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FOCUS ON SCIENCE EDUCATION REFORM

With this issue of *Principled Practice*, four people with close connections to science education reflect on the work yet to be done as reform efforts unfold. Offering perspectives based on long experience, Angelo Collins (director of the National Science Education Standards Project and associate director for NCISLA), Senta Raizen (director of the National Center for Improving Science Education), and Rich Lehrer and Leona Schauble (education researchers at the University of Wisconsin–Madison) discuss issues and impediments to U.S. science education reform — and offer ideas about ways we might address these. They focus on the following questions:

WHAT ARE WE LEARNING AS U.S. SCIENCE EDUCATION UNDERGOES REFORM?

WHAT DO WE STILL NEED TO LEARN?

HOW CAN SCIENCE EDUCATION BE STRENGTHENED?

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Standards Are Not Enough

INTERVIEW WITH *ANGELO COLLINS*, DIRECTOR OF THE NATIONAL SCIENCE EDUCATION STANDARDS PROJECT (1991–1995), AND ASSOCIATE DIRECTOR FOR NCISLA

- Written by Susan Smetzer Anderson

Angelo Collins is Associate Director for the National Center for Improving Student Learning and Achievement in Mathematics & Science and a researcher/teacher educator at Vanderbilt University's Peabody College. Collins also works with the Interstate New Teacher Assessment and Support Consortium to help prepare K–12 teachers to be competent science teachers.

"Sometimes people think that if we just write good standards, all the education problems will be solved. That's not true," states Angelo Collins.

As the director of the National Science Education Standards Project (1991–1995), Collins is qualified to speak about standards. Working with scientists, curriculum developers, policymakers, teacher educators, and teachers at all levels, she found herself being a bridge between groups, trying to build understanding and common vision through the long *Standards* development process. Writing and rewriting standard drafts and accounting for public input and differences of opinion, Collins shepherded the *Standards* to public release.

The *Standards*, Collins says, is "a visionary document, geared to challenge our assumptions about science education." The *Standards*' aim — for all students to be scientifically literate in the 21st century — is both ambitious and far off, she acknowledges. Reform of all components of the education system will be required to make it possible.

Collins comments, "Reform is a complex process, and — although I have grown to hate the word — it needs to be *systemic*. There are hundreds of diagrams of the components of the education system; however, it is necessary to change all of them — in concert — to enable reform to happen. Designing new curriculum is necessary but not sufficient. Teacher training is necessary but not sufficient. Assessing kids and changing administration approaches are necessary but not sufficient. All of the system components need to be reformed and working together."

Collins likens education reform to a geared mechanism, in which all the gears and shafts are designed to click in sync. If one piece fails, the mechanism can lock or painfully grind.

The science standards are one piece of a complex reform process. The overall reform effort, Collins states, is fraught with problems. Addressing the problems in a holistic way is labor intensive: "People want a quick fix. They're not willing to engage in the long, arduous process of change. A mentality exists that 'It is somebody else's problem.' If someone else would design curriculum materials, things would be okay."

INFORMATION SHARING IS REQUIRED

Because reform requires much more than new curricula, Collins thinks that researchers, teachers, policymakers, and other participants need to do a better job of sharing information to help reform to happen: "Just as we need to recognize the complexity of reform, we need to become better at sharing what we do know about how students learn, curriculum assessment, and how to leverage policy. Research and development need to occur at several different levels of the education enterprise. We need to research within and across system levels. We need to know more about leading-edge researchers who are looking hard at how students learn at one site, and building knowledge that can push the field forward. We need to work with researchers who synthesize research and make it available to people applying it to different subject matter and settings. There are also folks like developers, who are trying to mass-produce information to make it available to districts. We need to work with them, too."

STANDARDS PROD RESEARCH

In her article, "National Science Education Standards: A Political Document,"[1] Collins indicates that today's standards-charged climate undoubtedly influences the work of science education researchers. As they work in the education system, researchers can be influenced by the political movements of the system, as well as be potentially influential players within the system. The *Standards*, in fact, prompt several research questions, Collins writes:

> The *Standards* provide an almost limitless supply of real research questions about how and how much students are able to achieve, about teachers and how they conduct and learn to conduct their practice, about how to assess what students have come to understand and be able to do, about materials that promote high-quality scientific literacy, and about supports and constraints to classrooms and schools as communities of learners, to name just a few. (p. 725)

Astute researchers, Collins writes, should be aware of ways their research can influence the science education system: "Awareness of political realities as well as active participation in shaping policy by some science education researchers will be required if the concerns and products of research are to substantially affect the science education system" (p. 725).

TEACHERS ARE KEY TO REFORM MOVEMENT

Now influencing the science education system through her research and work as a teacher educator at Vanderbilt University, Collins also works with the Interstate New Teacher Assessment and Support Consortium (INTASC) to help prepare K–12 teachers to be competent science teachers. Her work is premised on her belief that "Teachers are the key to the reform movement." She states, "Solid teacher assessment and education are essential to preparing teachers who understand what the reform movement in science education is all about."

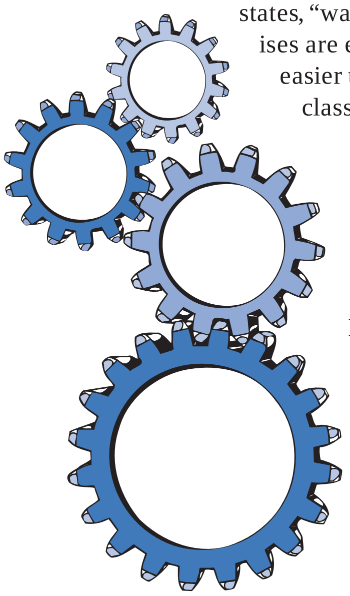
Chairing the INTASC science group, Collins is helping to develop standards, assessment procedures, and support systems for 75 beginning K–12 teachers in Ohio, Indiana, South Carolina, Louisiana, and Rhode Island. "We are designing a process that allows for teachers to gradually increase in knowledge and skills. Professional development is a big component of our work."

Here, Collins is bringing together research and practice in a professional development process. State contacts conduct teacher workshops for first- through third-year teachers. With the assistance of mentors, teachers compile portfolios that are scored over the summer. The research model permits comparison of different mentoring models across the different states and comparison of differences between first-, second- and third-year teachers moving through the process. According to Collins, the training and research process is very iterative: "We will be doing it all again next year, with a revised handbook, mentor and scoring systems."

CONTINUOUS WORK REQUIRED FOR SCIENTIFIC LITERACY

The end goal of all of this work — and her work on the *Standards* document — is scientific literacy for teachers and students. "My hope is that we will produce a generation of students understanding important science content, how these important ideas came to be, and how science is important in their everyday life."

Collins is concerned about how time-demanding it is to work for and sustain reform. As the year 2000 approaches, it is clear the United States has yet to achieve the goals set by the National Governors Association and President Bush in 1989 — for U.S. students to be first in the world in mathematics and science. This goal, Collins states, "was easy to agree with, because it was a promise. Promises are easier than policies. Even devising difficult policies is easier than devising programs and changed practices in the classroom."



She continues, "Let's go back to the tower of gears. We need to recognize not only the value of communication (connection) between the different gears in the system, but also the value of the work performed by each piece. Coordinating the work between pieces is actually a research problem. How do we do that? In reality, we are never going to get it done. Every day, new science is being done, with various players in the system taking different approaches to scientific problems. Just as one question is answered, another emerges. Just so, we are never going to be done with the work of reform. It is continuous."

1 1998. *Journal of Research in Science Teaching*, 35, 7, 711–727.

Rethinking Science Education With an International Perspective

INTERVIEW WITH *SENTA RAIZEN*, DIRECTOR OF THE NATIONAL CENTER FOR IMPROVING SCIENCE EDUCATION

NCISLA invited Senta Raizen to contribute the first Guest View to Principled Practice. *Raizen brings her vast experience as a researcher and director of the National Center for Improving Science Education to this discussion of science education reform. Guest Views will continue to be featured in* Principled Practice *to advance idea exchange about key education issues and research questions among NCISLA researchers and outside experts.*

"I believe very strongly that we can learn from other countries. They can help us to 'think outside the box' and see what the possibilities are." Senta Raizen offers this comment, as she reflects on the evolution of science education reform in the United States. As a chemist, educator, and researcher, Raizen has participated in U.S. education reform movements since the 1960s. Serving as director of the National Center for Improving Science Education (NCISE) since 1988, she also has conducted educational research in several European countries and brings an international perspective to reform discussions. She remembers when the United States was gripped with fear that it had fallen behind its international neighbors after the Soviet Union successfully launched the Sputnik satellite in 1957. Immediately thereafter, the United States began to direct elite students into the science education "pipeline" in an effort to catch up with its Cold War competitor. "As part of the reaction to Sputnik," Raizen states, "new emphasis was placed on strengthening high school curricula and teaching. Over time, reforms filtered down to the lower grades, and there was more of an emphasis on all students learning." Even so, science education tended to be presented in uncoordinated course blocks, and only the students perceived to be most successful at learning science were encouraged to take upper level courses.

Several times since Sputnik, policymakers and educators have voiced concern about U.S. students falling behind their international neighbors. The 1983 document, *A Nation at Risk: The Imperative for Educational Reform*[1] signaled a new reform push out of growing anxiety that the United States had lost its competitive edge in technology and commerce. That same fear spurred the National Governors Association and President George Bush to set six ambitious education goals at a 1989 education summit, including the oft-repeated goal: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

Although at the time this goal may have appeared attainable, results of the 1996 Third International Mathematics and Science Study (TIMSS) indicate that U.S. students continue to lag behind other industrial nations on certain test scores. From her vantage point as a researcher and member of the TIMSS advisory board, Raizen perceives three factors to be working in tandem to undermine the long-term effectiveness of U.S. science reform efforts. Overall, she is concerned that the large-scale assessment strategies used (and proposed) in the United States, combined with inadequate teacher preparation and poor curriculum coordination between grades, inhibit the United States in making significant reform progress. Furthermore, Raizen is not convinced that all students are likely to be well served under current reform conditions. She states, "we're simply paying lip service to all students learning."

"There's a lot we can learn from other countries in terms of what students are expected to do. Other countries have very high expectations, especially in terms of the physical sciences. According to the TIMSS results, U.S. students (in populations 1 and 2) are weak in physical sciences. Furthermore, we bring a very small proportion of our students to the point of passing the advanced placement exams. Other countries bring one-fourth to one-third of their students to the point of passing equivalent college exams. In the United States, approximately 4% of our students make it that far . . . With all our talk about bringing our students up to rigorous standards, we do worse than many industrialized countries. That's a big surprise to people. About 25 or 30 years ago, we could be competitive," Raizen states. That is no longer the case.

REFORM NEEDS TO GO FURTHER

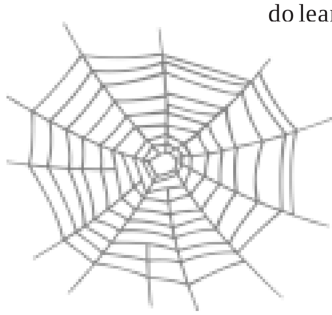
When asked "What have we learned about science reform to date?" Raizen immediately answers, "Science reform takes a long time, and it needs to be sustained. Furthermore, it needs to be systemic . . . You can think of a beautiful spider web," she describes. "If you want to move it from one place to another, you can't just take one strand . . . you must take hold of all the anchors to move it."

As she discusses the need to reform the whole, Raizen immediately discusses weaknesses of certain strands in the U.S. movement. In her reflections, she observes how other countries sometimes take different educational approaches, with positive results. At the same time, Raizen does not suggest that these other approaches should — or could — be adopted wholesale in locally managed U.S. schools. Rather, she contends that reform leaders (ranging from the local teacher to the national policymaker) could use the insights gleaned from abroad as a compelling backdrop for reflection about the strengths and weaknesses of U.S. practice.

U.S. SCIENCE CURRICULA DISORGANIZED

One weakness in U.S. science education of concern to Raizen is the lack of coordination of curricula across grade levels. She states, "It is really problematic that our country's science education lacks coherence from grade to grade. Programs can be very splintered, because they focus on different things and don't necessarily fit into an overall curriculum . . . Typically, a second-grade teacher doesn't talk to the upper-grade teachers within a school . . . Our curriculum is arranged so that we have all these unarticulated courses." Before students enter physics, biology, or chemistry, there is no guarantee that they will have the fundamental background or concepts that bridge the sciences or link them one to another.

Interestingly, young students in the United States performed reasonably well in the population 1 TIMSS assessment in science. Raizen indicates that this is because "a number of countries don't teach formal science until third grade. That's not to say that their students don't have pre-science learning. Rather, these countries don't disaggregate science education from the rest of their subjects. And, while their children do learn to observe, they don't learn formal science until later."



Although younger U.S. students might be learning more formal science at an earlier age, the typical disaggregation of courses throughout students' K–12 education appears to work to their disadvantage. Raizen does not expect this situation to change quickly, stating, "I think our schools will be very slow to change. It seems pretty clear from all we know about learning that kids would be much better off if they had a continuous stream of three or four sciences – for example, physical, earth, and life science – so that they can build on their knowledge instead of learning it in chunks . . . Basically, we need to address major issues about science curricula. That means we also need to address major issues about teacher education."

UNITED STATES NEEDS TO VALUE AND BETTER PREPARE TEACHERS

Raizen is forthright in her assessment that U.S. teachers are inadequately prepared to take on the tough job of teaching science at the elementary and secondary levels, stating, "I don't think we know enough about how to develop really good teachers in the subjects they need to know and in how they assess and lead students to understand scientific concepts. These are really difficult tasks to do, and we provide teachers difficult circumstances to do them."

Drawing comparisons to other countries, Raizen notes that a French colleague told her France does a better job than the United States in preparing secondary teachers in scientific disciplines. In Norway, observers attribute secondary students' achievement to teachers' very strong disciplinary training. As for valuing teachers, Raizen says that some cantons in Switzerland pay their teachers twice as much, relatively speaking, as we pay U.S. teachers.

"These countries," Raizen states, "claim that their teachers could go into research as well as into teaching. In the United States we tend not to view teachers that way. We tend to view teachers at the K–12 level as being the people who couldn't really make it in their discipline." A contributing factor, Raizen contends, is that U.S. teachers rarely take research courses at the undergraduate level: "You don't really learn what scientific research is unless you go to graduate school."

To support her point, Raizen indicates that NCISE studies have found that teachers with research experience better understand what science is (procedurally) and are better equipped to help students learn and gain experience in science. Furthermore, NCISE studies have found that if teachers gain research experience through in-depth professional development programs, they are more likely to make meaningful changes

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to their education practice to advance student understanding of science.

This point comes alive as Raizen describes interactions she had with teachers participating in a Department of Energy program designed to provide 8 weeks of scientific research experience. As an evaluator, Raizen was excited to hear more than one teacher express enthusiasm about learning how to pursue in-depth inquiry and group research. She illustrates, "One teacher claimed, 'I finally understand what research is and understand that you can't answer scientific questions in two weeks.'" Prior to participating in the program, this teacher had typically asked his students to plan science fair projects two weeks before the spring fair. Now he asks students to plan inquiry-driven projects in September and to carry them out over several months.

THE DILEMMA OF SUSTAINED INQUIRY AND LARGE-SCALE ASSESSMENTS

If science is viewed as a sustained, inquiry-driven process, science education ideally should seek to enhance students' abilities to undertake sustained scientific inquiry. However, an uncomfortable trend is developing in education reform, Raizen points out, with classroom teaching being increasingly influenced by large-scale assessments that fail to capture students' abilities to do sustained work.

Raizen states, "I don't know if current approaches that emphasize accountability to drive reform are going to be as successful as people hope or intend. For one thing, I don't think large-scale assessments can capture all the important goals that we have in science education. This isn't because large-scale assessments are always flawed; I think we can learn a lot from assessments like TIMSS, NAEP, or state assessments — especially as they become more sophisticated at detecting reasoning. However, any on-demand, time-limited assessment leaves out important things, like the ability of students to do sustained work, which is fundamental to doing science."

Another wrinkle in the assessment picture, Raizen notes, is the lack of articulation (or meshing) between teachers' authentic assessments and large-scale assessments. Raizen is concerned that if teachers are held accountable through large-scale assessments, they may teach to those assessments rather than designing their classrooms around the ultimate goals of science reform: to enhance student understanding and capacity to conduct in-depth inquiry.

Raizen elaborates, "A very good teacher in California can use the state standards and do good work, designing a science education program that builds student understanding of specific concepts. But a not-so-good teacher will teach to particular items on the state test and fail to build a coherent program that draws scientific concepts together. In effect, that teacher will be teaching factoids." Although students may learn the "factoids," they are not necessarily going to develop greater depth of understanding or appreciation for scientific practice.

To some degree, U.S. assessment practices appear to differ from other countries' approaches to student accountability. "If you look at the way other countries view student accountability," Raizen elaborates, "they typically emphasize individual accountability. Most other countries don't even test their students in the early grades. At whatever point students are tested, the results have immediate individual consequences, for example, through explicit placement in different kinds of schools. We do this very covertly in our country, through tracking."

For example, 9th grade Japanese students take very tough examinations, and the results of those exams dictate which schools students attend. The same is true in Germany. Up to that point, the students experience the same curriculum and requirements. "The expectation is," Raizen states, "that the students will be held individually accountable to learn the material."

It appears that in the United States, teachers are being held accountable to teach to tests, and that a lack of agreed-on vision for science content and poor teacher professional development combine to undermine the potential of reform. Raizen states, "I'm not sure we are going the right direction by having the accountability wag the dog. Yet I'm also not sure the situation is going to change. So we need to change the accountability measures and give schools and teachers the capacity to work with the measures — and to teach competently across them."

1 1983. *A nation at risk: The imperative for educational reform*. Washington, D.C.: U.S. Government Priority Office. National Commission on Excellence in Education.

· · · CENTER MISSION · · ·

The Center's mission is to craft, implement in schools, and validate a set of principles for designing classroom instruction that promotes student understanding in mathematics and science.

To achieve this mission, we are conducting a sustained program of research and development in school classrooms in collaboration with school staffs to do the following:

1. *Identify a set of design principles.*
2. *Demonstrate,* ***in classrooms,*** *the impact of the design principles on student achievement.*
3. *Clarify how schools can be organized to support teaching for understanding.*
4. *Develop a theory of instruction related to teaching for understanding.*
5. *Find ways to provide both information and procedures for policymakers, school administrators, and teachers so they can use our findings to create, and sustain, classrooms that promote student understanding.*

Tackling the Question: What Science Should Students Learn?

INTERVIEW WITH NCISLA ASSOCIATE DIRECTOR *RICH LEHRER* & COLLABORATING RESEARCHER *LEONA SCHAUBLE*, UNIVERSITY OF WISCONSIN–MADISON

Leona Schauble and Rich Lehrer, collaborating researchers at the University of Wisconsin–Madison, study the ways elementary and middle school students understand and make sense of mathematics and science. Both also work with the National Center for Improving Student Learning & Achievement in Mathematics & Science.

Leona Schauble readily admits that she and fellow researcher, Rich Lehrer, don't consider themselves to be science reform experts. In fact, their research is not necessarily considered to be within the science education mainstream. However, as cognitive development and learning researchers, Schauble and Lehrer have a unique and valuable perspective to add to science education reform discussions. Having worked together at the Wisconsin Center for Education Research since 1993, Schauble and Lehrer have collaborated on innovative mathematics and science education research at the elementary and middle school level. "Like many science education researchers, we work at the classroom level," Lehrer elaborates. "But we provide another angle on science education because we come from a research community that views instruction from a design perspective. Basically, we begin by questioning traditional assumptions about what science is worth teaching, especially for young children. We then collaborate with teachers to design classroom instruction that is sensitive to the resources children can bring to scientific inquiry at different points of their intellectual development."

PUTTING MODELING AND MATHEMATICS AT THE CENTER OF SCIENCE INSTRUCTION

As they discuss traditional education practice, Schauble and Lehrer raise questions about the way science is typically taught and what is taught. With an eye on prevalent science curricula, they perceive two fundamental problems with the way science instruction is conceptualized and carried out in classrooms.

First, in their view traditional science instruction tends to disregard, or worse, misunderstand the way children develop intellectually or cognitively. Many, perhaps most, curricula tend to be shaped around scientific disciplines without accounting for the way children think or understand scientific processes and concepts. Others are based on outmoded conceptions of development that underestimate children's capabilities. "For example," Schauble elaborates, "some curricula cast first-graders as 'concrete operational' in their intellectual processing and therefore unable to engage in complex forms of reasoning. Such curricula plainly underrate kids' learning potential."

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Second, Lehrer and Schauble suggest curricula misrepresent scientific practice by neglecting to build understanding of science as a modeling activity that encompasses in-depth inquiry, theoretical reasoning, and mathematization of the world. Addressing these topics in their research, Lehrer and Schauble work with teachers to codesign and evaluate learning environments where students engage in scientific and mathematical inquiry directed toward model-building. Lehrer explains: "We want to put the invention, testing, and revision of models that capture important scientific ideas at the center of science instruction. Learning science often has been assumed to be a process of accumulating facts and pieces. We are interested instead in the way that kids put pieces together, the way they inquire about the world and generate models. For example, we have observed how children can build increasingly complex models of elbow joints and then invent mathematical functions that describe the relationship between effort and load about that joint . . . We look at the way students test and refine their models as they learn." Lehrer and Schauble point out that scientists, regardless of their background or discipline, engage in the development and refinement of models. Model-building is at the heart of the "scientific method." Lehrer and Schauble reason that engaging students in the practice of science means engaging students in the practice of modeling.

This second-grade student created a scientific model of an elbow joint out of paper towel tubes, popsicle sticks, string, and tape.

As they have studied the ways kids make sense of science, Lehrer and Schauble have found it essential to put mathematics at the center of science education. They believe that if children develop a grasp of important mathematics concepts, they are more prepared to understand powerful scientific ideas that would otherwise be inaccessible to them as young students. However, they do not suggest that students should spend their time memorizing and applying formulae. Instead, Lehrer and Schauble emphasize that children need to be able to use mathematical ideas productively—about geometry, data, measurement, and probability, for example—as resources for reasoning about science. Lehrer is quick to point out, "We are not suggesting that science and mathematics need to be always entwined together. We think each discipline has its own structure. However, if we put mathematics practice into children's hands, children can engage in more rigorous forms of science than they typically have."

ADDRESSING WHAT AND HOW WE SHOULD TEACH ACROSS GRADES

Lehrer points out that we can learn about what is NOT working in science instruction by observing usual practices in mathematics. "Mathematics learning is assumed to be cumulative from grade to grade," comments Lehrer. "Strangely, there are no such assumptions for science. Even where people have talked about a spiral of curriculum, usually topics are simply repeated in subsequent years without building on what students have learned previously." Lehrer and Schauble explain that students can hardly be expected to advance to rigorous work in science if they are repeatedly exposed to disjointed, unconnected topics that do not build cumulatively and coherently from grade to grade.

The disjointed nature of science instruction during the K–8 and secondary years is a problem that needs to be seriously addressed, according to Schauble and Lehrer. (See also Raizen, p. 5) "So far, we know from observing the reform movement that there is a great need for careful thought and choices about what is most worth accomplishing in school science," states Schauble. "Although the standards movements have been important in helping to develop a sense of good science learning and teaching, there are still far too many visions at play, ranging from science concepts, processes, the history of science, and the nature of science, to science, society, and technology. How are we going to build a solid research base about student learning in science without good agreement about what school science is? In our view, focus is badly needed. And that focus should come not from what we have historically done, but from careful consideration of both core disciplinary themes and how children's understanding of those themes develops."

We are not going to make any progress in reform until we make some choices about the focus of science education within a wider perspective of our goals for students' learning.

— Rich Lehrer & Leona Schauble

At the secondary level, Lehrer points out, some thoughtful discussions are occurring about the value of building science curricula around students' increasing understanding of important scientific ideas. For example, there are proposals to invert the usual sequence of high school courses so that physics, the foundational science, is taught first, followed by chemistry and finally by biology.

"The dilemma is," Lehrer continues, "What do we do with science education in the K–8 years? All the issues about what to teach during these years are still on the table, even if there is some profitable discussion occurring about what to teach at the secondary level." To address this gap, Lehrer and Schauble propose that professionals from various disciplines work together to tackle the pressing task of building a science education strategy that connects topically across grades. "We suggest, based on our experience, that we can use an educational approach that integrates modeling in instruction. Still, we need to decide what models are most worth focusing on. We are presently using a series of criteria for making these decisions. We select fundamental themes or 'big ideas' in science that play a central role in scientific disciplines (an example is the theme of 'diversity' in biology). We favor themes that can be entered easily by young children, but that provide plenty of 'lift' and challenge for older students. Moreover, we emphasize core concepts that are amenable to the modeling approach that we are committed to."

"Once core concepts are identified," Lehrer adds, "researchers and teachers will be in position to build a knowledge base about students' thinking. We believe that instructional decisions should be guided by knowledge about how students' ideas develop, including typical patterns and frequent variants. A teacher with this knowledge is in a good position to capitalize on the ideas that emerge in classroom inquiry, turning them toward scientifically fruitful directions. Robust understanding of the typical pathways of children's thinking can also help prepare preservice teachers to teach science effectively."

SPANNING DISCIPLINES TO BUILD THE MOVEMENT

Like Angelo Collins (see p. 2), Lehrer and Schauble perceive value in education researchers, scientists, teachers, and psychologists communicating with one another about the best ways to teach children science and what science to teach kids. This cross-disciplinary communication, Schauble notes, seems to be increasing. "Until the last 10 years," Schauble observes, "science and mathematics were disciplines that seldom talked to each other. We were in a similar situation with science educators and psychologists who study scientific reasoning. Now, under the leadership of a few individuals, that is beginning to change. Now people are crossing across the 'boxes' — the traditional disciplinary divisions that have kept us apart. We are realizing that we are working on similar problems and that it is very important that we learn from each other. As this happens, our specializations evolve."

Schauble and Lehrer feel that their research has been enriched as they have crossed traditional disciplinary divisions, and they urge that a cross-disciplinary approach can likewise strengthen science education reform efforts. "The contribution we are making is that we have disciplinary knowledge of development and learning, and we are working at the boundaries of what have heretofore been separate domains: psychology, teaching, learning, mathematics, and science. We think it is important to consider the intersections between these separate domains. Because researchers and professionals are sequestered in their various fields, we are not used to having a common language or a common point of view. It is critical that we try to develop a common vision across people and positions — both in the research realm and the practice realm — and across several levels of analysis (from the student, to the classroom, school, district, community, state, and nation) to deal concretely with science education reform. We need to have a much more nuanced view of teaching and learning."

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BUILDING SUSTAINABLE REFORM WITH AN EYE TO HISTORY AND LONG-TERM RESEARCH

Although Lehrer and Schauble are somewhat encouraged that cross-disciplinary discussions about the focus of science education appear to be on the rise, they are concerned that these discussions may be occurring in a historical vacuum. The current reform movement is not the first and only one. As a former chemistry teacher, Lehrer recalls previous education reform efforts and laments their lack of historical documentation, stating, "Many of the past reform curricula are out of print, and our institutional memory in the field of science reform is fading fast. This does not encourage building an understanding of what has or has not worked in the past. We're convinced that we need to build a memory within the field so that we can build a sustainable reform." One implication, according to Lehrer, and Schauble, is the need to attend to far more than curriculum. "In the past, curriculum was considered the engine of change, and little attention was paid to professional development or teaching for student understanding. We now know that although it is important, curriculum alone cannot generate and sustain reform. We also need careful attention to professional development, structural support for good teaching and learning, and support from parents and community members."

To help the science education reform movement gain some theoretical ground and momentum, Lehrer and Schauble propose that researchers conduct long-term studies of the development of student thinking across grade levels. In the past, Schauble states, "there was little emphasis on long-term development of student understanding. Researchers might compare kids at different ages, but that didn't help us understand how an idea at one age evolves into another idea at a subsequent age." Lehrer points out that educators have not taken a long-term view, either. "What we have seen is that students' understanding of science is fragile and conceivably stunted when they move each year to a new teacher who may have an entirely different view of science education."

Lehrer and Schauble concur there is a clear need for participants in the reform effort to retrench and examine the history, vision, and research unfolding in science education and to discuss important questions impeding the movement. Key among them is the question: How do we design science education so that it builds systematically across grades and helps students learn science by posing questions and devising models to answer them? Implicit in this question is another: Are current usual science instruction practices adequate to serve students or the purposes of science education? Neither Schauble nor Lehrer thinks so. Still, they fervently hope that communication across disciplines can be facilitated and leveraged to build a common language and vision for powerful science content and teaching.

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NEWSLETTER INFORMATION

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Communication Director
Susan Smetzer Anderson

Newsletter Production
Kristen Roderick & Linda Endlich

Announcing **NEW PUBLICATIONS** *by* **NCISLA** *Researchers*

Boats, Balloons and Classroom Video: Science Teaching as Inquiry
Ann Rosebery and Beth Warren, Editors

This book lets elementary science teachers and other readers take part in a unique professional development experience. Working together, a group of elementary teachers, along with educational researchers and scientists, conduct their own scientific investigations and explore their students' learning in the classroom. In the process, they make important discoveries about the power of "doing" science and ways they can shape dynamic learning experiences for their students. Several questions relevant to professional development and elementary science teaching are addressed. (Heinemann Publishers)

Children's Mathematics: Cognitively Guided Instruction — with two multi-media CDs
Thomas P. Carpenter, Elizabeth Fennema, Megan Loef Franke, Linda Levi,and Susan B. Empson

Written for teachers and professional development staff, this book describes how children develop mathematically and learn mathematics. The authors describe how instruction can be organized to foster student learning. The two accompanying CDs show students and teachers implementing the described strategies. (Heinemann Publishers)

Designing Learning Environments for Developing Understanding of Geometry and Space — A Volume in the Studies in Mathematical Thinking and Learning Series
Richard Lehrer and Daniel Chazan, Editors

This volume highlights the editors' vision of a general geometry education, development of student thinking in everyday and classroom contexts, and the role of technologies. It is written for university faculty, researchers, graduate students and teachers involved in mathematics education. (Lawrence Erlbaum Associates, Inc.)

Mathematics Classrooms That Promote Understanding — A Volume in the Studies in Mathematical Thinking and Learning Series
Elizabeth Fennema and Thomas A. Romberg, Editors

Written at a level appropriate for master's degree students, this book synthesizes implications of research conducted by NCISLA and integrates studies of mathematics teaching and learning. (Lawrence Erlbaum Associates, Inc.)

IF YOU WOULD LIKE MORE INFORMATION ABOUT THESE PUBLICATIONS, CONTACT THE

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Thank You, Readers

More than 800 of you took precious time to reply to an E-mail survey sent to more than 2,000 *Principled Practice* subscribers this fall. Your responses were immensely helpful! Many of you provided excellent input about what you would like us to include in our publications, what types of information you need in your occupation, and ways we can better present information to meet your needs. With your help, we are creating new publications.

Research briefs are in the wings. These short write-ups will specifically describe study results mounting at several NCISLA projects. In addition, the briefs will highlight the practical and policy considerations suggested by our research results.

Principled Practice is now being re-angled to focus on perspectives and issues in science and mathematics education. The articles will examine educators' observations and concerns about such pressing issues as science education reform (see this issue) and equity in mathematics and science education (to be covered in a future publication). Our intent is to provide a vehicle for discussion and recommendations: a site for idea exchange.

In the near future, you will also hear about our new web site (in development) and a stunning four-color poster about student learning and understanding. Stay tuned.

As NCISLA moves forward in compiling research results, we will refer to your comments for direction in our publications. Thank you again for your input. You will be hearing much more from us.

Best wishes,

Susan Smetzer Anderson
Communication Director

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