we can’t allow even one student not to learn. We used to just accept that some students sit back and do nothing. Now, teachers aren’t going to allow that” (Love, 2001, 7.11).

Using Data/Getting Results points to better use of data as “the compelling evidence that grounds conclusions in actual results, not in

speculation.” An inquiry-based approach requires time to frame solutions, but results in solutions that hit the mark with greater accuracy and are revised as needed to keep hitting the mark in dynamic educational environments. “In inquiry-based schools, teachers and administrators continually ask questions about how to improve student learning, experiment with new ideas and rigorously use data to uncover problems and monitor results....Researchers in both business and education agree that these qualities are hallmarks of the most successful organizations” (Love, 2001, p.1.11).

References

- Donahue, P. L., Finnegan, R. J., Lutkus, A. D., Allen, N. L. & Campbell, J.R. (2001). *The nation’s report card: Fourth-grade reading 2000*, NCES 2001-499. Washington, DC: U.S. Department of Education.
- Johnson, R. (1996). *Setting our sights: Measuring equity in school change*. Los Angeles, CA: The Achievement Council.
- Love, N. (2001). *Using data /getting results: A practical guide to school improvement in mathematics and science*. Norwood, MA: Christopher Gordon.

Diane Ready is a free-lance writer in Mansfield, Massachusetts.

This article is based on interviews with Nancy Love and Chris Demers.

Correspondence concerning this article may be sent to nancy_love@terc.edu.

Using Data/Getting Results was produced by the Regional Alliance at TERC with funding from the U.S. Department of Education #R168R50028 and #R139A000013.

Algebra in the early grades

by David Carraher, Analúcia Schliemann,
and Bárbara M. Brizuela

Consider the following problem:

Mary and John each have a piggy bank.

On **Sunday** they both had the same amount in their piggy banks.

On **Monday**, their grandmother comes to visit and gives \$3 to each of them.

On **Tuesday**, they go together to the bookstore. Mary spends \$3 on a book. John spends \$5 on a calendar with pictures of dogs on it.

On **Wednesday**, John washes his neighbor's car and makes \$4. Mary also made \$4 babysitting. They run to put their money in their piggy banks.

Show how much money Mary and John have on each day. Compare their amounts for each day. Show how much money they end with.

This is no ordinary arithmetic problem. It doesn't say how much money John and Mary had on Sunday. And you cannot know how much they have on any day. So what's the point?

If you think about it, you can compare Mary's and John's amounts on each day, determine who ends up with more money, and learn whether each child ends with more or less money than they started with. To do so, you need to examine the relations among the amounts and work with unknown values, drawing conclusions that are true for whatever amounts the children began with. This is a problem of "algebraic arithmetic."

Although K–12 mathematics curricula have long been built on the assumption that arithmetic and algebra are distinct areas of mathematics, there are reasons for treating them as intertwined and overlapping. Traditional arithmetic requires students to perform calculations on particular numbers, but students also need to move from thinking merely about individual values to looking at sets of values. If we tell students the initial amounts for the "piggy bank" problem, they can simply calculate the answer. Without defining the amount, students must represent and operate on unknown values.

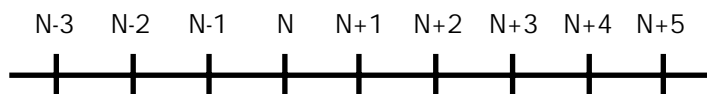
In the Early Algebra, Early Arithmetic project at TERC, we have been investigating how young students think about and represent functions and unknowns, using both

their own and conventional symbols. When presented with tasks similar to the "piggy bank" problem, third grade students participating in the project have been doing some remarkable mathematics.

The following is an account of how one class and their teacher, Bárbara, worked through the problem.¹

Representing An Unknown Amount

The students were first given the problem in its entirety, so that they could understand that it consisted of a number of parts. Then they received a problem sheet with just Sunday's information. The sheet also had the following variable number line (or N-number line):



The students worked alone or in pairs, trying to represent on paper what was described in the problem.

Sunday. After Kimberley reads the Sunday part for the whole class, Bárbara asks whether they know how much money Mary and John have. In unison the children exclaim "no" and do not appear to be bothered by that. The children state that the amount is "any number" and "anything" and a few suggest it is "N." Talik offers, "N, it's for anything."

Bárbara asks how they should represent the first step in the problem. Filipe says, "You could make some money in them [the piggy banks], but it has to be the same amount." When Bárbara reminds him that he doesn't know what the amount is, he suggests writing N. Bárbara tells the students that they can use the N-number line on their problem sheet. She also draws a copy of it on the board.

Jennifer uses N to represent the initial amount in each bank. She draws two piggy banks, labeling one for Mary, the other for John, and writes next to them a large N along with the statement "Don't know?" David (from the project research team) points to "N" on her handout and asks:

¹The students attend a public elementary school in a multi-cultural, working-class community.

David: Why did you write that down?

Jennifer: Because you don't know. You don't know how much amount they have.

David: [...] What does that mean to you?

Jennifer: N means any number.

David: Do they each have N, or do they have N together?

Jennifer: (No response.)

David: How much does Mary have?

Jennifer: N.

David: And how about John?

Jennifer: N.

David: Is that the same N or do they have different Ns?

Jennifer: They're the same, because it said on Sunday that they had the same amount of money.

David: And so, if we say that John has N, is it that they have, like, ten dollars each?

Jennifer: No.

David: Why not?

Jennifer: Because we don't know how much they have.

The children themselves proposed using N to represent an unknown quantity. The researchers had introduced the convention before in other contexts but now it was making its way into their own repertoire of representational tools. Several children appeared to be comfortable with the notation for an unknown as well as with the idea that they could work with quantities that might remain unknown. Some started by attributing a particular value to the unknown amounts in the piggy banks but, as they discussed what they were doing, most of them seemed to accept that this was only a guess. Their written work shows that by the end of the class 13 of the 16 children adopted N to represent how much money Mary and John began with. One child chose to represent the unknown quantities with question marks and only two children persisted using an initial specific amount in their worksheets.

Talking About Changes in Unknown Amounts

Monday. The children infer that Mary and John would continue having the same amount of money as each other, and that they both had \$3 more than the day before. As Talik explains, "Before they had the same amount of money, plus three, [now] they both had three more, so it's the same amount."

Bárbara asks the children to propose a way to show the amounts on Monday. Most of the children use N in their depictions. Nathan proposes that on Monday they would each have N plus 3 "because we don't know how much money they had on Sunday, and they got plus ...and they got three more dollars on Monday."

Jeffrey offers a drawing (Figure 1) as an explanation. Three units are drawn on top of each quantity, N, of unspecified amount. Some students use a question mark in their representations. Filipe represents the amount of money on Monday as "?+3." Bárbara comments on Filipe's use of a question mark. He and other children acknowledge that N is another way to show the question mark.

Tuesday. Mary and John have begun to spend money and that makes some of the students uncomfortable. They want to make sure that both have enough money in their piggy banks to cover what they spend. One student supposes that they probably have ten dollars, most assume that there is at least \$5 in

the piggy banks by the end of Monday, otherwise John could not have bought a \$5 calendar. (They seem uncomfortable with him spending money he doesn't have.)

Bárbara recalls for the class what happened on Sunday and Monday. The children agree that on Monday Mary and John had the same amounts. In response to Bárbara's question about the amounts on Tuesday, the children agree that Mary and John will have different amounts of money because John spent more money than Mary.

Jennifer describes what happened from Sunday to Tuesday and concludes that on Tuesday Mary ends up with the same amount of money that she had on Sunday, "because she spends her \$3." Bárbara encourages the children to use the N-number line to represent the transactions from Sunday to Tuesday.

Continuing the dialogue with students, Bárbara draws green arrows going from N to N+3 and then back to N

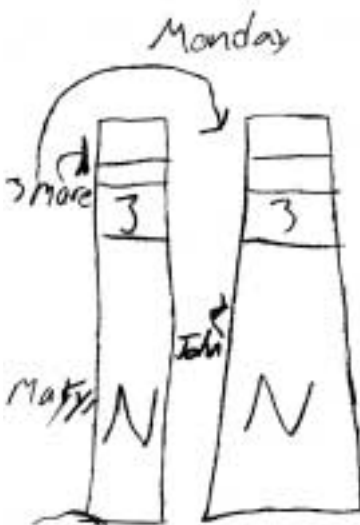
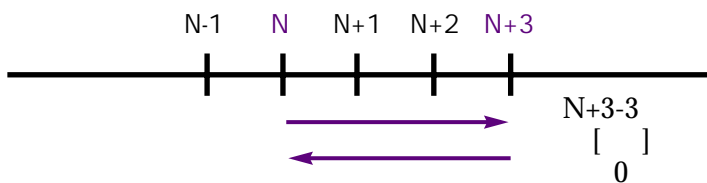


Figure 1. Jeffrey's representation of $N+3$

again. She uses notation as well and writes $N+3-3$. She puts a bracket under $+3-3$ and a zero below it, commenting that $+3-3$ is the same as zero, and extends the notation to $N+3-3=N+0=N$.



Jennifer then explains how the \$3 dollars spent negates the \$3 given by the grandmother, “Because you added 3, right? And then she took, she spent those 3 and she has the number she started with.”

Using the N-number line Bárbara leads the students through John’s transactions, drawing arrows from N to N+3, then N-2, for each step of her

David (the researcher) asks Jennifer how much John would have to receive to have the amount he had on Sunday. She answers that we would have to give two dollars to John. Using the number line, she explains that if he is at N-2 and we add 2, we get back to N. Bárbara represents what Jennifer has said as: $N-2+2=N$. Eagerly grabbing the marker, Jennifer brackets the sub-expression, “ $-2+2$,” and writes a zero under it. Bárbara asks why it equals zero. Together with Jennifer, she goes through the steps corresponding to $N-2+2$ on the number line and lands at N. Talik shows how this works if N were 150. Bárbara uses Talik’s example to demonstrate how, given a specified amount like 150, you always return to the point of departure on the number line.

Wednesday. Bárbara asks whether Mary and John will end up with the same amount on Wednesday. James says “No.” Arianna explains that Mary will have $N+4$ and John will have $N+2$.

Bárbara asks Arianna to tell the story using the N-number line on the board.

Arianna represents the changes for John and for Mary. Bárbara then writes out the notations,

$N+4=N+4$, then $N-2+4=N+2$.

Talik explains this by saying that if you take 2 from the 4, it will equal 2. To clarify where the 2 comes from,

Bárbara represents the following operations on a regular number line: $-2+4=2$.

Bárbara asks if anyone can explain the equation referring to

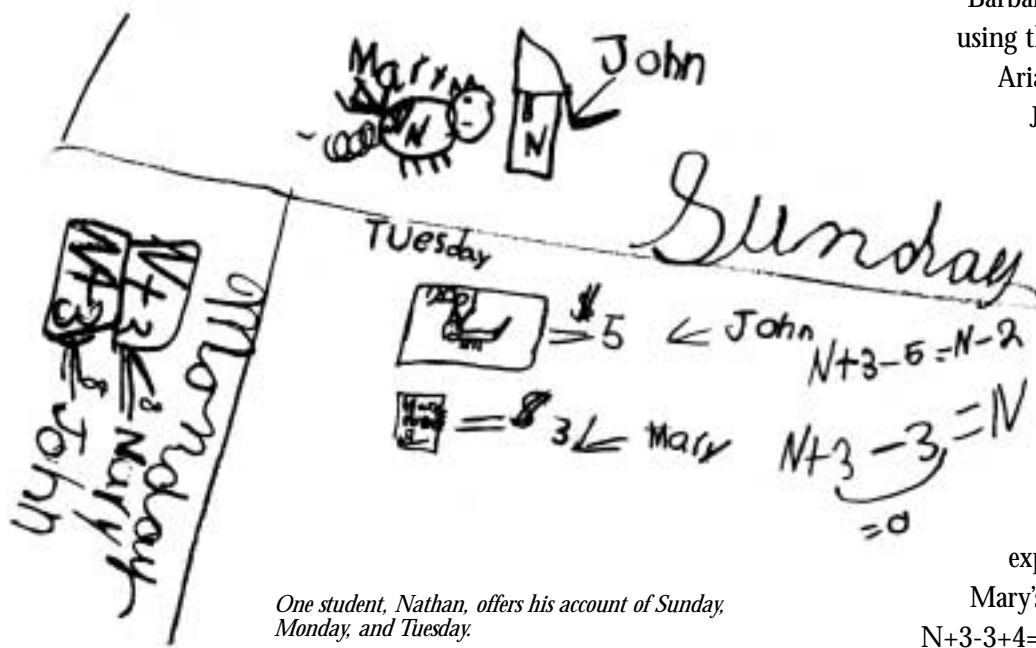
Mary’s situation, namely,

$N+3-3+4=N+4$. Talik again volunteers and

crosses out the $+3-3$ saying that it isn’t needed

anymore. This is a significant moment because no one has ever introduced the procedure of striking out the sum of a number and its additive inverse (although they had used brackets to simplify sums). It may well represent the meaningful emergence of a syntactical rule.

Bárbara brackets the numbers and shows that $+3-3$ yields zero. She proposes to write out the “long” equation for John, $N+3-5+4=N+2$. The students help her to go through each step in the story and build the equation from scratch. But they do not get the result, $N+2$, immediately. When the variable number line comes into the picture they see that the result is $N+2$.



One student, Nathan, offers his account of Sunday, Monday, and Tuesday.

drawing. While sketching each arrow, she repeatedly draws upon the students’ comments to arrive at the notation, $N+3-5$. Some children suggest that this is equal to “N minus 2.” Bárbara continues, writing $N+3-5=N-2$. She asks Jennifer to use the number line in the front of the class to point to the difference between John’s and Mary’s amounts on Tuesday. Jennifer first points ambiguously to a position between N-2 and N-1. When Bárbara asks her to show exactly where the difference starts and ends, Jennifer correctly points to N-2 and to N as the endpoints.

When Bárbara asks Jennifer to show how the equation can be simplified and Jennifer hesitates, Bárbara points out that this problem regarding John's amount is harder than the one regarding Mary. Bárbara asks her to start out with $+3-5$; Jennifer says -2 . Then they bracket the second part at $-2+4$, and Jennifer, counting on her fingers, says it is $+2$ and writes it out. Talik explains, "N is anything, plus 3 minus 5 is minus 2; N minus 2 plus 4, equals (counting on his fingers) N plus 2.

Talik then tries to group the numbers differently, adding 3 and 4 and then taking away 5. Bárbara points out how the numbers could be grouped a different way and shows that $+3+4$ yields $+7$. When she subtracts 5, she ends up at $+2$, the same place suggested by Jennifer.

Thursday. The students are given the final part of the problem and learn that Mary ends with \$9 in her piggy bank. Several students respond that N has to be 5. Bárbara asks the children, "How much does John have in his piggy bank?" Some say incorrectly that he has two more; other children say that he has 7. Some of the students figure this out from adding $5+2$, others from the fact that John was known to have 2 less than Mary, since $N+2$ is two less than $N+4$.

Bárbara ends by filling out a data table that includes the names of Mary and John and the different days of the week with the children's suggestions for how much money each one had on each of the different days. Some students suggest using expressions containing N and others suggest expressions containing the now known value, 5.

Some Reflections

The lesson described above is typical in several ways of the 12 lessons carried out with the students in three grade 3 classrooms. The students' responses were diverse, with some relying more than others on instantiating unknowns to particular values. Over time, however, in each lesson and across the lessons the students increasingly came to use algebraic notations and number line representations as a natural means of describing the events of stories.

Our experience has convinced us that children as young as eight and nine years of age can learn to comfortably use letters to represent unknown values, and can operate on representations involving letters and numbers without having to instantiate them. To conclude that the sequence of operations " $N+3-5+4$ " is equal to $N+2$, and to explain, as many children did, that N plus 2 must equal two more than what John started out with, whatever that value might be, is a significant

Early Algebra, Early Arithmetic


[Home](#)
[Classroom Materials](#)
[Reviews](#)
[News/Events](#)
[Links/References](#)
[Our Work](#)
[About Us](#)

Welcome to the Early Algebra, Early Arithmetic Website!

What is Early Algebra?

Early Algebra is an approach to early mathematics teaching and learning. It includes many topics in arithmetic, such as the four operations, but it does so in novel ways. Early algebra does not aim to increase the amount of mathematics students must learn. Rather, it is about teaching time-honored topics of early mathematics in deeper, more challenging ways.

Early Algebra is also an area of research. Several mathematics educators have suggested that algebra should enter the early mathematics curriculum (and they have initiated systematic studies. (The Early Algebra, Early Arithmetic web site has an extensive bibliography of research in this emerging field.)

Still, much remains to be done. We view algebraic arithmetic as an exciting proposition, but one for which the ramifications can be known only if a significant number of people undertake systematic teaching experiments and research.

To learn more visit the Early Algebra, Early Arithmetic web site www.terc.edu/earlyalgebra/.

achievement—one that many people would think young children incapable of understanding. Yet we found such cases to be frequent and not confined to any particular kind of problem context. It would be a mistake to dismiss such advances as mere concrete solutions, unworthy of the label "algebraic." Children were able to operate on unknown values and draw inferences about these operations while fully realizing that they did not know the values of the unknowns.

By arguing that children can learn algebraic concepts early we are not denying the developmental nature of these concepts, much less asserting that any mathematical concept can be learned at any time. Algebraic understanding will evolve slowly over the course of many years. But we need not await adolescence to intervene in its evolution.

David Carraher is a Senior Scientist at TERC, Analúcia D. Schliemann is Professor of Education at Tufts University Department of Education, and Bárbara M. Brizuela is a doctoral candidate in Learning and Teaching at the Harvard Graduate School of Education.
david_carraher@terc.edu

The Early Algebra, Early Arithmetic project is funded by the National Science Foundation #REC-9909591.



Re-opening the science door

It's Friday and the teacher logs on to her computer to get a jump on next week's physics assignment. She knows she will be working through an investigation, recording predictions and findings in her journal, and preparing for class discussion and debate. She learns that the week will be an encounter with Newton's second law. The teacher and her classmates (other teachers) will carry out the investigation supported by a scientist and a science educator. She may never meet the other members of her class, however, since, like her, they do all their work at home and online.

Pioneering Teachers

The teacher is participating in a fully online master's program in science education, developed by TERC and Lesley University. She is one of 27 educators (grades K–8), who along with program developers are pioneering an inquiry-based approach to learning science online. Some of the teachers have strong science backgrounds and even science research experience. Others commented that they were slightly afraid of science but enrolled in the program because they wanted to give their students a better science experience than they had as students.

The program seeks to “re-open the door to science” by providing teachers with a safe environment where they can think hard, work collaboratively, and extend their science understandings. Totalling 33 credit hours, the program helps teachers increase their knowledge of physics, biology, earth science, engineering, and ecology, while exploring new ways to support their students' science learning. Developing expertise with computer-based technology, they learn ways to enhance learning with technology.

A scientist and a science educator facilitate each course, in which learning occurs through sustained inquiry—a series of related investigations carried out at home. This is followed by in-depth discussion—teachers share results, look for patterns or discrepancies in their findings, and generate explanations based on their data.

The teachers' coursework carries over to the classroom. They develop strategies for paying attention to their students' ideas, for supporting learning through inquiry, and for assessing inquiry-based science.

They practice these strategies in their own classrooms and share successes and dilemmas.

Testing the Waters

With Try Science, a 3-credit course that explores the science in a glass of water, the teachers were able to try investigation-based science and online learning before making a commitment to the master's program. The course allowed each teacher to answer the questions: Could I be successful with science? Would I enjoy learning in this new environment?

Encountering Motion

The teachers are now in the middle of their second course, Investigating Physics. They are studying motion and forces and strategies for paying close attention to children's ideas.

This week they logged on to learn they will be working with Newton's second law, investigating the relationships among force, mass, and acceleration. They are assured that their investigations will help demystify $F=ma$.

Their investigation requires a cart, penny rolls, a binder clip and their kitchen table. (See Figure 1.) They consider the following scenario:



Figure 1: Investigations are done at home, often on students' kitchen tables.

You thread a string through the hook on the front of your cart and tie it tightly. At the other end of this string, you attach a medium-sized binder clip. You place two penny rolls in a plastic sandwich bag and hold it with the binder clip. Then you place a number of penny rolls in your cart, hang the bag over the edge of the table, and let your cart roll!

The challenge is to use this set up to explore the quantitative relationship among force (F), mass (m), and acceleration (a) by varying the number of penny rolls in the bag or in the cart.

In this investigation you will compare the accelerations for different combinations of mass and force. First, watch and listen to the cart as it moves. What difference do you notice in how the cart accelerates with differing numbers of pennies on the cart (mass) and differing numbers of pennies on the end of the string (force)? Try various combinations of numbers of penny rolls in the cart and in the bag.

The cart's motion happens quickly, so the teachers go online to look at digital videos that show different combinations of pennies on the cart and in the bag. Since each frame is an equal unit of time, the teachers can analyze the different combinations. How far does the cart travel between frames? Is this distance changing? The teachers tape a transparency on their computer screen and mark where the cart is in each frame to determine whether it is speeding up, slowing down, or going at a constant speed.

The teachers share their findings with their six-person study group and discuss the science behind the events. Working collaboratively, they compare results, ask each other questions, and develop new understandings.

This feels like a work in progress—or at least my understanding is!...The pattern I noticed between the videos and my playing was that the amount of force was equal to the acceleration of the amount of mass. What I mean by this is that the mass of the cart accelerated in direct relation to the amount of force. For example, 1 penny roll cart with 4 rolls on the string accelerated and moved faster than the cart with 1 roll of pennies and 1 roll on the string.... The greater force resulted in faster acceleration. Also, the mass in the cart was constant, so if the mass is constant it takes more force to accelerate quickly and less force to accelerate slowly.

Now, with greater mass, it took more force to accelerate as quickly as when there was less mass. So, the greater the mass, the more force to accelerate that mass to certain acceleration....I couldn't resist [taping] another transparency [to the computer screen] and this also illuminated the acceleration.

The group is not online simultaneously. Instead they post within a certain time period. Teachers comment that the online environment offers more time to think than a conventional science class.

During science classes when I was in school ... another student would answer the question before I even had time to begin thinking. Then the discussion would be over and ... any understanding that I wanted to develop would be gone. So, this format is much more productive for me.

Finally, the week's study ends with the challenge of finding $F=ma$ in your life. People didn't need to look far.

Try Science (3 credits)

Science content: Science as inquiry and a human endeavor
Pedagogical focus: Developing conceptual understanding through science inquiry

Investigating Physics (6 credits)

Science content: Exploring the organizing principles of forces and motion
Pedagogical focus: Paying attention to learners' ideas about scientific phenomena

Biology Explorations in Variation, Diversity and Adoption (6 credits)

Science content: An introduction to adaptation using an evolutionary perspective
Pedagogical focus: Classroom facilitation

Registration Deadline: September 5, 2001

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

For a demo of the online environment, visit scienceonline.terc.edu

I had the opportunity this evening to "experiment" with a very full shopping cart! :-) I noticed that whenever I accelerated the cart, I had to exert a lot of force, but to keep it moving at a constant velocity took very little effort. I now see that I am merely overcoming outside forces, mostly frictional forces, when I am maintaining the cart's constant velocity which is why the force I exert is so minimal. Acceleration is a different story! Whenever I started moving the shopping cart, stopped it, or turned it, I had to exert a lot of force on the shopping cart. What I find amazing is that I always 'knew' this, as I have an abundance of grocery shopping experience, but I never connected turning or stopping the carriage with acceleration! By connecting $F=ma$ to this particular example, it really makes sense to me!

Things are really starting to click for me. I am gaining deeper insight on motion, rather than my merely swallowing a bunch of scientific facts that I really don't have any true understanding of, but can repeat back.

Reaching the Goal

In December 2002, these pioneering teachers will complete their last program course and earn a master's degree. Like all Lesley graduates, they will be invited to participate in graduation. Perhaps then, they will come to campus and finally meet face-to-face.

Susan J. Doubler is Principal Investigator and Co-Director of the Lesley/TERC Master's Project. Gail Matthews-DeNatale is the online learning coordinator. Andee Rubin is Lead Developer of the Investigating Physics course. sue_doubler@terc.edu; gail_mathews-denatale@terc.edu; andee_rubin@terc.edu

The Lesley/TERC Master's Project is funded by the U.S. Department of Education #P116D990066 and the National Science Foundation #ES-I9911770.

Children's Ways With Words

This excerpt is from the *Children's Ways With Words in Science and Mathematics* conference report prepared by **Ann S. Rosebery** and **Beth Warren**.

At a time when children from culturally and linguistically diverse backgrounds represent the fastest growing school-age population in the United States,¹ too many of these children are failing in school science and mathematics. Their sense of themselves as learners and thinkers, their possible career trajectories, and the well-being and resilience of our nation's social, economic, and political life are in jeopardy. The under-representation of poor and minority students in advanced sciences and mathematics is a complicated problem and, as the many attempts at addressing it attest, there are no simple solutions. Poverty, oppression, racism, lack of access to and history with formal schooling, social and economic stratification, and the like all contribute in powerful ways (Kozol, 1991; Mehan, 1991; Oakes, 1986).

The current science and mathematics education reform movements, while explicitly acknowledging their concern for "equity for all," have not directly or seriously addressed the problem. Instead, like previous well-intentioned but limited reform movements, they assume that high-quality curricula and authentic activity aligned with rigorous standards will result in high achievement for students living in poverty or from culturally and linguistically diverse backgrounds (AAAS, 1993; NCTM, 1989; NRC, 1996). Historically, however, the details of education reform in this country have been typically worked out in mainstream contexts, with the underlying assumption that they can then simply be exported to non-mainstream contexts (e.g., urban and rural school systems, bilingual/English as a Second language settings). In fact, reforms rarely "trickle down" successfully, in part because they have not been explicitly conceptualized in relation to diverse communities of learners or dynamic notions of culture (Gonzalez, 1999; Secada, 1989).

How can science and mathematics education reform be reconceptualized with poor and minority students in mind? One avenue that seems worth pursuing is to pool what is known about issues of equity and access with what is known about reforming science and mathematics education to create a new community of educators and researchers concerned

with, in the words of Deborah Ball (1997), being both "responsive to children and responsible to the discipline."

A Conversation Across Disciplines

This approach was explored at a national conference that brought together educators and researchers from diverse backgrounds and disciplines. *Children's Ways With Words in Science and Mathematics: A Conversation Across Disciplines* sought to begin a dialogue on issues central to improving learning and teaching for students from low-income, racial, linguistic, and ethnic minority backgrounds. Participants drew on their experiences as teachers, researchers, administrators, policymakers, and students in fields that included biology, physics, mathematics, psychology, linguistics, sociology, and cognitive science. The conference was organized around the analysis and interpretation of videotaped cases of classroom science and mathematics teaching and learning. Conference attendees investigated connections between children's ways with words and those characteristic of scientific and mathematical disciplines and the varied ways in which students and teachers enact these relationships to foster learning.

To enable the dialogue to expand to a wider audience, participants agreed upon key questions and recommendations for further research that can inform policies, classroom practices, and teacher professional development programs.

An Agenda for Research and Public Discussion

1. Learning Science and Mathematics

The question of "what counts" as scientific and mathematical knowledge and practice, and how learning emerges in classroom interaction provoked ongoing and intense discussion. Participants considered significant features of mathematics and science classrooms which emphasize teaching for understanding. Engaging students in a group practice aligned with important characteristics of adult mathematical or scientific practice, inquiry, and argumentation—and with community norms of mathematical or scientific accountability—was a primary focus. The case studies illuminated various relationships between what practicing scientists and mathematicians do, what students do in classrooms designed to

(continued on page 16)

¹There are now more than five million school-age children who come from homes in which English is not spoken. In several states, children from linguistic and cultural minorities represent more than 25% of the school-age population (e.g., AZ, CA, NY, FL, TX, NM) and in many large urban districts this figure is 50% or more (e.g., NYC, San Francisco, Los Angeles).

Research on Intellectual Resources for Learning Science

Studies in literacy and language use can inform the dialogue on issues of educational equity for low-income, racial, ethnic and linguistic minority children and on designing contexts in which these children learn and achieve. Much of this research focuses on what Shirley Brice Heath (1983) calls “ways with words”: the varying ways in which members of different communities engage in argumentation or storytelling, who participates when and for what purposes, how ways of talking and interacting that seem ‘natural’ to members of one community are experienced as culturally strange by another.

Studies in this tradition document how differences in ways with words affect students’ engagement in academic tasks and classroom communication (Cazden, 1988; Michaels, 1981; Moll, Estrada, Diaz & Lopes, 1980; Tharp & Gallimore, 1988). Teachers take in what children are trying to convey through the filters of their own knowledge, histories, and expectations. These include expectations as to what constitutes an explanation or what kinds of prior knowledge, experiences, and skills support scientific reasoning. Despite the best of intentions, teachers can misunderstand children who say and do things differently from what they expect. They can hear these children, who are often from backgrounds different from their own, as off-topic, confused, illogical, lacking in essential vocabulary; in short, as unscientific.

Recent research is countering this view of minority students’ abilities in science. In two studies, researchers revisited their initial negative interpretations of minority students’ learning to characterize the depth and coherence in the children’s thinking and uses of language (Gee & Clinton, in press; Michaels & Sohmer, 2000). Research at the Chèche Konnen Center is focusing on the intellectual resources that children from diverse backgrounds bring to the science classroom. The resources have been identified as powerful in constructing and conveying scientific meanings: narratives of everyday experience, culturally based practices of argumentation, embodied imagining, and the grammatical and conceptual resources of children’s first languages (Ballenger, 1997; Conant, Rosebery, Warren & Hudicourt-Barnes, 2001; Hudicourt-Barnes, 2000; Warren, Ballenger, Ogonowski, Rosebery & Hudicourt-Barnes, 2001). This research is showing that children from diverse backgrounds can harness powerful intellectual resources that reflect those used in science and those valued in national science standards. It further shows that when teachers take up and build on them, these resources have the potential to enhance learning for all students.

Further Reading

- Ballenger, C. (1997). Social identities, moral narratives, scientific argumentation: Science talk in a bilingual classroom. *Language and Education*, 11(1), 1–14.
- Cazden, C. (1988). *Classroom discourse*. Portsmouth, NH: Heinemann.
- Conant, F., Rosebery, A., Warren, B. & Hudicourt-Barnes, J. (2001). The sound of drums. In E. McIntyre, A. Rosebery, and N. González, (Eds.), *Building bridges: Linking home and school* (pp. 51–60). Portsmouth: Heinemann.
- Gee, J. & Clinton, K. (in press). An African-American child’s ‘science talk.’ In M. Gallego & S. Hollingsworth (Eds.), *Challenging a single standard: Multiple perspectives on literacy*. Norwood, NJ: Erlbaum.
- Heath, S. B. (1983). *Ways with words*. New York: Cambridge University Press.
- Hudicourt-Barnes, J. (2000, March). Style of argumentation in Haitian Creole. Paper presented at the 31st Annual Conference on African Linguistics, Boston University. Available from the Chèche Konnen Center at TERC.
- Michaels, S. (1981). “Sharing Time”: Children’s narrative styles and differential access to literacy. *Language in Society*, 10, 423–442.
- Michaels, S. & Sohmer, R. (2000). Narratives and inscriptions: Cultural tools, power and powerful sensemaking. In B. Cope & M. Kalantzis (Eds.), *Multiliteracies* (pp. 267–288). London and New York: Routledge.
- Moll, L.C., Estrada, E., Diaz, E., and Lopes, L. (1980, July). The organization of bilingual lessons: Implications for schooling. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition*, 2(3), 53–58.
- Tharp, R. & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning and schooling in social context*. Cambridge: Cambridge University Press.
- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday languages. *Journal of Research in Science Teaching*, 38, 1–24.

teach for understanding, and the ways schooling typically represents and assesses scientific and mathematical knowledge and learning. In addition, the cases showed students using sense-making resources, including forms of argumentation, explanations, juxtaposition of models, and other strategies that enhanced their learning. The following questions arose for further study:

- How does disciplinary understanding form and emerge in classroom interaction? How can researchers and teachers better understand the nature of such learning and how to foster it?
- How do skilled teachers use students' understanding, no matter how unusual, wrong, or imperfect, as powerful levers for change?
- How close or distant are the uses of language in mathematics and science classrooms to the uses of language in professional mathematical or scientific practice? What implications do answers to this question have for discourse in science and mathematics classrooms?
- As we create "authentic contexts" for learning science and mathematics, do we need to re-think what counts as evidence of understanding in these disciplines? How is disciplinary rigor maintained? Do we see changes in the participation, learning, and achievement of typically marginalized students in such contexts? How do typically successful students fare?

2. Teacher Preparation

Analysis of the cases gave rise to questions and concerns about the preparation and professional development of teachers, given the need to teach in ways that are responsive to children and responsible to the disciplines of science and mathematics. Teaching in this way is a complex act, requiring knowledge of both students' diverse ways of using language and of knowing and of the ideas and practices of the discipline under study. If taken seriously, this constitutes a rigorous re-definition of teaching and implies a significant rethinking of professional development and preparation. Participants posed the following questions for further research:

- What forms of professional development in science and mathematics will help beginning and experienced teachers see the deep connections between disciplinary ideas and practices and children's understandings and sense-making?

- What do teachers need to know about children's sense-making in relation to a) central ideas and practices of scientific and mathematical disciplines; b) uses of language and other semiotic systems (e.g., notational systems, tool use); and c) cultural resources and the knowledge and ways of knowing children bring into the classroom from their homes and communities?
- What forms of professional preparation and development are needed to help teachers see the intellectual strengths of children who are classified as "at risk"?
- What tools and forms of professional community can support teachers' ongoing learning and use of both theoretical knowledge (e.g., of teaching, learning, and the discipline) and highly situated local knowledge (e.g., of particular children and classrooms)?
- What do these questions imply for the preparation of teacher educators and others who teach teachers?

3. Teaching as a Profession

Two cases featured teacher-researchers who were involved in developing and presenting the cases. These individuals engage in a professional practice that includes participation in a science or mathematics learning community, documentation of classroom episodes that focus on students' sense-making, analysis of discussion of these episodes with colleagues, and presentation of their research to other audiences. Alone and in concert with colleagues, they formulate and puzzle through questions and interpretations of classroom life. They do this 1) to better understand their children's ideas and ways with words and their own sense of the discipline, and 2) to refine and elaborate their own practice in an ongoing fashion. The grounded and public nature of this kind of practice prompted participants to pose questions regarding the development of a professional teaching community:

- How can education researchers, policymakers, administrators, and parents learn to see and respect the intellectual strengths and pedagogical skills of teachers?
- How do critical self-reflection and disciplinary learning become an integral part of teaching?

4. Theory and Method in Educational Research

The conference was designed to bring diverse disciplinary perspectives into contact in the context of grounded discussion of cases of classroom interaction in science and mathematics.

The Conference

Participants explored their respective theoretical and methodological assumptions and values in relation to the nature of learning and teaching, science and mathematics, language and other symbol use, classroom interaction, and the construct of diversity. In these discussions, always serious and at times heated, participants confronted productive differences and tensions among the metaphors and paradigms represented in the group. Various questions arose:

- How can theory and method in educational research be informed by multi-disciplinary groups working on common data?
- What does the construct “diversity” encompass, and how can it be used productively in analyzing learning and teaching? E.g., how does diversity with respect to a) students’ sense-making resources, b) different types of representational systems, and c) different types of curricular environments play out in classrooms? How is linguistic diversity identified and organized as a “problem” or a “resource,” instructionally, theoretically, politically?
- How can we bring researchers closer to the experience of the students and teachers for whom they design problems, investigations, activities, and the like?

5. Building Cross-disciplinary Community and Forums

Participants valued greatly the opportunity to develop interpretations of complex cases studies in interaction with the perspectives, assumptions, and methods of individuals from a range of disciplines and life experiences. Participants enthusiastically endorsed this conference design (rather than the typical paper presentations) and urged the following actions:

- Expanding the community to include more researchers, teachers, administrators, and policymakers. Create additional forums across the country, not a larger conference, to include this constituency.
- Creating forums to involve parents and children in exploring and discussing “what counts” as learning in science and mathematics, high-quality curriculum and teaching, and meaningful assessment. There is not as yet publicly shared language for what is meant by high-quality teaching and learning in urban classrooms.
- Creating a journal devoted to promoting multidisciplinary research on learning and teaching in science and mathematics in urban settings.

Children’s Ways With Words in Science and Mathematics: A Conversation Across Disciplines took place December, 4–7, 1999, at the University of New Hampshire. It was organized by the Chèche Konnen Center at TERC and co-sponsored by the Center on Research, Education, Diversity and Excellence (CREDE) at the University of California, Santa Cruz, and the National Center for Improving Student Learning and Achievement (NCISLA) at the University of Wisconsin–Madison.

Learn more about CREDE and NCISLA at www.crede.ucsc.edu and www.wcer.wisc.edu/ncisla. The organizations have produced a joint newsletter on diverse students’ learning in mathematics and science, which is available from the NCISLA web site.

References

- American Association for the Advancement of Science, Project 2061. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- Ball, D. (1997). What do students know? Facing challenges of distance, context and desire in trying to hear children. In B.J. Biddle, T.L. Good & I.F. Goodson (Eds.), *International handbook of teachers and teaching*. Dordrecht, Netherlands: Kluwer.
- González, N. (1999). What will we do when culture doesn’t exist anymore? *Anthropology and Education Quarterly*, 30 (4), 431–435.
- Kozol, J. (1991). *Savage inequalities: Children in America’s schools*. New York: Crown Publishers, Inc.
- Mehan, H. (1991). *Sociological foundations supporting the study of cultural diversity*. The National Center for Research on Cultural Diversity and Second Language Learning, Research Report 1. Santa Cruz, CA: University of California.
- National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation for school mathematics*. Reston, VA: NCTM.
- National Research Council. (1996). *National science education standards*. Washington DC: National Academy Press.
- Oakes, J. (1986). Tracking, inequality, and the rhetoric of school reform: Why schools don’t change. *Journal of Education*, 168, 61–80.
- Secada, W. (1989). Agenda setting, enlightened self-interest, and equity in mathematics education. *Peabody Journal of Education*, 66(2), 22–56.
- Ann S. Rosebery and Beth Warren are co-directors of the Chèche Konnen Center at TERC.*
ann_rosebery@terc.edu; beth_warren@terc.edu
- The conference was funded by the National Science Foundation #ESI - 9555712, and the U.S. Department of Education, #R305A6007-98 and #R306A60001.*

The [Inquiry] approach... *builds on each student's strengths, knowledge, and natural curiosity.*

arts, simply because assessing the learning that occurs is complex? I would argue that the course of responsible educators is to “stay the course.”

By staying the course I do not mean that we accept the current level of student achievement or resist attempts to change classroom practice. Rather I am advocating that we stay a course which is guided by a clear vision for student learning, grounded in practices that honor the abilities and potential of our teachers and students. Following such a course can lead to a continuous cycle of innovation and improvement, where creative ideas are tested and high-quality materials and best practices emerge.

Setting a clear vision. As the story goes, during a visit to a NASA space facility, then-President John F. Kennedy stopped his tour to ask a nearby custodian what he was doing. The response: “I’m putting a man on the moon.” Such clarity! In education, we tend to eschew a common vision in the interest of a particular agenda and are tempted to allow our remedy to drive our goal statement. Better teachers, improved facilities, more demanding tests, up-to-date curricula, smart uses of technology, parent involvement; all of these are on the list of remedies. It is hard to keep a united public focus on what is best for all students, and at the same time to ask how each proposed intervention is likely to improve student learning. We must not forget that persistence is essential to a bold vision.

Through 36 years of research and development work in the field of mathematics and science education, TERC has often been reminded that our vision for inquiry teaching and learning is not easy to sustain. Sometimes an inquiry approach is popular; sometimes it is not. Yet, TERC’s classroom experience has consistently shown that effective teaching in a mode that guides students to be active learners enables them to acquire evermore-sophisticated knowledge and the conceptual frameworks to use that knowledge. The approach is inherently inclusive and can provide the

strongest foundation for learning because it builds on each student’s strengths, knowledge, and natural curiosity. It is TERC’s mission and responsibility to stay the course by holding student learning and learning for *all* students as its uncluttered focus.

Honoring teachers as professionals. Daily, it seems, there is a new scheme to hold school administrators and teachers accountable for the failings of education. Often ill prepared, frequently working in severely inadequate conditions, poorly paid, and lacking resources, teachers are beleaguered. It is frightening to consider that, if we as a nation valued citizens’ health as we apparently value students’ learning, our medical doctors might substitute any bachelor’s degree for what is required of doctors: a B.S. or B.A. degree, 4 years of medical school, 2 to 3 years residency, and 1 to 4 years specialty training.

Linda Darling-Hammond, in much of her recent research, has investigated and measured the impact on student achievement of investments in teachers. She has found that teacher qualifications (licensing examination scores, experience), increased teacher preparation, and ongoing professional development, particularly that which engages teachers in the content of their work, are the most important, statistically significant indicators of increases in student achievement (2000). The Glenn Commission report on mathematics and science teaching, *Before It’s Too Late*, gives the same clear message. The report argues for an immediate investment in teacher professional development, teacher recruitment and preparation, and an improved working environment for teachers (2000). These findings and conclusions are not surprising to educators; what is disappointing is the lack of a positive, coherent public policy response. Teachers are TERC’s partners in research and development; much of our work today is in developing strong learning opportunities for teachers. Keeping our sights on the opportunities and the challenges of teaching, and not on the rhetoric of failure, is a commitment TERC and our colleagues must continue to share and demonstrate.

Beginning with our students; believing in all students. One hundred years ago the homogeneity of our nation's student body could easily be summed as predominately "of European heritage." Today's summation is increasingly complex. Our data say that 35% of our student body today, and 45% by 2020, will be minority; one in four students will be of Hispanic origins. There will be less than 1% growth in the number of children in K–12 classrooms by 2010, during which time our total population will increase by 9%. The school population will be heavily concentrated, with our 100 largest public school districts educating 23% of our public school students. These districts tend to be in cities where multi-ethnic, multiracial populations and poverty rates are highest.¹

What do these data tell us? As I see it, the data cry out for an inclusive, flexible education policy and creative education programs designed to ensure effective learning experiences for all children, poor and not poor, from all cultures and races. If our nation does not do this, we will deny significant population groups access to future economic and social prosperity and we will reap the consequences of a polarized society of "haves" and "have nots."

Research and teacher professional development initiatives at TERC are helping us improve our understanding and appreciation of how students from low-income, ethnic, and minority backgrounds make sense of science concepts. Working with teachers and students in highly diverse classrooms, we are evolving a pedagogical approach that integrates students' ideas and everyday accounts of scientific phenomena with the forms and language characteristic of the discipline of science (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Our work is informed by many, including the important contributions of Lisa Delpit in her consideration of the implications for teaching and learning of two cultures—one of power and one of disenfranchisement (1995, pp. 21–47). Lauren Resnick, in her argument for an "effort driven" education system (rather than the current "aptitude oriented" system), provides a provocative implementation

strategy for all students (1995, pp. 55–62). Our nation's education task remains the same; the characteristics of our student body are, however, changing dramatically. If we are to stay the course, TERC must vigorously pursue teaching and learning strategies that meet all students' needs.

Creating and disseminating examples

America has a uniquely local perspective on education decisionmaking. There is no national curriculum, no uniform teacher training syllabus. National standards are guidelines; state and local standards have clout only as they are driven by testing. Education materials are supplied by publishers whose traditional job is to provide the school market with texts that meet standards' requirements and are readily useable by the majority of teachers, without necessitating special training or changes in teacher practice or classroom management. All these factors strongly favor incremental change. There is not a lot of room for innovation, pioneering, or risk-taking.

Such circumstances provide an imperative for the existence and high performance of places like TERC. If not from schools, government, or publishers, from where should come the examples of the possible, the stretches to create new opportunities, the risk to do the untested?

**Keeping our sights
on the opportunities
and the challenges of teaching...is
a commitment TERC and our colleagues
must continue to share and demonstrate.**

And who must have the discipline to ensure that their materials and practices improve student learning? TERC was founded with the mandate to evolve creative ideas into innovative examples that result in improved learning. For TERC this is staying the course.

Some TERC examples remind us of the challenge and the opportunity. In the mid-1980s, the ideas for *Kids Network* (a telecollaborative elementary and middle grades science curriculum) and *Investigations in Data, Number, and Space* (an elementary mathematics curriculum) were formed. It is now 15 years later. Thousands of classrooms with hundreds of thousands of students have used one or both of these inquiry-based curricula. The data we have for student learning and the changes we've witnessed in teacher practice are impressive (Mokros, forthcoming; Raizen & Britton, 1997).

¹Sources of data: U.S. Census Bureau population projections (Series A and NP-T1) and National Center for Education Statistics (2000), Characteristics of the 100 Largest Public Elementary & Secondary School Districts in the United States: 1998–99.

for...creative education programs designed to ensure effective learning experiences for all children, poor and not poor, from all cultures and races.

We have created examples for ourselves, and also reminders that significant contributions happen slowly and require sustained effort. We can only hope that current efforts, such as those TERC is now exploring in algebra for the elementary grades, in an on-line master's degree program in science education, and in earth science informed by space exploration will, with diligence, make the same kind of difference.

Sorting and embracing change. Schools and our education system have the unenviable reputation of being impervious to change. Certainly very few would argue change for its own sake, but there is an urgent and poignant message in the snail-paced rate of response to the dissatisfactions expressed at all levels about our current education practices. Consider the following two examples, which are both critique and opportunity; the first is situated in teaching and the second in technology.

Stigler and Hiebert compared mathematics teaching methods in the United States to those of nations whose students outperformed U.S. students in the Third International Mathematics and Science Study. They discovered dramatic differences among the practices of each nation. They found mathematics teaching in the United States to be “extremely limited, focused for the most part on a narrow band of procedural skills.” In contrast, Japanese teachers gave students as much time for “solving challenging problems and discussing mathematical concepts as they do practicing skills” (2000, pp. 10–11). Can we as a nation learn from the study, and from the conclusion that is hard to avoid, that making marginal changes in teaching basic skills and facts, i.e., doing better what we already do, is no solution.

When business and industry first invested in personal computers and then in Internet capacities, they did so to improve the efficiency of their existing work practices. After years of investment and training, work practices themselves changed to take advantage of the power of technology (Milken, 1998). Instead of retrofitting technology to

traditional instructional approaches,

can we as educators find the appropriate applications of technology that change and enhance instruction and learning?

To stay the course is to embrace change when change holds promise

for bringing us closer to our vision. Much of TERC's innovative, inquiry-based curricula requires changes in teacher practice, including acquisition of content knowledge, ability to lead project-based learning, skill in creating “team engaged” rather than “teacher instructed” learning experiences, and ability to support and assess student progress using several assessment tools. These are areas in which we are working. TERC is also among educators working with teachers, staff developers, administrators, and policymakers to use technology to enhance learning for all students. We understand that the purpose of technology in classroom instruction is not to replace the teacher or to enable the teacher to do the same task but with a new gadget. Rather, it is to provide the teacher with tools that invite improvements in teaching practice and to encourage students' individual and team engagement with their own learning (Feldman, Konold, & Coulter, 1999).

Improving our own practice. If vision is the anchor and the reach of our work, improvement in our practice is our necessary discipline. TERC has learned much about teaching and learning through our nearly four decades of research, development, and dissemination activities. We have learned, for example, about the powerful positive impact on teaching of teachers invested in their own learning. We know that it is not enough to provide technology to schools, to create a new curriculum, or to provide education activities driven by the emergence of new data. It is not enough to offer teachers isolated summer workshops and expect an impact on their practice. We are sobered by the experiences of watching states and school districts move away from inquiry-based standards and curricula when the necessities of changes in teacher practice, school cultures, parent expectations, and alignment of curriculum with teaching and assessment receive too little attention or seem overwhelming.

TERC is committed as an organization and as individual professionals to our own critical assessment. Is the idea we are developing important? That is, might it improve teaching or learning? Has the research we have conducted been shared and has it informed our own development efforts? Do we ask questions about the impact on student learning of our models and materials? When the results disappoint, do we learn from them and change? These are not easy questions to answer, but the rigor with which we address them determines our progress in staying the course.

Additionally, as we have witnessed the struggles of the last decade, we at TERC increasingly find ourselves asking the question: How should we join the messy conversations of public discourse, at district, state, and national levels? It's tough to move a nation. The heavy lifting of public participation is not the usual domain of researchers, developers, or educators. Yet it is here, in addition to our writing and our classroom presence, that our voices must be heard and we must learn. Advocacy for what we understand about student learning and about teaching is a vital part of the public discourse; collectively, it is our responsibility to share, to listen, and to advocate. It is a dimension to add or expand in our effort to stay the course.

Staying the course. An important vision is not the work of a single day, one individual, or a simple solution. Far more likely, it takes time, commitment, patience and persuasion, honesty, and hard work. It is easy to become distracted. On the one hand, America is at the dawn of a new millennium, experiencing the first light of an information age and the emerging rays of the most culturally diverse nation on earth. It is the best of times: our nation has the resources, the intellectual capital, and the opportunity to educate all of its students. On the other hand, there are moments when it may feel like the worst of times. The political will to establish policies and programs of inclusion is not apparent, much heated argument obscures our priorities, and the investment of resources is paltry. Whether it is the threats or the opportunities that we sense most keenly, TERC has a continuing commitment to excellence and innovation in pursuit of teaching and learning. TERC will stay the course.

References

- Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives* 8(1) [epaa.asu.edu/epaa/v8n1/].
- Delpit, L. (1995). *Other people's children: Cultural conflict in the classroom*. New York: The New Press.
- Feldman, A., Konold, C. & Coulter, B. (1999). *Network science, a decade later: The Internet and classroom learning*. Mahway, NJ: Lawrence Erlbaum.
- Milken, L. (1998, June). *Learning technology: The opportunity and responsibility*. Keynote speech presented at the Milken Family Foundation National Education Conference.
- Mokros, J. (forthcoming). The impact of Investigations on children's understanding of number. In S. Senk & D. Thompson (Eds.), *What research says about reform math curricula*.
- National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late*. A report to the nation from the National Commission. Washington, DC: author.
- Raizen, S. & Britton, E. (1997). *Bold ventures: Vol. 2. Case studies of U.S. innovations in science education*. Dordrecht: Kluwer Academic Publishers.
- Resnick, L. B. (1995). From aptitude to effort: A new foundation for our schools. *Daedalus* 124(4), 55–62.
- Stigler, J.W. & Hiebert, J. (2000). *The teaching gap: The best ideas from the world's teachers for improving education in the classroom*. New York: The Free Press.
- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday languages. *Journal of research in science teaching*, 38, 1–24.
- Barbara C. Sampson is president and CEO of TERC.
barbara_sampson@terc.edu*

To stay the
course
is to embrace change
when change holds promise
for bringing us closer to
our vision.

TERC-Manning School Collaboration

TERC and the Manning School in Boston are initiating a teacher-based effort to improve the mathematics learning of students with special needs. The goals of the project are to provide classroom-based findings about how students with special needs can learn mathematics with the *Investigations in Number, Data and Space* curriculum; and to identify ways to facilitate the collaboration between classroom and special education teachers in order to enhance the teaching and learning of mathematics by these students. The project will also inform others about promising practices by developing findings, strategies, and examples into presentations for the Manning staff and parents, and a workshop for a group of Boston teachers. Funded by the Boston Annenberg Challenge Fund.

Youth Tech Entrepreneurs (YTE) Curriculum Development

TERC was selected by the Massachusetts Youth Tech Entrepreneurs to co-develop a curriculum called Teachers' Guide to Student Leadership and IT Service Projects. Massachusetts schools that adopt the Department of Education-endorsed program will use the guide to facilitate project-based courses in computer basics and web fundamentals and design for grades 10–12. YTE's key objectives of promoting student leadership, school and community service, students as teachers, and entrepreneurship will be interwoven with standards-based objectives. Funded by Youth Tech Entrepreneurs through a grant from the Massachusetts Department of Education.

Adapting Kids Network for Deaf Students

TERC, in collaboration with Vcom3D and the National Technical Institute for the Deaf, is modifying two units of the Kids Network science curriculum to incorporate the SigningAvatar™

accessibility software. The software enables signing of the web activities and resources. The project will evaluate the extent to which the addition of signing promotes standards-based learning outcomes for deaf and hard of hearing students. TERC is responsible for the curriculum-related modifications, evaluation, and documentation of best practices for using the SigningAvatar™ technology to increase accessibility of web-based science materials to students with hearing disabilities. Funded by the National Science Foundation.

Developing the Story of Algebra in Grades K–5

This project will help build the foundation for incorporating algebra consistently throughout the grades in the revision of the *Investigations in Number, Data, and Space* curriculum.

It allows for the undertaking of a conceptual review of algebra in the elementary grades—gathering information from research, curriculum projects, and professional development projects. This review will be a learning tool for the Investigations staff, for the teachers with whom they work, and for teachers in other contexts, such as the ExxonMobil sites. In addition, visits will be made to elementary classrooms to study the possibilities for algebraic thinking that arise in the context of number. Funded by the ExxonMobil Foundation.

Leveraging Learning Teachers Guides

The project is preparing a web-based version of the teachers guides for the Leveraging Learning science curriculum units, grades 3–5 and 6–8. Funded by TERC.

Resources By TERC

Assessment Sourcebooks

Developers of the *Investigations in Number, Data, and Space* mathematics curriculum have created a set of end-of-unit assessment tasks for each *Investigations* unit in grades 1–5. These five Sourcebooks provide teachers with a set of 4–6 tasks designed to assess the important mathematical ideas in each unit. The books offer information about the mathematical significance of the tasks; support for examining student work; and a checklist of mathematical skills covered in the unit. There are reproducible student sheets in both English and Spanish. Assessment Sourcebooks are available from Scott Foresman (1-800-552-2259). Each Sourcebook: \$27. See sample pages at www.lab.brown.edu/investigations/new/assessment-sourcebook.html.

Global Lab

This full-year, introductory science course launches students in grades 6–9 on a collaborative scientific enterprise. Students choose a local “study site” for interdisciplinary, hands-on explorations in four essential areas: interaction of matter and energy; bio-geochemical cycles; biomes and biodiversity; and Earth as a system. Easy-to-use web tools enable classes to publish and share their findings. Complete curriculum (print materials, instruments, supplies, and network membership): \$1300. Available from Kendall/Hunt Publishing Company, 1-800-542-6657.

Investigations Implementation Institute

An Implementation Institute, Planning for Professional Development and Leadership Development, will be held July 9–11, 2001, in Billerica, Massachusetts. It is designed for experienced teachers, staff developers, and administrators who play lead roles in teacher support and professional development in schools and districts implementing the *Investigations in Number, Data, and Space* elementary mathematics curriculum. Participants will explore implementation issues, review staff development materials, engage in model professional development sessions, and interact with other leaders from across the country. Cost: \$100 per participant plus expenses. Limited availability. Contact lorraine_brooks@terc.edu.

Investigations Workshops for Transforming Mathematics

Professional development opportunities exist for elementary school teachers implementing the curriculum *Investigations in Number, Data, and Space*. Offered across the country, the five-day Level 1 workshops stress teachers' mathematics learning and focus on some of the roles they are assuming in classrooms (e.g., learners, researchers, facilitators of mathematics learning). A three-day Level 2 workshop on Number and Computation is available for teachers who have attended the Level 1 workshop or who have been using *Investigations* for at least two years. Also available this year, a five-day Leadership Workshop designed for teachers, math specialists, and administrators who are responsible for supporting

Investigations implementation. Visit projects.terc.edu/investigations-workshops, or call Peter Swanson at TERC.

Astrobiology Curriculum

TERC's year-long interdisciplinary science curriculum (18 chapters and 75 hands-on activities), designed for all ability levels of 8th and 9th grade students, is nearing completion. The project would like to contract several teachers to field test newly developed activities in the fall. Payment is \$50 per activity for testing and completing an evaluation form. If interested, please fill out the "For More Information" form at astrobio.terc.edu. Also, see the web site for a set of sample curriculum activities that you are free to download and use in your classrooms.

cut here

Reader Response and Order Form

Are you on our mailing list? We are delighted to send you Hands On! To help cover costs, please send us a contribution.

- ☐ Yes! Add me to your mailing list.
 Send me ☐ print only ☐ electronic only ☐ both versions
 I am contributing ☐ \$35 ☐ \$25 ☐ \$20

Name _____

Title _____

Organization _____

Address _____

City, State, Zip _____

Email address _____

☐ My address has changed. (Please complete form above.)

Occupation

- ☐ Administrator/Principal ☐ Science Coordinator
☐ Technology Specialist ☐ Math Coordinator
☐ Researcher ☐ Business/Industry
☐ Government Agency ☐ Scientist

☐ Teacher:

Level ☐ K–8 ☐ 9–12 ☐ College/University

☐ Other: _____

Areas of interest (check as many as apply):

- ☐ Mathematics ☐ Science ☐ Earth and Space Science
☐ Technology

S'01

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

Publications	#	Price	Subtotal
<i>Student & Scientist Partnerships Conference Report</i>		5.00	
<i>EdGIS Conference Report</i>		5.00	
<i>Learning Along Electronic Paths: Journeys with the NGS Kids Network</i>		15.00	
<i>Working Papers Research Series</i>			
Body Motion and Graphing		5.00	
Encouraging Inquiry in a Seventh-Grade Mathematics Class		5.00	
Teachers' Perspectives on Children's Talk in Science		5.00	
Science Talk in a Bilingual Classroom		5.00	
Children, Additive Change & Calculus		5.00	
Equity in the Future Tense: Redefining Relationships Among Teachers, Students & Science in Linguistic Minority Classrooms		5.00	
By TERC product catalog and supplement		FREE	
TERC Annual Report		FREE	
Current Projects 2000		FREE	
Hands On! Contribution			
Shipping for international orders only		10.00	
Total enclosed			

Get Involved

Massachusetts Earth Science Alliance

The Center for Earth and Space Science Education at TERC, in partnership with Massachusetts Earth science teachers, has established the Massachusetts Earth Science Alliance (MESA), a consortium working to promote state-wide improvement of K-12 Earth science education in public and private schools. Members include Earth and space science teachers, scientists, school districts, state and federal agencies, educational developers and publishers, science museums, institutions for the training and professional development of teachers, and the business community. New members are welcome! Learn more at mesa.terc.edu.

NASA Student Involvement Program (NSIP)

NSIP stimulates and rewards student research on NASA's missions of exploration and discovery. Five competition areas support national education standards and feature Educator's Resource Guides, including assessment rubrics designed to help teachers and students as they conduct research and prepare projects for submission. If your students have been working on research projects, they have probably

met most entry requirements. Submission deadline: Feb. 1, 2002. Competition entry guidelines at education.nasa.gov/nsip.

Leveraging Learning

Pre-publication versions of the Leveraging Learning science units for grades 3-5 and 6-8 are available for use during the 2001-02 school year. Students conduct hands-on/minds-on experiments, exchange data and letters with other students, and conduct web-based activities that use reading, writing, and communicating to gain in-depth understanding of the science. Each unit requires 6-8 weeks of class time. Visit LL.terc.edu or contact judy_vesel@terc.edu.

Online Science-athon

Join the Online Science-athon, selected as one of Ten Model Project-Based Learning activities by WestEd. Designed to be engaging and fun, easy to integrate into teaching, and instructive, the challenges include: Marble Roll (force and motion), How Tall Am I? (heredity), and Catching Sunshine (solar energy). Each challenge takes 10-12 hours of class time; involves data collection, sharing, display, and analysis; and can be done in grades 2-8. Visit scithon.terc.edu or contact judy_vesel@terc.edu.

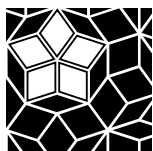
NEWS
NEWS
NEWS

Science that Counts in the Workplace, a high school physics curriculum nearing completion at TERC, will be published by Kendall/Hunt Publishing Company. SCW contextualizes learning in authentic workplace-related projects and includes an embedded assessment system presented as a series of challenges (see "Assessment: Educate or audit" in the Fall 2000 *Hands On!*). Publication date is 2003.

Hands-On Universe (HOU)

HOU seeks teachers to participate in a study of the effectiveness of professional development strategies used to support HOU program implementation. Teachers will give their high school students access to the same tools that professional astronomers use: image processing software and images from large observatory telescopes. Students learn science, mathematics, and technology in the context of astronomical explorations. A stipend and academic credits are available. Visit hou.lbl.gov or contact mihorahm@uclink4.berkeley.edu.

See more [Get Involved](#)
on pages 7 and 23



TERC

2067 Massachusetts Avenue
Cambridge, MA 02140
phone (617) 547-0430
fax (617) 349-3535
www.terc.edu

Nonprofit Org.
U.S. Postage

PAID

Boston, MA
Permit No. 9