Project 2061
American Association for the Advancement of Science

Atlas of Science Literacy

Mapping Growth of Understanding from K to 12

Educators across the country are using learning goals such as those found in *Benchmarks for Science Literacy* to shape what they teach and when. But learning goals used in isolation won't help students achieve science literacy. For example, research suggests that the concepts of a spherical earth, space, and gravity should be taught in close connection to each other. Students cannot accept that gravity is center-directed if they do not know the earth is round. Nor can they believe in a spherical earth without some knowledge of gravity to account for why people on the "bottom" don't fall off! To make the best use of learning goals, educators need to see the connections among them. They need to understand how the ideas and skills they are teaching build on what they taught before, make sense in terms of what else they are teaching, and lay a foundation for what they will teach next.

Atlas of Science Literacy, Project 2061's newest publication, shows the connections among the learning goals in *Benchmarks* through a collection of nearly 50 "strand maps" that graphically depict how students' understanding might grow from grades K–12. Each map displays the ideas, skills, and the connections among them that are part of achieving literacy in a particular topic, showing where each step along the way comes from and where it leads. Educators can study the maps to see how the ideas and skills that students learn in different grades and topics—and even disciplines—depend on and support one another.

Context, Connections, and Sequence

Atlas does not prescribe a particular curriculum or instructional strategy. Instead, it presents a framework meant to inspire a variety of different ways to design and organize learning experiences. The maps can help educators to:

Understand goals. Many people interpret the benchmarks and other learning goals as loose topics rather than specific ideas and skills. Maps help educators to understand the precise meaning of a benchmark by clarifying its context: where it comes from, where it leads, and how it relates to other benchmarks.

Design curriculum. The sequencing of learning goals in the maps can guide educators in assigning specific content to different grades and subjects to ensure the cumulative effectiveness of instruction. Designers should take account of connections among the ideas and skills students will be expected to learn.

Plan instruction. Maps can focus attention on what parts of a benchmark need to be

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2061 today

Science Literacy for a Changing Future

Mathematics
Natural Sciences
Social Sciences
Technology

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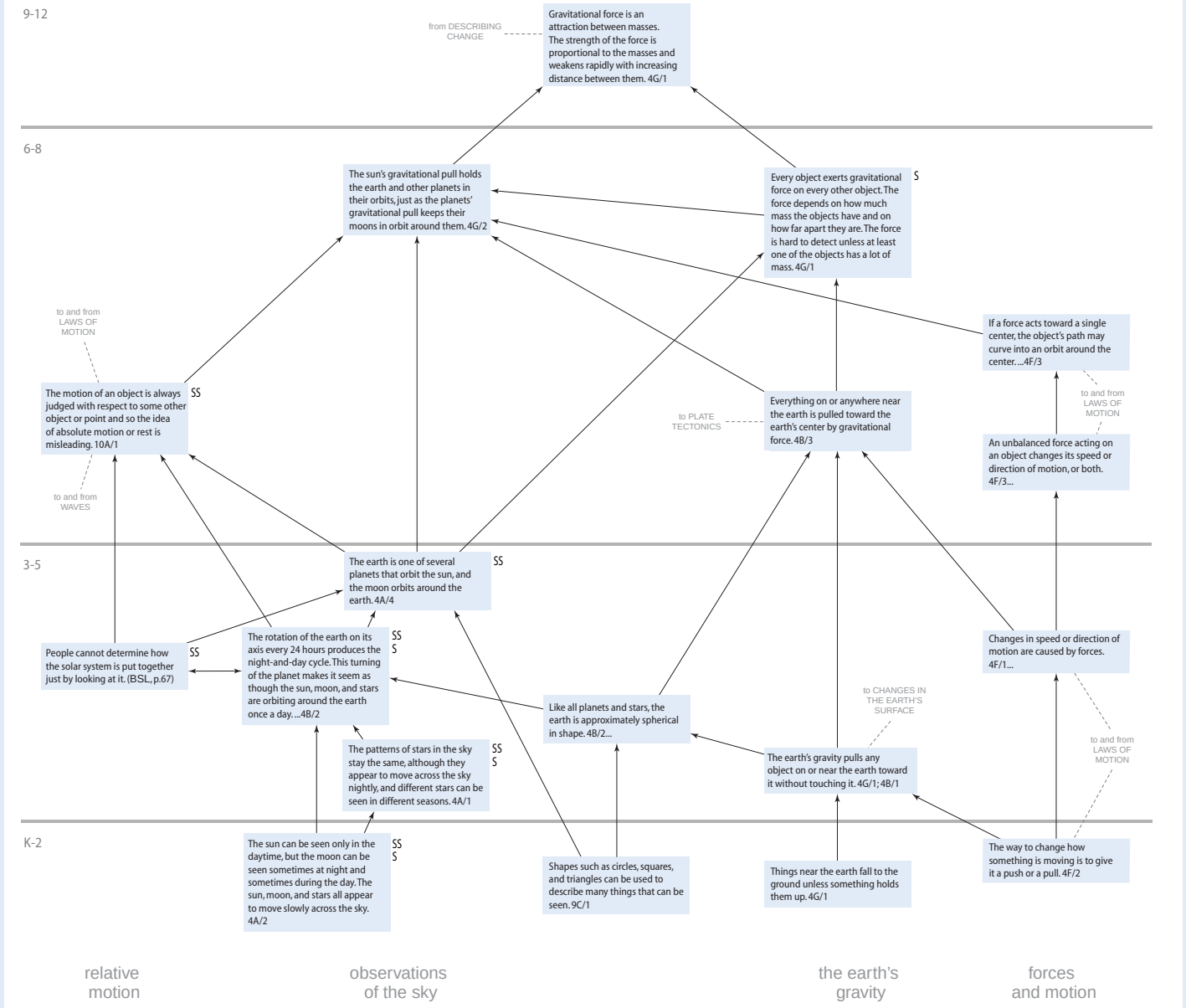
A Strand Map on Gravity



■ Labeled strands at the bottom of each map loosely suggest groups of benchmarks that develop over multiple grade ranges. These strands often interweave and overlap as they develop.

■ Connections between benchmarks imply that one "contributes to achieving" the other. Connections are based on the logic of the subject matter, general principles of cognitive development, and, insofar as possible, on the published research into how students learn.

■ Because any one map collects all the benchmarks relevant to a particular topic regardless of where else they appear, maps often share benchmarks. By using dotted lines, the maps indicate connections between maps in different clusters and chapters.

Atlas of Science Literacy *from page 1*

prepared for in instruction and what parts should be emphasized to support later learning. When students are struggling with an idea, maps can be used to decide what conceptual support might be needed. When students see how the things they learn fit together, they are more likely to understand and retain them.

Develop or evaluate curriculum materials. Maps can help materials developers decide what benchmarks to target when. Maps can also encourage them to think about activities and lessons that address the specific ideas in the benchmarks—rather than only something under the same general topic heading—at an appropriate level of sophistication. Developing or analyzing materials requires a deep understanding of the targeted benchmark itself, the prerequisite ideas that contribute to it, and conceptual connections that should be highlighted in the text of the material or the teacher guide.

Construct and analyze assessment. When used in interpreting assessment, maps can help answer questions about when it is appropriate to assess particular ideas and skills, and why students might have had trouble with a task. With maps as a framework, assessments can be designed to probe where students are in their growth of understanding, rather than how well they know a collection of isolated ideas.

Prepare teachers. Whether in a pre-service or in-service context, all of the activities listed above can sharpen teachers' sense of what benchmarks mean and how to help students attain them. Teachers report that their own content knowledge is improved by studying the connections among benchmarks in the maps.

Organization of *Atlas*

Atlas is organized into the same chapters as *Benchmarks*. Each *Atlas* chapter includes "clusters" of closely related maps that loosely correspond to the sections in the matching *Benchmarks* chapters. Each map is accompanied by a general discussion of the topic at hand, a brief summary of the content of the map and its major strands, and remarks on related themes and historical episodes. Notes on interesting aspects of the maps and relevant cognitive research from *Benchmarks* are also included. Approximately half of the learning goals from *Benchmarks for Science Literacy* are covered in this edition of *Atlas*, which is being co-published with the National Science Teachers Association and will be available in 2001. Project 2061 plans to map the remaining benchmarks in a subsequent edition.

Lessons from Minnesota

Bill Linder-Scholer is executive director of SciMath^{MN}, a public/private partnership in Minnesota that supports standards-based, systemic improvements in the teaching and learning of K–12 science and mathematics. The organization sponsored Minnesota's participation as a "mini-nation" in the 1995 Third International Mathematics and Science Study (TIMSS). Project 2061 staff member Susan Shuttleworth recently interviewed Linder-Scholer via e-mail about how he has utilized Project 2061's tools and what he has learned from TIMSS.

SS: What is SciMath^{MN}'s mission?

BL: Our mission is standards-based systemic reform for K–12 mathematics and science education in the state of Minnesota. We work both within the existing K–12 system, serving as a complementary service to the math and science functions within the state department of public instruction, and as a change agent from the outside, with guidance provided by a separate nonprofit board of directors. Our work includes both K–12 reforms and related initiatives for teacher education reform.

We get state and private-sector funding and focus on three areas: policy, program development, and public awareness. In regard to policy, we advocate for state-level policies and programs that embody the ideas of the national math and science standards and that align statewide standards, local practice, statewide testing, and teacher licensure in math and science. Our program development focuses on providing research, tools, and training to help school districts implement the standards and align teaching and learning practices. For example, we play a role in translating the vision of standards-based education into local practice by disseminating important tools such as Project 2061's curriculum-materials evaluation procedure. And we increase public awareness by conducting activities to engage educators, parents, the business community, policymakers, and the community at large about the need for standards-based systemic reform.

SS: What role has Project 2061 played in your efforts?

BL: Early on, Project 2061's *Benchmarks for Science Literacy* was one of the touchstones consulted by our founders in designing a mission and goals for the state and for our long-term work. Dissemination of *Benchmarks* in Minnesota supported local efforts to meet the state's own content standards, which were designed with the national documents as primary models. And we have collaborated with Project 2061 on public awareness issues, particularly around outreach to parents. Project 2061's director, George Nelson, has participated in several Minnesota-based initiatives focused on designing parent materials and conducting broad-scale outreach. He recorded a 60-second public service announcement to parents, which is available over SciMath^{MN}'s Web site as part of our ongoing public awareness activity.

We've used Project 2061's textbook analyses to advocate for standards-based reforms, particularly with district leadership and curriculum leaders. We've hosted several workshops on Project 2061's curriculum-materials evaluation procedure, and educators in White Bear Lake and Duluth used information from these workshops to help them choose a new elementary math text. We're now looking at ways to disseminate these workshops more broadly across the state.

SS: SciMath^{MN} sponsored Minnesota's participation in TIMSS. Minnesota scored second only to Singapore in 8th-grade science. What did you learn from the TIMSS results?

BL: Minnesota was the only state in the U.S. that participated in TIMSS testing and survey work at all three grade levels—4th, 8th, and

About Project 2061

Project 2061 of the American Association for the Advancement of Science has developed a set of reform tools to help educators meet science literacy goals.

Science for All Americans (OUP, $14.95) describes what every citizen needs to know in science, mathematics, and technology. ***Benchmarks for Science Literacy*** (OUP, $26.50) presents specific learning goals in science, mathematics, and technology for the end of grades 2, 5, 8, and 12. Both books are available in Spanish (OUP-Mexico). ***Resources for Science Literacy: Professional Development*** (OUP, $49.95) provides educators with valuable materials to improve their own knowledge and skills. ***Blueprints for Reform*** (OUP, $17.95) outlines changes needed in a dozen areas of the education system to improve learning in science, mathematics, and technology. ***Dialogue on Early Childhood Science, Mathematics, and Technology Education*** (AAAS, $12.95) discusses the latest findings on teaching these subjects to preschool children. ***Middle Grades Mathematics Textbooks: A Benchmarks-Based Evaluation*** (AAAS, $89) presents the results of Project 2061's analysis of both widely used and newly developed middle grades mathematics texts. ***Designs for Science Literacy*** and ***Designs on Disk*** (OUP, $32.50) provide a theoretical framework and practical guidelines for designing coherent K–12 curricula. ***Atlas of Science Literacy*** (AAAS, $49.95) maps out connections among benchmarks to show students' growth of understanding from K–12.

AAAS gratefully acknowledges the following Project 2061 supporters: Carnegie Corporation of New York, Hewlett-Packard Company, John D. and Catherine T. MacArthur Foundation, Andrew W. Mellon Foundation, National Science Foundation, and The Pew Charitable Trusts.

For more information contact: Project 2061/AAAS, 1333 H Street, NW, P.O. Box 34446, Washington, D.C. 20005; Phone: 202-326-6666; Fax: 202-842-5196; E-mail: project2061@aaas.org; Web site: www.project2061.org.

To order Project 2061 products call Oxford University Press (OUP), 1-800-451-7556; OUP Mexico, 011-52-5-592-5600, ext. 166; AAAS Distribution Center, 1-800-222-7809.

12th. The lessons we learned from this unique participation have been surprising and very helpful to our work on standards.

The surprises come in getting beyond the "horse-race" aspects of the TIMSS scale scores—the fact that Minnesota's 8th grade science scores were equal to the best in the world on TIMSS. The more interesting question is why we scored so well in science and not in mathematics. The answers offer hope to any state that aims to improve math and science performance across its system.

Because similar students were taking the science and mathematics tests, the usual reasons for differences in performance—students' backgrounds, parents' education, etcetera—don't apply. Instead, our attention turns to the core academic issues of curriculum and instruction. The key reasons for a strong performance in science, but not in math, reflect the differences in opportunity to learn and in what the TIMSS researchers call focus and coherence. Minnesota accidentally achieved a powerful consensus around topics and texts for middle school science but didn't in math. All Minnesota 8th graders take the same science course, but in any given school they may experience up to five different math courses. In addition, much like the overall U.S. findings, instruction in Minnesota science classrooms was relatively less text-based and more hands-on than instruction in typical math classes. Minnesota students seem to have benefited from this instructional difference. This one instance where Minnesota's performance stood out dramatically from the overall U.S. student performance provides helpful support for the role of standards and for systemic approaches.

SciMath^{MN} is using TIMSS materials and related professional development guides to take these messages to school districts and policymakers, both through broad dissemination of the TIMSS results and through seminars we have created for district teams. The National Education Goals Panel recently released its case study of the Minnesota TIMSS results, which has also provided us with another convenient tool for further dissemination.

SS: Are there any other pressing problems in K–12 science and mathematics education that you are working to address?

BL: The challenges we face in Minnesota are essentially the same as most other states are facing. We are trying to achieve improvements via standards and statewide systemic approaches while at the same time battling complacency over current approaches to schooling and low expectations for student achievement. Also we are battling the sometimes counter effect of the nationwide rush to accountability in the form of statewide testing that is not always aligned with the goals of standards-based reform.

To learn more about SciMath^{MN}, visit www.scimathmn.org. To view the recently released National Education Goals Panel report Minnesota and TIMSS, Exploring High Achievement in Eighth Grade Science, *visit www.negp.gov/reports/mntimss.pdf.*

Bill Linder-Scholer

Early on, Project 2061's Benchmarks for Science Literacy *was one of the touchstones consulted by our founders in designing a mission and goals for the state and for our long-term work.*

Visit Project 2061's exhibit booth at the following conferences in 2001:

American Association for the Advancement of Science
February 15–20, 2001, San Francisco, CA
Contact: (202) 326-6450; www.aaas.org

Association for Supervision and Curriculum Development
March 17–19, 2001, Boston, MA
Contact: (800) 933-ASCD; www.ascd.org

National Science Teachers Association—National Convention
March 22–25, 2001, St. Louis, MO
Contact: (703) 243-7100; www.nsta.org

National Council of Teachers of Mathematics
April 4–7, 2001, Orlando, FL
Contact: (703) 620-9840; www.nctm.org

Spreading Project 2061's Vision

Project 2061's Professional Development Programs (PDP) continue to promote the Project's vision of science literacy for all people through workshops and new partnerships. From Chicago, Illinois to Beijing, China, PDP activities are teaching individuals and organizations about how Project 2061's benchmarks-based approach to improving science, mathematics, and technology education can contribute to their local reform efforts.

In summer 2000 alone, PDP conducted nearly 20 workshops in the United States and Central America. Among the organizations participating in the workshops were the SMART Consortium, Cleveland, Ohio; NASA's Jet Propulsion Laboratory at the California Institute of Technology; and the First in the World Consortium, Chicago, Illinois. In addition to studying and using Project 2061's benchmarks-based tools for curriculum reform, workshop participants had an opportunity to model the dynamics of a classroom learning community.

Visit www.pdp2061.org to learn about open enrollment workshops scheduled across the country in 2001.

Modeling Classroom Learning

The demonstration of how to be learners as well as teachers in the classroom was especially valuable for teachers involved in a summer workshop for DC ACTS. This three-year project, sponsored by the National Science Foundation, is focusing on the challenges and possibilities of education reform and subject integration in the District of Columbia Public Schools (DCPS). Project 2061 is partnering with AAAS colleagues, the Carnegie Institution of Washington, and DCPS on the project. Participants in the summer workshop included teams of science, mathematics, and English teachers. Michael D. Hughes, a 7th and 8th grade English teacher at Deal Junior High School, noted that the Project 2061 workshop directly influenced his classroom practice. "In addition to the terrific content presented in the workshop, the methods of instruction modeled to us in class simulations changed the way I prepare lessons. I now am more careful to begin the discovery process from the student's personal experience and understanding, instead of presenting the content information first," said Hughes.

Open Enrollment

As in the workshops for DC ACTS, the demonstration of effective teaching strategies is a major component in PDP's new "open enrollment" workshops for teachers, administrators, and curriculum developers. This past fall PDP launched these new workshops in seven East Coast cities enabling educators to study Project 2061's professional development offerings over a period of three days. Participant Sharon Angus-Smith, Education/Program Developer at the Academy of Natural Sciences in Philadelphia, stated, "The teaching strategies presented were excellent. They demonstrated how to deliver material so that students can best grasp it and use it to modify their ideas of the world." By eliciting participants' ideas, using peer discussion groups, and presenting model lessons, workshop leaders demonstrated the kinds of pedagogical thinking and practice that teachers need to combine with content-aligned materials when implementing benchmarks and standards in their classrooms.

Asian Tour Launches New Partnership

Project 2061 director George Nelson and Scott May, head of Project 2061 Professional Development Programs, traveled to Japan and China in October 2000. Their visits to Tokyo, Hong Kong, Beijing, and Shanghai inaugurated Project 2061's partnership with the University of Pennsylvania Graduate School of Education to promote science and mathematics literacy in Asian and European countries. In presentations to teacher and university groups and meetings with senior government officials, Nelson and May discussed U.S. education reform and Project 2061's use of specific learning goals in evaluating curricula, instruction, and assessments. As an outgrowth of the new partnership, PDP also conducted a five-day workshop at the University of Pennsylvania in November for 25 educators from China and Singapore.

For more information about Project 2061's Professional Development Programs call 1-888-PDP-2061, e-mail pdp2061@aaas.org, or visit www.pdp2061.org.

Director's Notes

Less and More

At Project 2061 we often talk about "less is more" meaning that in order for students to learn more of the important concepts in science, mathematics, and technology, less total "stuff" should be taught. That way the time necessary for real learning to take place is available. In *Designs for Science Literacy*, and especially in *Designs on Disk*, we go so far as to list topics that could be omitted from the literacy curriculum in order to free up this time. And these lists include many traditional favorites from today's canonical curriculum. "Take them out!" we say. But we have a little secret to share. We want to add some things into the curriculum, too.

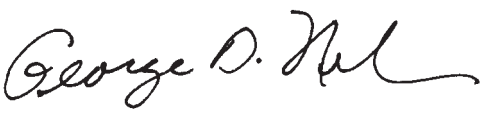
I'm talking about the understandings of the nature of science, mathematics, and technology; the historical episodes; the common themes; and the skills and habits of mind that make up science literacy. These have always been a part of Project 2061's goals—the parts generally shorted by the states when they use *Benchmarks* to guide them in creating their own standards. Now *Atlas of Science Literacy* is forcing us to focus on these ideas and another common omission from today's curriculum—the connections among the knowledge and skills within and across disciplines and within science, mathematics, and technology themselves.

Important Connections

For example, in order to understand how the fossil record supports the idea of evolution, students should understand how we know that fossils are remnants of once-living organisms and that they are old and their ages can be determined. So students will need to know some important ideas from geology to understand how fossils are formed, from physics to understand how the abundance of specific elements and isotopes can help determine the absolute age of fossil-containing rocks, and from mathematics to understand just how the ages are calculated. Then, students will need knowledge of scientific inquiry and technology to understand just how we collect and interpret the evidence. Knowledge of the nature of scientific theories will help them appreciate how powerful the ideas of evolution and natural selection have been for explaining the fossil record and the current distribution of species, and how well they fit within and support the general scientific enterprise. The history of how Lyell argued for an ancient Earth and how his accumulation and synthesis of massive amounts of evidence to support his arguments influenced Darwin is one of the great scientific stories. Knowing it helps students appreciate both the scientific arguments and the scientific culture.

Atlas brings these connected goals together for us and challenges us to think in new ways about how curriculum could be restructured to make them a part of our students' educational experiences. We aren't necessarily advocating for an integrated curriculum—though that is one possible approach among many that should be tried—rather we are advocating for curriculum that explicitly includes the connections among concepts as important learning goals in themselves. This is part of the idea of coherence put forward in the last chapter of *Designs*.

Our new tools, *Atlas* and *Designs,* help us understand that "less is more," but that some of the "less" is not just what is left over after "stuff" is removed. "Less" includes new knowledge and new skills that together with the important knowledge and skills from the traditional curriculum make up literacy. We offer these new tools as works-in-progress and look forward to your feedback and comments to help us improve future editions as you use them in your important work. Please stay in touch.



George D. Nelson
Director

"Less" includes new knowledge and new skills that together with the important knowledge and skills from the traditional curriculum make up literacy.

FYI

Project 2061 to Host Textbook Conferences
Project 2061 will convene educators, curriculum developers, publishers, scientists and mathematicians, and state and national policymakers to plan a strategy for improving science and mathematics textbooks over the next five years. The invitation-only conferences, to be held in February and September in Washington, D.C., will include workshop sessions on Project 2061's curriculum-materials evaluation procedure and in-depth discussions about what is needed to develop more effective texts.

Focusing on New Teachers
With funding from the John D. and Catherine T. MacArthur Foundation, Project 2061 recently completed a study of the preparation and induction of new teachers into the field of K–12 science education. The three-year project, conducted with universities and public schools in Colorado and Maryland, set out to educate university faculty, in-service mentor teachers, and pre-service teachers about teaching for science literacy. Project accomplishments included the development of new benchmarks-based university science and methods courses and improved methods for mentoring new teachers.

Conversation on Technology Education Continues
The proceedings of the AAAS Technology Education Research Conference are now available on-line at www.project2061.org. The December 1999 conference was sponsored by Project 2061 and funded by the National Science Foundation. In the proceedings, an overview of the conference and 17 papers by conference participants reflect on the conference's dialogue about a research agenda for improving K–12 technology education. Plans are underway for a second conference to be held in April 2001, which will focus on explaining specific research models for technology education and designing specific research projects. For more information contact Fernando Cajas at (202) 326-6209 or fcajas@aaas.org.

Project 2061 Tools Translated into Mandarin
The Chinese Academy of Science and Technology (CAST) has completed translations of several Project 2061 books into Mandarin Chinese. *Science for All Americans* (1989), *Benchmarks for Science Literacy* (1993), and *Blueprints for Reform* (1998) will soon be available for release throughout mainland China.

Introducing…
Project 2061 is pleased to announce three new staff members. **Stedman Willard**, previously a high school physics teacher at The Asheville School in North Carolina, has joined Project 2061 as a senior program associate. He first encountered the work of Project 2061 as an editor of science textbooks at Harcourt Brace School Publishers in Orlando, FL. He has a B.S. in Earth, Atmospheric, and Planetary Science from the Massachusetts Institute of Technology. **Michele Lee** is the new science workshop leader for Project 2061 Professional Development Programs. She holds an Ed.M. in Learning and Teaching from Harvard University and comes to the Project from Norwood School in Bethesda, MD, where she was a science teacher and the K–6 science coordinator. **Catherine Tramontana** has joined the communications department as an associate editor. Previously a copy editor with EEI Communications in Alexandria, VA, she recently completed a Ph.D. in Literatures in English from Rutgers University.

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