APS physics

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Larry Woolf-Editor

IN THIS ISSUE

Greetings from the Chair!

David Haase

Mr. Wizard–Don Herbert–died recently. To a large number of us, Saturday mornings in the 1950's included visits to his TV home for experiments on science. I still remember how he demonstrated the compressive strength of glass by standing on a window pane. He showed us how the impulse from a CO2 pellet gun canister could propel a bowling ball hanging from a string, while a heavy blow from a hammer left the ball almost motionless. I also remember looking forward to Mr. Wizard's monthly newsletter, which described science activities I could try. One article even explained why a helium balloon floating in an automobile moves towards the right during a left turn.

Possibly no American since Benjamin Franklin has personally demonstrated science to the public in such interesting ways and to such notable effect as did Don Herbert. An obituary in Time Magazine reported that the "Watch Mr. Wizard" show "in the '60's and '70's was cited by half the applicants to Rockefeller University, the renowned biomedical institute, as a reason for their early interest in science."

Of course, in the Sputnik era Mr. Wizard was doing the right thing at the right time. Science was critical to the national economic and defense needs. He took advantage of the possibilities of the new medium of TV making direct connections to the viewers. To his credit Mr. Wizard spoke to children as if they had the ability to understand science. The science was good stuff–surprising, well-explained and rigorous. There were participatory investigations and gee-whiz and many meaningful science insights.

As APS members we are the ones who succeeded in fulfilling the dream. We work with the curiosity, invention and wonder that Mr. Wizard showed us, and we get paid for it. But Mr. Wizard's big message was that the wonder of investigation is meant for us to share, in particular with the generation that will follow us.

This issue of the Forum on Education newsletter highlights issues that will affect the next generation of scientists–new science curricula and approaches to teacher preparation. Scientists like us should be aware of and support such initiatives. We can lobby for better education policies and curricula and spread the word about science.

Just as in the 50's there are many good civic reasons for us to support K-12 science education. Today we need scientists and engineers for national competitiveness, for the health of the science-technology enterprise, for the economic welfare of our citizens and children. Mr. Wizard's life reminds us that, in the end, these global goals are reached by individuals, like you and me, who were lured into science by wonder and curiosity. If the scientific enterprise is worth doing, it is worth passing on to the next generation. Please read the articles. Please help a child to see the wonder.

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Editor's Introduction to the K-12 Science Curricula Articles

Lawrence Woolf

A recent report (Roseman, 2006) from AAAS Project 2061 pointed out the need for closer collaboration between institutions of higher education and the K-12 education system: "It is … clear that educators at both levels have knowledge and expertise that can be of benefit to the other."

This section of the newsletter will hopefully help educators in higher education learn from the experience of K-12 science educators, particularly curriculum developers. These articles describe some of the most innovative and widely used inquiry based science programs in K-12 science education. All programs have the commonality of students actively involved in their learning, although each has their own unique approach. Most involve a carefully sequenced progressive series of activities that follow a learning cycle. The activities are arranged around coherent learning goals that are based on national science standards.

Providing a broader perspective are articles on the impact of national (but voluntary) K-12 science education standards as well as the role of the NSF in funding the development of innovative K-12 science curricula.

When soliciting articles for this newsletter, I asked the authors to consider the following issues:

- How was your program developed, what key aspects have made it successful, and what issues arose during its implementation?
- What lessons learned from your curriculum development are applicable to undergraduate and graduate level instructional materials?
- The National Science Education Standards have recently played a major role in shaping curriculum and instruction at the K-12 level. Would standards be useful at the undergraduate and graduate levels?

While not all authors explicitly addressed these issues, the readers should find that the authors' discussions provide ample food for thought.

There are a variety of reasons why K-12 science curricula should be of interest and relevant to Forum members:

- The science skills and knowledge of students entering colleges and universities result from K-12 science curricula.
- Many students in colleges and universities will someday be

using these K-12 science curricula if they become teachers, so they will need appropriate pre-service professional development.

• Engaging and effective K-12 science curricula will increase the number and diversity of future scientists and engineers and will increase the science literacy of all students.

• These curricula follow the scientific process where students engage in and then explore physical phenomena by planning and performing experiments, learn to understand and explain their results in a variety of ways, talk and write about their efforts, and then utilize their new knowledge (Morrow, 2000). As such, these curricula are preparing students to be independent scientific thinkers and investigators, which are also goals of higher education.

The utilization of inquiry based active learning in K-12 science education began more than 40 years ago. This innovation is starting to diffuse into higher education. Lessons learned from K-12 science education reform should be applicable to improving undergraduate as well as graduate science education.

1. Roseman, Jo Ellen and Koppal, Mary, "Ensuring That College Graduates are Science Literate: Implications of K-12 Benchmarks and Standards," Chapter 32 in the *Handbook of College Science Teaching*, NSTA Press 2006. Online at <www.project2061.org/handbook>

2. Morrow, Cherilynn A., "What Are the Similarities between Scientific Research and Science Education Reform?", Space Science Institute, March 2000, Online at <http://www.scientistsineducation.org/reccd/presentations/Similar.pdf>

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Development of K-12 Instructional Materials at the National Science Foundation

Gerhard Salinger

Funding the development of instructional materials at the National Science Foundation began shortly after the NSF was established in 1950. The early materials were inquiry-oriented, hands-on materials from which students learned how science is done; teachers are helped to change their practice. The key developers were practicing scientists. One of the early physics projects, *Physical Sciences Study Project* (PSSC), still in use today, has influenced almost all high school physics texts (and texts in other sciences as well) written since. The activities developed to help students understand the concepts are classics; but many are being forgotten and some science educators judge the newly developed activities to be not as effective. Other early high school curricula, Harvard Project Physics, Chem Study, Chemistry–a Bond Approach, the Blue (Molecular), Yellow (Systematics) and Green (Ecological) approaches to high school biology and Investigating the Earth, influenced traditional publishers to change their texts to adopt new pedagogies and new content. Many of these texts targeted high school students expected to be in the pipeline to become scientists and engineers; but the effect on college level texts was limited.

Similarly there was a development of instructional materials for elementary school students also led by a physicist–Bob Karplus. Before the development of the "alphabet soup" of elementary school science curricula (SCIS, USMES, SAVI, SAPA, MinniMaST and ESS, some of which are still in use), almost no elementary school science text had hands-on activities for students. Since then almost all elementary school science texts have them.

These projects required the involvement of practicing scientists, science educators and teachers. All three are necessary and have key contributions to make. The materials were pilot tested by excellent teachers in classrooms to determine that the concepts can be taught and field tested more broadly to determine the scaffolds needed to teach with them. These ideas have guided the program since the beginning. The early materials, however, did not have extensive large scale evaluations of student learning.

The importance of this effort can be determined by the studies that show that textbooks are a major influence on what students learn and that teachers spend much of class time using a textbook.

After NSF recovered from the shut down of the Education Directorate in the early 1980's, the funding of instructional materials continued, but now with an emphasis on science education for all students. The American Chemical Society developed ChemComm that used real world contexts to motivate the learning of chemistry. These were followed in the 1990's by Biology in Community Settings, Active Physics and EarthComm. These texts look very different from the traditional texts, but engage more students in the study of the science. There is evidence that students who learn from these texts have the background to do well in college courses. They had wrestled with the concepts. These and many other instructional materials that also embedded science learning in real-world contexts were developed as described above.

In the late 1980's the Instructional Materials Development (IMD) program decided that there would be more impact if there were some systemic initiatives to develop materials. In order to increase the use of the materials in schools, proposals were requested for the development of instructional materials that included a developer, a publisher and a school system. The majority of the materials funded covered several years at the elementary or middle school levels, including Science and Technology for Children and Full Option Science System. For various reasons none of the original partnerships stayed intact, but some of the materials, particularly at the elementary school level were published and still see extensive use.

Nationally, the idea of standards for K-12 education became popular. The emphasis shifted from educating the science and engineering pipeline to science, technology, engineering and mathematics (STEM) for ALL students. Project 2061 at the American Association for the Advancement of Science (AAAS), with NSF and other funding, studied what all students should know in science, mathematics, social science and technology by the time they left high school. This study resulted in the publication of the influential monograph, *Science for All Americans*, that described both content to be understood and the habits of mind to be developed. The National Council of Teachers of Mathematics developed the Curriculum and Evaluation Standards for School Mathematics. These standards not only described the mathematics students should know when they leave high school; but also described what students should know at various grade bands. In response, NSF funded the National Research Council (NRC) to convene scientists, science educators and teachers to develop the National Science Education Standards, while Project 2061 used its funding to write the Benchmarks for Science Literacy. All of these standards emphasized understanding over memorization and depth over breadth. Standards in other subjects were funded by the US Department of Education.

To implement the mathematics standards, the Materials Development program funded the development of three comprehensive curricula at the elementary level, five at the middle school level and four for high schools. The best of these built on the development and testing of modules funded earlier. After the science standards were published, NSF funded no comprehensive elementary school curricula; however the developers of those curricula were very active in the standards process. About ten comprehensive curricula were funded at the middle school level–most were multidisciplinary and each had a different focus. At the high school level, NSF funded one-year curricula with a disciplinary focus –six in physics, three in chemistry, five in biology, two each in Earth science and Environmental science. A few curricula were multidisciplinary. All of these materials were developed in a manner similar to that described above, but now evaluators external to the project evaluated student performance. Most demonstrated significant gains in understanding the content and the processes of the discipline. The different pedagogy caused heated discussion, particularly in mathematics. The Mathematics Standards were revised in 2000–but the emphasis remains on reasoning, pattern recognition and discourse.

In the 1980s, research in cognitive science led to deeper understanding about student learning. So in the 1990s, to help the education community understand and apply the findings from cognitive science, IMD funded or co-funded and provided the leadership and management of grants to the NRC for:

- Knowing What Students Know,
- Systems for State Science Assessments
- America's Lab Report
- Taking Science to Schools
- Evaluating Curricular Effectiveness
- Investigating the Influence of Standards

In addition, IMD co-funded workshops addressing the topics of bridging the gap between classroom and large-scale assessment, assessing technological literacy, fluency in information and communications technology and use of multiple methods of evaluation.

To translate these ideas into instructional materials, the IMD program sponsored annual meetings of Principal Investigators of comprehensive materials development projects -creating a community of developers. A spirit of "coopetetion" developed so that the art and science of materials development also advanced. The insights of cognitive science, particularly *How People Learn*, pervaded the discussion of how to provide challenging STEM content for ALL students. There was increased emphasis on formative evaluation, teacher support materials, and dissemination.

In the 1990's the IMD program initiated projects that investigated the learning of technological design and its application to learning science. After developing some modules and a middle school curriculum, NSF (together with NASA) funded the International Technology Education Association to develop the *Standards for Technological Literacy*. The National Academy of Engineering was instrumental in shaping these standards and went on to encourage much more engineering education in both formal and informal situations in *Technically Speaking*. In *Tech Tally*, the Academy also investigated the state of assessment in technology education. Now there is much more interest in having students learn about design. (Design is also part of both sets of science standards.) The IMD program has developed several sets of materials in which learning is through design as well as inquiry. Design has a role in Active Physics and Active Chemistry.

As the pressure for accountability mounted, the IMD program demanded better evaluation of materials being developed and also funded the development of assessment items both for modifying instruction and for large scale testing. AAAS developed, with NSF funding, an instrument to determine whether textbooks really addressed the spirit of the standards–helping student understand concepts in depth. Most of the traditional science texts did not measure up and the NSF-funded texts fared only slightly better.

In 2000, a special solicitation requested developers to use a process described by Grant Wiggins and Jay McTighe in their monograph *Understanding by Design*. The process is to first set the learning goals to be achieved. The second step is to describe what a student would know and be able to do if the goal was achieved. Only after these two issues are resolved, should the activities that help students achieve the goals be developed. It may seem an obvious approach, but heretofore most developers had thought first about activities that engage students and only after developing them would they determine how they might address standards. Many other curriculum developers still use this method.

The comprehensive instructional materials developed for the middle school and the high school are still undergoing development, but the evaluations to date are very positive. Rather than spend an entire year on one discipline, in two of these curricula (IQWST (Investigating and Questioning Our World through Science and Technology) and BSCS Science: An Inquiry Approach), students learn some of each science discipline each year. The third (Foundation Science) instructs one semester of each discipline of the high school curriculum each semester so that at the end of the junior year the student has one year of two disciplines and one semester of the other two. The multi-disciplinary approach supports the assessment of science at the end of the 10th grade. These materials also develop increasing sophistication with science processes such as the ability to marshal evidence to provide a warrant for a claim.

Taking Science to School, a recent study by the National Research Council again funded by NSF, describes the idea of a learning progression, which takes the backward design process even further. A learning progression sequences instruction over several years so that students develop ever more sophisticated ways of thinking about a topic as they progress through school. In its new Discovery Research K12 program (DR-K12) (which grew out of Instructional Materials and Teacher Professional Continuum programs), one of the issues being addressed is the understanding of learning progressions. The progression is not only about the content and process, but teachers must understand how the content and processes that students are learning at one level also provide the basis for deeper understanding of key concepts at the next level. The Atlas developed by AAAS is helpful in this regard.

The DR-K12 program will continue the development of instructional modules with an emphasis on understanding how the instructional system–materials, teachers, and schools–helps or hinders student understanding of key concepts.

This article has mainly looked at the ideas that drive the instructional materials development program at NSF. Major physics projects include Active Physics, Hands-on Physics, Science that Counts in the Workplace. PRISMS, Minds-on Physics, Assessing to Learn, and InterActions in Physics. Physics is also a major part in many of the multidisciplinary programs. Particularly Active Physics has demonstrated that students can learn physics at the ninth grade level, giving rise to inversion of the high school curriculum, which also makes good sense as the emphasis in biology is more a molecular and quantitative approach.

The changes in physics instruction rely heavily on the very active program in physics education research largely funded by the Division of Research, Evaluation and Communications at NSF. At the same time there were programs to provide professional development to teachers, which led to the modeling approach at Arizona State University and to the careful work by the Physics Education group at the University of Washington among others.

There still is controversy about the new methods of teaching physics which emphasize understanding over memorization and mathematical problem solving. In 1999, NSF funded the group at Boston College who were instrumental in the development and analysis of the TIMSS test, to give the TIMSS test to students who studied from NSF funded materials or whose teachers had participated in NSF funded professional development workshops. These students performed one-half standard deviation better than US students with similar backgrounds who had taken the original TIMSS test.

This article is meant to provide an overview of materials development at NSF. Details and specific information can be obtained from the author.

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The Influence of National Standards on Science Education

Rodger W. Bybee

In the early 1990s, I began working on the *National Science Education Standards* (NRC, 1996) as chair of the content working group. In 1995, Diane Ravitch published *National Standards in American Education: A Citizens Guide* which stimulated a national conversation about standards. As a participant in the national conversation I soon realized several objections to national standards. For example, some expressed concerns about the imposition of values, the potential of a national curriculum, the priority of states rights, the reduction of equality of opportunity, and the very real concern that alone national standards will stand as policies without aligned curriculum programs and improved classroom practices. These and other concerns describe some of the challenges of national standards.

At the same time, I recognized the long-term potential influence of national standards for science education. First, it is the case that national standards can influence all the important components of the educational system. Second, they identify the most fundamental goals—learning outcomes. Third, standards at the national level are necessary for equality of educational opportunity. Finally, I find little reason to have different state and local content standards for science because the basic concepts of science do not vary from state to state.

While that national conversation continues, national standards also have been the basis for national, state, and local policies; elementary, middle, and high school programs, and changes in curriculum, instruction, and assessment practices. So, I am confident in responding to a question about the past influence of national standards by stating that they have demonstrated one very important characteristic, namely they have changed fundamental components of science education at a scale that makes a difference. Some would certainly question whether the changes have been good or bad. I would argue that on balance, the national standards have had a positive influence on the science education system. This said, the influence has often been weak. That is the bad news. The good news is that the influence of national standards has been continuous and generally in the direction of more coherent, focused, and rigorous state policies, school programs, and classroom practices. After release of the standards in 1996 the National Research Council undertook the task of developing a framework for research in mathematics, science, and technology education. The report has been used to frame questions and guide investigations of the influence of standards (NRC, 2002). There is evidence supporting the generally positive influence of national standards (NRC, 2003, Sunal and Wright, 2006).

In the past year, there have been new calls for national standards from several major urban school districts, the Council of Great City Schools, Council of Chief State School Officers, the National Science Board, and members of Congress. These discussions are simultaneously encouraging and discouraging. They continue the national conversation about what our society needs from a science education, the role of standards, and the requirements for fundamental changes within the science education system. These discussions present the encouraging side of calls for national standards.

The discouraging side of the discussion centers on the fact that we already have national standards for science education. Although the national standards need revision, could be reduced, may be presented in more helpful ways, and should address contemporary social and educational advances, we do have a major national investment in standards. There is very little to suggest that developing new national standards will be endorsed by states, embraced by publishers, accepted by teacher educators, and implemented by test makers.

Revising the *National Science Education Standards* (NRC, 1996) could meet the aims of those calling for new national standards. A revision would serve an additional aim, namely, signaling the education community that these national standards may continue to be used in the formulation of policies, development of curricula, and foundation for assessments. As an alternative to revision, I would note that the National Assessment of Educational Progress (NAEP) used the *National Science Education Standards* (NRC 1996) and *Benchmarks for Science Literacy* (AAAS, 1993) as the conceptual framework for NAEP Science 2009. So, for the contemporary perspective, I argue that we have national standards for the content of science education, what we need is to revise and improve those standards and work for wider understanding, endorsement, and alignment in state frameworks and assessments, teacher education and licensure, and school science programs.

As to the future influence of national standards, it seems there are several significant issues looming on the horizon. One has already been mentioned. The NAEP Science 2009 test will use a framework based on the national standards. This situation suggests minor revision and improvement of current national standards in order to align with the priorities of national assessments from 2009 to 2019.

From its enactment in January 2002 the No Child Left Behind Act (NCLB) has placed time and attention on literacy and mathematics and used assessment results as a means of determining adequate yearly progress for schools attaining desired outcomes. Beginning this year, student achievement in science will be included as an outcome. While the No Child Left Behind is a significant civil rights statement, unfortunately, the mechanisms for implementation are generally a disaster. In the Sputnik era we learned that "teacher proof" curricula were not effective. Now, many educators are realizing that "school punishment" likewise is not an effective reform strategy in the NCLB era.

One omission and a major issue in the use of NCLB as a stimulus for reform has been a lack of instructional materials. We have the policy and assessments but, lack curriculum materials that will facilitate effective science teaching. I think this omission of emphasis on well designed instructional materials will have long-term detrimental consequences for science education.

The continued interest in the public's attention to the United States ranking on international assessments presents another issue for which the influence of national standards would be considered. One of the insights from higher achieving countries is the coherence of their school science curricula and assessments. Continued attention to national standards will serve to increase coherence among the central components of science education. This view builds on the long-term positive benefit of the standards. The national standards do emphasize teaching science as inquiry and this approach holds the possibility of addressing several of the important outcomes that are consistent with recommendations from business and industry–understanding systems, solving complex problems, developing critical thinking, and using evidence as the basis for decisions, (BSCS, 2007).

Finally, there are emerging concerns about America's economic competitiveness and the need to prepare a 21st century workforce. Here too, national standards could provide a valuable influence as we consider the needs and appropriate responses for science education.

As I was completing this essay two recent statements underscored the need for national standards. On 4 May, *Science* had a brief article on the National Science Board report on STEM education. With the headline, "Report Urges More Coordination to Improve Science and Math" the report suggested the need for national standards. And on 8 June, *The New York Times* carried an article on the release of a U.S. Department of Education report that measured the extent of differences among states' academic standards. The headline, "States Found to Vary Widely on Education" and the articles first sentence, "Academic standards vary so drastically from state to state that a fourth grader judged proficient in reading in Mississippi or Tennessee would fall short of that mark in Massachusetts and South Carolina…" tell the story. For me, both of these articles make the case for national standards and the need for well designed instructional materials and assessments (Bybee, 2006, Bybee and Ferrini-Mundy, 1997).

At the same time the Secretary of Education published an editorial in the Washington Post (9 June 2007), in which she argued that national standards would "lower the academic bar" and do little to "address the persistent achievement gap." I argue just the opposite. National standards could raise the academic bar for states and still leave them with the freedom to select materials and provide professional development to achieve higher levels–for all students.

In this brief article I have discussed the influence of national standards for science education. They have provided a central focus for conversation and debate about essential issues and served as a foundation for science education policies, programs, and practices. My conclusion is that the national standards have had and will continue to be a positive influence on science education in the United States.

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Insights: An Elementary Hands-On Inquiry Science Curriculum

Karen Worth

Introduction

Insights: An Elementary Hands-On Inquiry Science Curriculum is a comprehensive science program designed to meet the needs of all children, while especially addressing those of urban students. It entered the market in 1994 as one of several inquiry-based curricula that resulted from a renewed focus on curriculum development by the National Science Foundation. In 2003, Kendall Hunt Publishing Company released a second edition of *Insights* that reflected the growing awareness of the importance of literacy in science and the need to provide even greater clarity for teachers about the conceptual structure of a unit. The *Insights* curriculum has been translated into French and Spanish and is used in France, Colombia, and a number of other countries. It has also been adopted in states and districts across the United States as a full K–6 program or as part of a unit-based program.

Development Process

The *Insights* curriculum drew from the growing body of research on teaching and learning. It built directly on the work in science education of the 1960s, in particular the Elementary Science Study (ESS) developed at the Education Development Center, Inc (EDC) under the leadership of MIT physicists Gerald Zacharias, Philip Morrison and Kenneth Friedman and in collaboration with educators and other scientists. The curriculum also reflects careful attention to the teaching of science in urban settings where many students are English language learners and many are from poor and minority homes. Responding to the research on specific instructional strategies that increase the success of these students, the *Insights* curriculum includes: direct exploratory and problem solving experiences with materials; an emphasis on relevance to the lives of students; extensive use of oral language; cooperative and team learning; and the inclusion of role models reflective of the racial, gender, and cultural make-up of the student body.

Insights was developed by a team of science educators at EDC in collaboration with teams of 10–12 teachers from four urban and one suburban school district. The teachers in these teams shared their classroom knowledge and experience at every stage of the development, from initial brainstorming to piloting to field-testing. The curriculum also benefited from the guidance and expertise of a distinguished panel of scientists, science educators, teachers, cognitive psychologists, and school administrators.

Critical to the development process was the work of the Center for the Study of Testing, Evaluation, and Educational Policy (CSTEEP) of Boston College. As evaluators of the project, members of CSTEEP worked alongside the development team, assessing the modules in terms of student outcomes and teacher usability and satisfaction. The assessments designed to measure student growth in the pilot–and field-testing were ultimately adapted as assessments for the modules themselves and are included in the Teacher's Guides.

Goals and Philosophy

The philosophy and goals of the *Insights* curriculum are based on the most current cognitive research on how children develop understanding of the world around them; the knowledge and experience of master teachers in creating environments for successful learning; and the consensus across the country, as expressed in the *National Science Education Standards*, of what science is important for elementary students to know and to understand.[1] The program reflects a belief that children construct their knowledge by building on or modifying the understandings they already have in place. It recognizes that children come to school with a lifetime of experience, knowledge, understandings, interests, and questions and that they must have learning experiences that are intrinsically interesting, relevant to their lives, and appropriate to their age level. The goals and philosophy support a view of teaching and learning as interactive processes with balances between: teacher-initiated and child-initiated activity; concrete explorations and the making of meaning through reflection, discourse and writing; and group and individual work. The philosophy and goals also are based on a view of science as a process of in-depth exploration of phenomena of the natural world and the development of meaning based in evidence.

The Modules

The 21 modules of the *Insights* curriculum are grouped into four levels, three of which span two grades: K–1, 2–3, 4–5, and 6. Each module is a six- to eight-week (if science is taught two to three times a week), in-depth study of one topic and a small number of concepts. Used together, the modules form a core curriculum for the elementary grades. Within each grade span, they may be arranged in a variety of ways to meet specific district or state guidelines. Common threads provide conceptual continuity and a gradual development of ideas and inquiry skills. Chart 1 shows all of the *Insights* modules.

Each module consists of a Teacher's Guide, and a kit of materials with student notebooks and selections of trade books available. There are no student texts. The module Overview is the starting place and provides an introduction to the unit. Included are the

Chart 1: The *Insights* Curriculum Modules

	K/1	2/3	4/5	6
Life Science	Myself and Others The Senses Living Things	Growing Things	Bones and Skeletons	Human Body Systems
Earth and Space Science	The Weather	Habitats Earth Materials	Reading the Environment The Earth, The Sun, and the Moon	There Is No Away
Physical Science	Balls and Ramps	Lifting Heavy Things Liquids Sound	Changes of State The Mysterious Powder Circuits and Pathways	Structures Music to My Ears

[1] It is interesting to note that this curriculum was written prior to the National Standards. No revision of content was necessary to align the curriculum with the Standards. However, because of its commitment to developing conceptual understanding of significant concepts, the Insights program does not attempt to cover all of the standards. To do so would sacrifice depth to coverage.

specific goals, and summary of learning experiences, the alignment with the *National Science Education Standards*, the curriculum frameworks (see below), a number of specific instructional strategies (e.g. working in groups, using notebooks, addressing diverse student needs; and basic management strategies.) This is followed by detailed guidelines for each of the 12–20 learning experiences in a module that provide an overview of the experience, specific conceptual and inquiry skill goals and assessment strategies, suggested time frame, list of materials needed, science terms, and advance preparation. Each learning experience also includes Home-School work suggestions. In contrast to traditional homework, these assignments are to be done by the child and an adult thus "bringing the science home" and they focus around questions and investigations that can be done in the home and community.

Science notebooks play a significant role in the Insights curriculum as records of student investigation and ideas. For teachers and students beginning to do inquiry based science there are structured student notebook pages and group recording sheets which are gathered together along with blank pages in a student science notebook, which can be purchased along with the materials. For teachers, there are guidelines and suggestions for how to encourage student writing about their work. Experienced teachers have found these structures to be stepping stones toward the ultimate goal of having students construct their own notebooks.

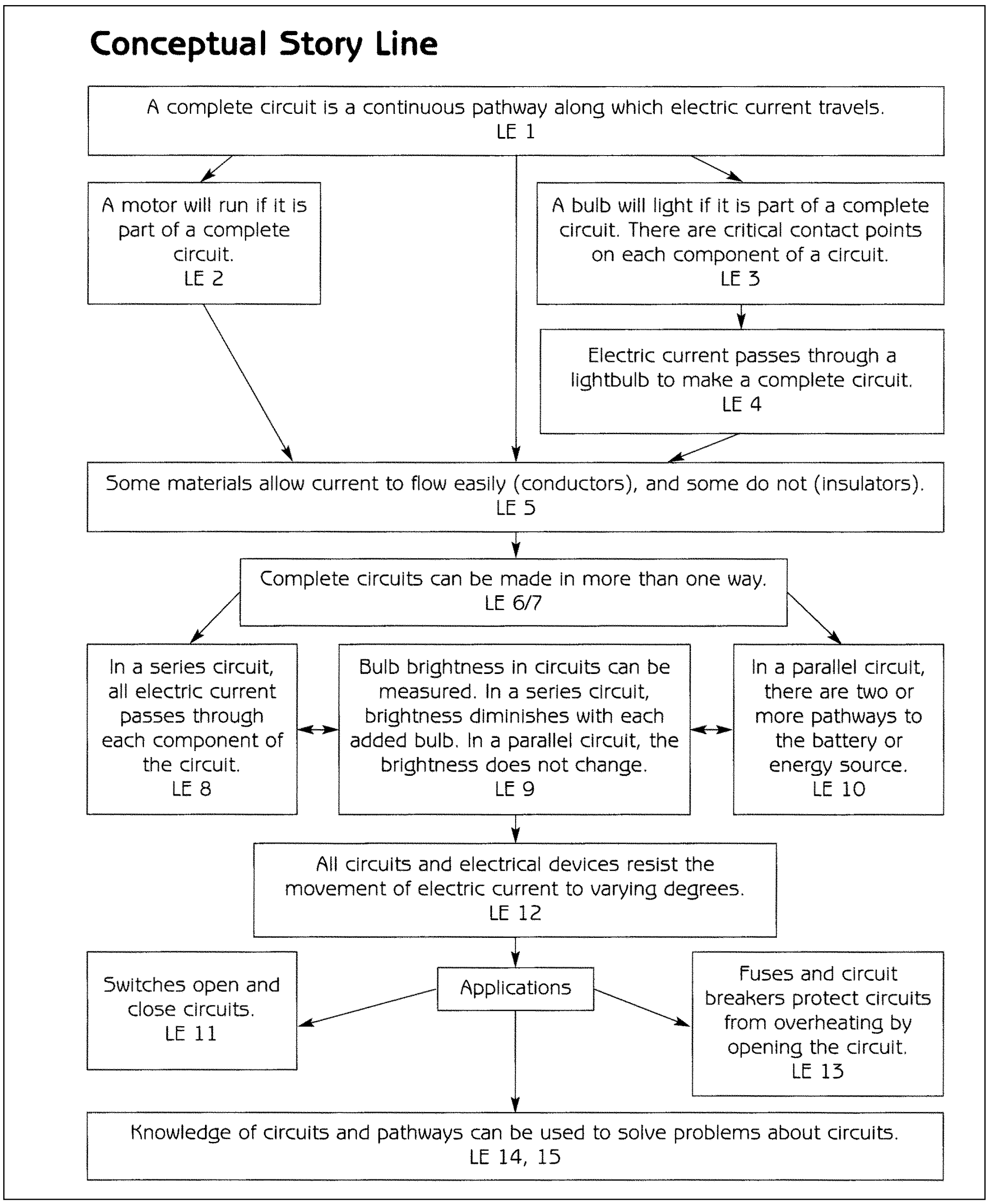
Curriculum as Professional Development

Professional development for teachers in teaching inquiry based science is absolutely critical. Curriculum by itself cannot substitute for long term effective professional development. However, curriculum can play an important role by providing teachers with guidance in its use and by making the design of the modules transparent. The *Insights* curriculum was intentionally designed to assist teachers as much as possible. The teacher's guide and the accompanying materials provide all that is necessary to implement the modules. Extensive guidance is included for preparation, structuring, and moving through each learning experience. But the modules also are designed to help teachers understand and feel more comfortable teaching science through inquiry in general and to develop their understanding of science curriculum design by laying bare the structures of the module and the thinking behind its development.

A Science Background section is especially useful to teachers with little background in science of the particular topic. It is a clear and easy to read overview and gives teachers some of the necessary science to teach each module. Each module also includes a resource section with books and other resources for students and the teacher.

Structural Elements

The conceptual storyline is one of the most important elements of the Insights Teacher's Guide. It provides teachers with a clear understanding of the sequence of concepts and how the student experiences build on one another. An example from the module Circuits and Pathways is reproduced here.



Science Teaching-Learning Framework

Phase 1: Getting Started

TEACHER	STUDENTS
probes for current knowledge and understanding	*share ideas*
motivates and stimulates	*raise questions*
sets challenges and poses problems	*make connections*
	predict
	set goals

Phase 2: Exploring and Discovering

TEACHER	STUDENTS	COOPERATIVE GROUPS
observes	*observe*	*discuss ideas*
facilitates	*explore*	*divide, share, and complete tasks*
mediates	*collect data*	*prepare reports*
assesses	*compare*	
	organize	
	question	
	problem solve	
	interpret and analyze	
	communicate	

Phase 3: Organizing and Processing for Meaning

TEACHER	STUDENTS
questions	*organize*
guides students	*evaluate*
assesses student understanding	*problem solve*
	use models
	interpret and analyze
	synthesize

Phase 4: Applying and Extending Ideas

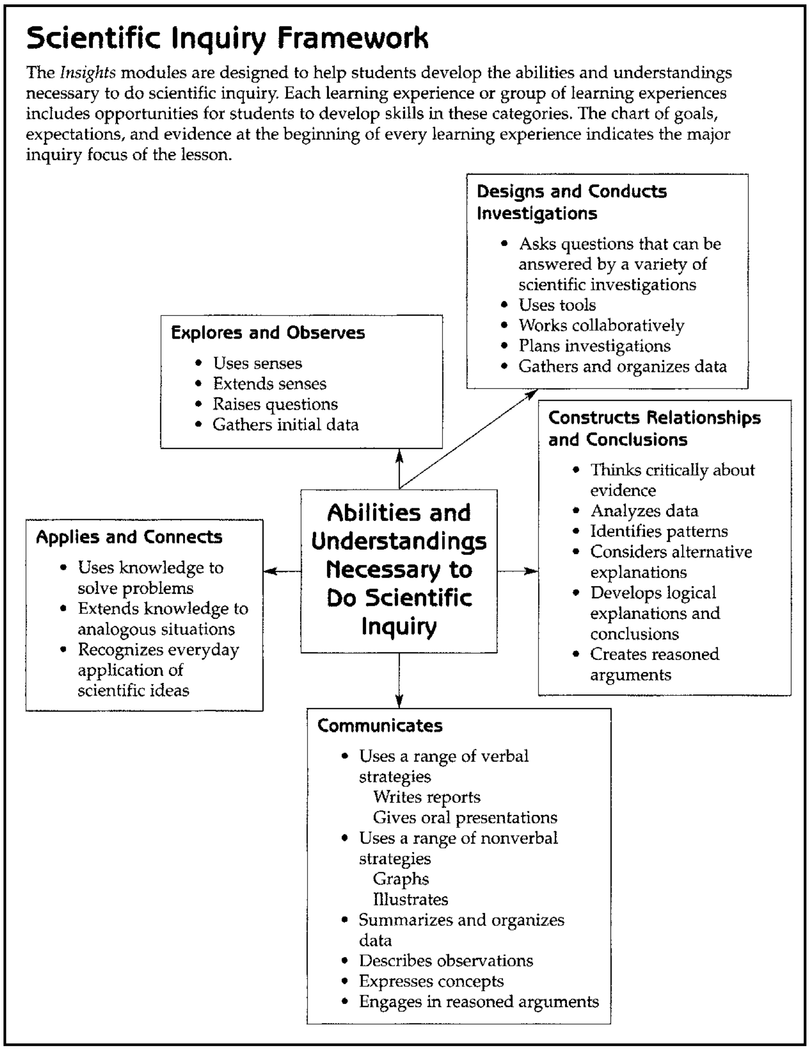
TEACHER	STUDENTS
facilitates	*apply*
assesses student understanding	*integrate*
	question
	infer
	create and invent

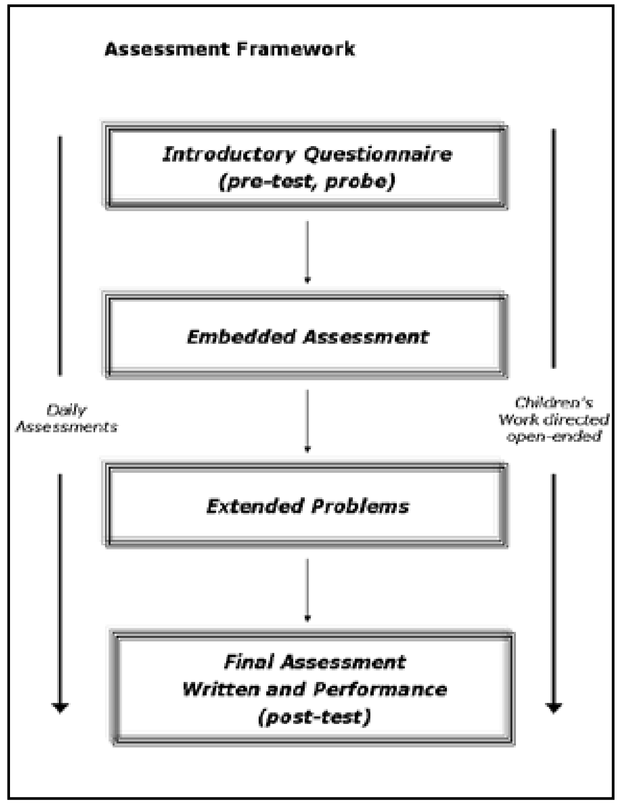
Guiding the structure of the module as a whole and the individual learning experiences are two basic frameworks: one for teaching and learning and the other for scientific inquiry. They are reproduced here.

Finally, the *Insights* assessment framework deserves special mention. Hands-on inquiry teaching is a constant interplay between providing students with opportunities to learn and assessing their growing understanding and skills. Each *Insights* module begins with an Introductory Assessment of open-ended questions that allows teachers to assess the knowledge the students bring to the topic and gives students the opportunity to share what they know. There is at least one formal embedded assessment in each module. It is designed as a learning experience where the teacher takes on the role of observer, circulating among the groups, observing which skills the students have mastered and which skills need further work.

At the end of the module, a Final Assessment measures students' growth and change over the course of the module. It consists of two-parts: the Performance Assessment and the Final Written Assessment. The Performance Assessment consists of a pre-planned, hands-on task or tasks. Students demonstrate their development of abilities and understandings necessary to do scientific inquiry and their understanding of concepts by applying these skills and knowledge to a problem and explaining what they did and why. This type of performance assessment probes students' depth of understanding and demonstrates their ability to apply their learning. The Final Written Assessment often includes questions from the Introductory Assessment for comparison purposes.

Ongoing observation is critical for providing the teacher with information on student progress so that daily adjustments are possible. Assessment questions in each learning experience, as well as guidance in looking at student work provide continu-





ous data to aid teachers in finding out how students are making sense of their science experiences and their growth in the use of inquiry skills. Each learning experience includes two to three of these assessments, set off with checks. Every module has charts on which to record assessment information and build a cumulative picture of student growth in concepts and skills.

Closing Thoughts

Inquiry based curricula such as Insights are not in use in the majority of elementary classrooms across the country. There are many reasons for this including the impact of testing and the current extraordinary emphasis on literacy and mathematics at the expense of all other subjects. But another important reason, more within the control of educators at all levels, is the lack of public understanding of science and the process of scientific inquiry. All the lay constituencies of public education–parents, state and national policy makers, school board members, members of the general public- have little understanding of the nature of science and scientific inquiry and thus either place little emphasis on science education or, more problematically, demand outcomes that are heavily focused on facts and information. In addition, elementary teachers who tend not to have strong science backgrounds themselves do not resist a marginalization of science or science teaching based in text. While not uniformly true, it is certainly fair to say that the experiences people have with science in high school and college- lectures and formulaic labs–is a significant part of this problem. If all students in secondary and higher education experienced inquiry based science learning as are children who experience Insights, teachers, school system administrators, parents, and policy makers, and the general public might have a different view of what science teaching and learning should be at the elementary level. The higher education community and, in particular, those who teach science courses, need to take on this challenge.

For further information see: www.kendallhunt.com and http://cse.edc.org/curriculum/materials.asp or contact kworth@edc.org.

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Changing the Course of Science Education

Jennifer Childress, Jim Benson, Claudia Campbell, and Sally Goetz Shuler

Would you send novice scientists into their laboratories and immediately tell them to create their own protocols and tools or to use an uncalibrated oscilloscope? The work of even the best scientists would be stifled by using faulty equipment or spending half of their time developing their own. The same applies to surgeons. And teachers. However, unlike beginning scientists and doctors, many new teachers *are* required to develop their own protocols and provide their own tools, or to use an uncalibrated tool–namely, a textbook.

This problem has existed for decades, as highlighted in the 1983 report "A Nation at Risk," which called attention to shortcomings in U.S. mathematics and science education. In response to this report, the National Academies and the Smithsonian Institution established a new organization in 1985–the National Science Resources Center (NSRC)–to improve the learning and teaching of science for all students in the United States and throughout the world. Using the resources of its parent institutions and the research on student learning, the NSRC has developed comprehensive programs to redesign and improve science education, including systemic leadership and professional development, and the research-based curriculum *Science and Technology Concepts*® (STC®) PROGRAM. Curriculum programs of this type represent the calibrated tools that teachers and students need to become scientifically-literate citizens and competitive members of the 21st century workforce.

Linking Research to Curriculum Development

There is an impressive body of research about the learning process, and cognitive scientists have a great deal of evidence about what is needed for effective learning to take place. In particular, this research has established three fundamental principles of learning, outlined as follows in How Students Learn: Science in the Classroom.[1]

1) Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.

2) To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual frame work, and (c) organize knowledge in ways that facilitate retrieval and application.

3) A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.[1]

To illustrate the first principle, we can examine a survey of Harvard graduates on their graduation day. When asked the ques-

Figure 1

The STC PROGRAM

Grade Level	Life and Earth Science		Physical Science and Technology	
Science and Technology for Children (STC				
K–1	Organisms	Weather	Solids and Liquids	Comparing and Measuring
2–3	The Life Cycle of Butterflies	Soils	Changes	Balancing and Weighing
	Plant Growth and Development*	Rocks and Minerals	Chemical Tests*	Sound*
4–5	Animal Studies*	Land and Water*	Electric Circuits*	Motion and Design*
	Microworlds*	Ecosystems*	Food Chemistry*	Floating and Sinking*
6	Experiments with Plants*	Measuring Time*	Magnets and Motors*	The Technology of Paper*
Science and Technology Concepts for Middle Schools (STC/MS)				
6–8	Human Body Systems	Catastrophic Events	Properties of Matter	Energy, Machines, and Motion
	Organisms—From Macro to Micro	Earth in Space	Light	Electrical Energy and Circuit Design

*STC BOOKS™ literacy supplement is available now, or will be available by fall 2007.

tion "where does all the mass of a tree come from?" most of the graduates replied that it must be derived from water and minerals from the soil[2]. These young adults can state the principles of photosynthesis on tests, but have never fully understood its concepts. Their preconceptions of the mass of CO_2 in the air and carbon's role in providing much of the mass of a tree hinder their application of the principles of photosynthesis to real-life problems.

To be effective, an educational program must incorporate all three of these principles of learning. It can accomplish this by following a four stage learning cycle:

1. **Focus** on student preconceptions and ideas;
2. Allow students to **explore** scientific questions with experimentation;
3. Encourage student **reflection** through data analysis and communication; and
4. Provide opportunities to **apply** new knowledge in new contexts and real-life situations.[3]

Curriculum programs that follow this type of learning cycle have been tested and used throughout the world, and a large body of evidence suggests that students in these programs perform better on standardized tests and tests of critical thinking and problem solving skills than do students taught in a traditional textbook-based classroom.[4-8] One such curriculum is the *Science and Technology Concepts* STC PROGRAM®, which was developed by the NSRC as part of its portfolio of services to the educational community.

Translating Research into Effective Learning Experiences

The NSRC developed its 32-unit K–8 curriculum program over more than a dozen years. The 24 elementary units–*Science and Technology for Children*® (STC®)–were published between 1991 and 1997. The eight middle school units–Science and *Technology Concepts for Middle Schools*™ (STC/MS™)–were published from 2000 to 2004. Some STC/MS units are also used in high school, up to the tenth grade level. These six- to twelve-week-units are designed to be increasingly cognitively demanding for students as they progress through grade levels and through individual units. The units follow a learning progression that is intended to build a foundation for continued, lifelong learning. See figure 1.

The STC PROGRAM is based on research that suggests that children learn science best through concrete, usually hands-on experiences as part of a learning cycle. Educational activities should relate directly to children's understanding of the world, with students investigating scientific phenomena firsthand. STC PROGRAM units provide students with opportunities to learn age-appropriate concepts and skills and to acquire scientific attitudes and habits of mind. The curriculum's design allows students to work independently as well as cooperatively to conduct and design investigations; ask questions; make and test predictions; record, reflect on, and share their findings; and apply the skills and knowledge they have gained to new situations.

The primary goals of the STC PROGRAM are to:

- Contribute to students' conceptual understanding of science at a level that is appropriate to their stage of cognitive development;
- Help children develop scientific attitudes and habits of mind, such as curiosity, respect for evidence, the capacity for critical reflections, flexibility, and respect for living things;
- Develop students' scientific reasoning and critical thinking; and
- Align with the National Science Education Standards of the National Research Council.

The assessments that are part of each STC PROGRAM unit provide guidance to teachers in how to document and evaluate student learning. Clearly defined goals, with corresponding performance-based assessments, can be found in a chart at the front of each teacher's guide to facilitate teacher assessment of student learning. Each unit also offers a post-unit assessment as well as an appendix of final assessments.

The NSRC has also developed a literacy complement to 16 of its elementary units. (See figure 1). These books help teachers link students' science activities to other areas of the curriculum, particularly history, language arts, and social studies. They provide an excellent means of meeting the National Research Council's National Science Education Standards, as well as most science standards. And they are unique in that they highlight work being done by scientists at the world's foremost museum complex–the Smithsonian Institution.

Everything needed to teach NSRC science courses–teacher's guide, student books, and equipment and materials–is available from the NSRC's publisher, Carolina Biological Supply Company.

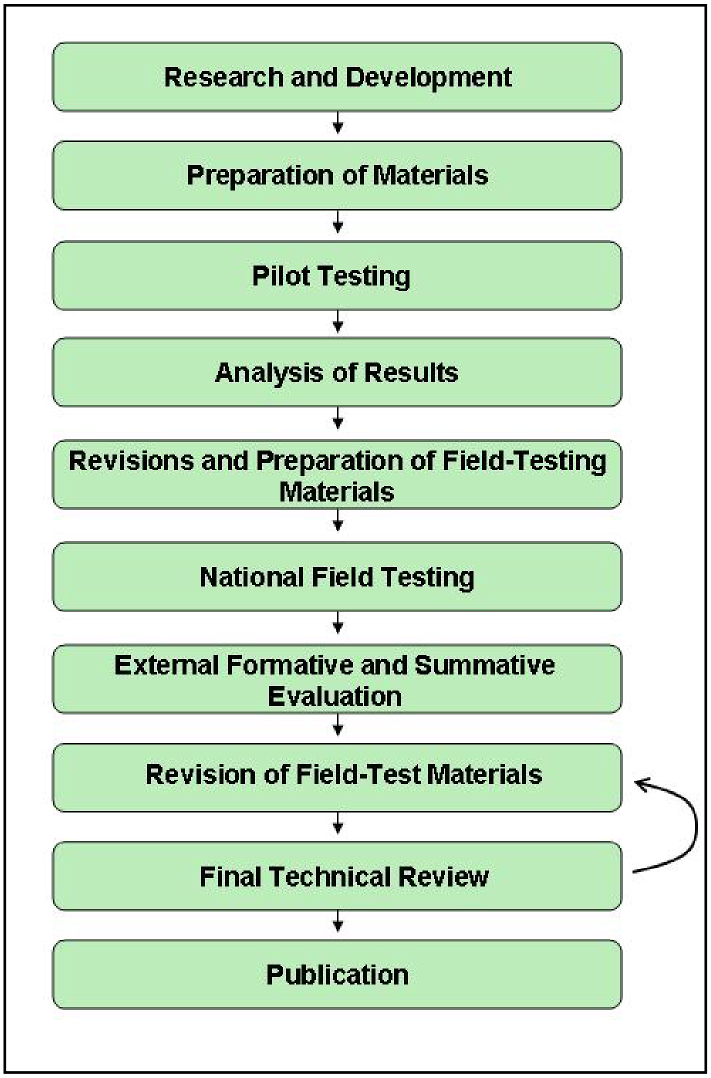
Ensuring the Quality and Integrity of Instructional Materials

As part of an NSF-funded initiative, each of the STC PROGRAM units was developed using a rigorous process that ensured scientific accuracy, age-appropriate content, and pedagogical appropriateness. See figure 2.

As its first step in curriculum development, NSRC staff collected the research and best practices in science education, and brought together an advisory panel composed of external experts in different areas of science and pedagogy. The NSRC and the advisory panel researched and developed each of the curriculum units according to a protocol established with the assistance of evaluation consultants whose job was to ensure objectivity. They then prepared a preliminary outline of learning experiences to be included in each new unit.

The next step was to pilot test each unit in a school in the Washington, D.C. metropolitan area. Based on feedback from this ex-

Figure 2. The STC PROGRAM Research and Development Process



perience the NSRC team, with input from the advisory committee, evaluated and modified materials and procedures throughout the piloting process. NSRC staff then prepared field-test editions of units for use in 12 to 15 classrooms in regionally distinct areas of the country. Field-test classrooms were selected to represent varied demographic and socio-economic populations. Using information obtained from teachers and students at field-test sites, comments from members of the STC Advisory Panel, and formal reports from STC evaluators, the NSRC revised the field-test editions of the units to prepare them for final production.

Developmental Feedback. As part of NSF requirements, the NSRC developed a comprehensive evaluation plan to evaluate the STC PROGRAM materials with the assistance of the Program Evaluation and Research Group at the Lesley College Graduate School of Education in Cambridge, Massachusetts, and the Educational Testing Service. The evaluation plan defined strategies for assessing each phase of materials development, from the testing of initial ideas to the preparation of materials for publication.

In their review of the field-test editions, the evaluation consultants focused on the assessment instruments that are an integral part of each unit to ensure that they were developmentally appropriate and accurately reflected the NSRC's goals.

Like all other areas of science, our understanding of the learning process and cognition deepens and changes over time. As it does, the STC curricula are continually revised to ensure that students are receiving the best education possible.

Developing the System for Large-Scale Implementation

Although research-based curriculum is the basis for a sound science program, exemplary curriculum alone is insufficient to support effective science learning and teaching. To establish an effective infrastructure to support learning, leaders within a school district, region, or state must have or develop a shared vision of effective science learning and teaching and implement five essential components simultaneously. The NSRC has defined this system as the NSRC Theory of Action, depicted here.

Components of the system include:

- **A curriculum framework and comprehensive research-based science instructional program** based upon research findings;
- **Teachers participating in professional development programs** that are aligned with current research about adult learn ing designed to move teachers from novice to expert;
- **Assessments that are aligned with research about how students learn** and that elicit meaningful developmental feedback about student learning;
- **Cost-effective and efficient systems that supply resources and materials** to teachers; and **Administrative and community leaders who provide long-term support** for research-based science learning and teaching.

The NSRC provides assistance in implementing all of these strategies, beyond providing research-based curricula. National and regional Building Awareness Symposia bring together leaders from industry, engineering, science, government, and the educational community to inform them about and engage them in research-based science education improvement.

National and regional Strategic Planning Institutes assist local school district leadership teams–including a local scientist–in developing systemic, strategic plans for science education in their district. The leadership teams that participate in these institutes are exposed to several research-based curriculum programs, including but not limited to the NSRC's STC PROGRAM. Most of the school districts that have participated in these institutes have since adopted research-based curriculum units for use in their science classrooms.

Another component of the NSRC's leadership development portfolio is a world-class professional development program for teachers and scientists. The NSRC works with administrators and other local leaders to assist them in developing their ongoing professional development system, moving teachers from novice, to competent, to expert.

Recognizing the Ongoing Challenges to Research-Based Reform

Many challenges remain for science education in the United States. Most states use high-stakes tests that test only low-level learning skills, such as recitation, while ignoring the critical thinking skills that will be essential to life in the 21st century. Teachers are pressured to teach to these low-level tests, thereby reducing their emphasis on teaching real understanding of science. These tests are designed to match the state science standards, many of which do not align with the national standards or with the research on learning and teaching.

A second challenge for education redesign and improvement is that many teachers are unable to remain in one school district, teaching one age group, for as long as it takes to become an expert teacher. Ongoing teacher training in content and age-specific pedagogy is essential for students' academic success. When expert 6th grade teachers are transferred to a kindergarten class, for example, they become novices once more. The constant teacher turnover in American schools puts even more strain on an already overwhelmed professional development system.

The NSRC has found that it takes at least seven years for an entire community to shift its values on education, train leaders, fully implement a new way of learning and teaching, and see the outcomes of the new educational system. That time span creates another challenge for proponents of research-based curriculum materials–results are often demanded almost immediately by elected officials and business investors.

Conclusion

The National Academies and the Smithsonian Institution tasked the National Science Resources Center with changing the values around good learning and teaching in our country. Over the last 22 years, the NSRC has done this, creating discriminating consumers that demand rigorously tested curriculum materials based on education research. Today, about 22% of our nation's students have been educated in some form of research-based science programs, and that number is growing rapidly. The NSRC's vision is that all students in this country and throughout the world should be taught by competent teachers using world-class materials in a supporting environment.

The NSRC invites you to learn more about the research behind science education and to get involved in improving the education programs in your local school district, state, or region. Because the principles of good learning and teaching apply not only to elementary and secondary schools but also to undergraduate, graduate, and adult education, this research can inform your work in any sector of the workforce. Contact the NSRC at nsrcinfo@si.edu or visit the web at www.nsrconline.org to learn more.

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Water Skiers and SCUBA Divers

By Larry Malone

There are a couple of things amiss in American science education. First, we teach too much. Second, we teach too little. The "too much" is related to the unrealistic burden of science content proscribed in typical science standards. The "too little" is related to the depth of understanding students acquire from a survey approach to science instruction designed to "cover" the standards.

I was recently involved in a summer institute at the National Weather Center in Norman Oklahoma. We were preparing middle school science teachers to teach content that appears on numerous earth science standards around the country. The standards predictably include a menu of topics and concepts related to weather: atmosphere, wind, cloud formation, water cycle, and seasons. We could have presented the topic in a day, discussing the structure of Earth's atmosphere, naming winds, describing the conditions that produce clouds, reciting the traditional stations of the water cycle, learning the reasons for seasons. Like water skiers, the teachers would have skimmed rapidly across the surface of the content, pulled along by the powerful engine of coverage. At the end of the day, had the teachers managed to hold on tightly and concentrate, they may have acquired a substantial quantity of descriptive information about weather, possibly without even getting wet.

But we didn't. Instead we took a week and dove into the science of weather. We went deep below the clouds and thrashed around in the dangerous currents of the kinetic model of matter and energy transfer. As we pushed deeper into fundamental elements of weather—heat, clouds, precipitation, wind, storms—we found ourselves grappling with interactions between matter and energy. To understand weather, an earth science topic, we had to study physics.

Teaching for Conceptual Understanding

This approach to the study of weather is conceptual, not descriptive. In a conceptual curriculum, we are not satisfied with what happens; we strive to understand what makes things happen. For example, when a puddle of liquid water is exposed to the environment, it dries up—evaporates and disappears. That's descriptive; that's what we see. What we don't see are the interactions at the molecular level that explain what happens to the water and where it goes. Models of molecular kinetic energy, energy transfer, phase change, density, and conservation fit together like puzzle pieces. When the pieces are carefully assembled in meaningful ways, students construct a robust concept of water changing from liquid to gas, one molecule at a time, and entering the air. The water doesn't disappear, it decamps and enters the company of other molecules in the air, assuming a new identity (vapor) with new properties. In a conceptually oriented curriculum, evaporation ceases to be an event, it becomes a process—a process that has explanatory power in countless situations.

I have spent more than forty years developing elementary and middle school science curricula. The last 20 years have been devoted to the Full Option Science System (FOSS) program <www.fossweb.com>. FOSS provides research-based, active-learning experiences that teach important ideas about the natural world. During a lifetime of professional conversations with teachers and scientists, authentic interactions with students in classrooms, continuous redesign of the curriculum, and close collaboration with our publishing partner, Delta Education <www.delta-education.com>, we have made substantial advances in our understanding of the elements of good science instruction. Of the many lessons learned over the years, one stands out in stark relief: conceptual learning is hard for students and conceptual teaching is challenging for teachers.

Time and Timing

Conceptual learning requires substantial commitments to authentic engagement with scientific phenomena and intellectual energy. Both require time. And time is the most valuable commodity in education. In FOSS we think of concept development as a progressive, iterative cognitive process. First students experience a phenomenon that inspires interest and motivates exploration. The activity of interacting with, observing, and discussing the behaviors of objects, organisms, and systems provides sensory input to the brain. The process of stimulating neurons and activating neural pathways is learning. After the brain has assimilated the new input, it forges the bits into relationships, principles, and concepts in a social/cognitive process often referred to as constructivism. The constructed products are knowledge. Scientific concepts are some of the most highly valued classes of knowledge. Knowledge, however, is of limited value unless it is functional, that is, can be applied to explain a new phenomenon or create new knowledge. The ability to apply knowledge advances the learning to the level of understanding.

Effective conceptual teaching, however, must consider another dimension of time–the appropriate time in a student's academic career. The level of abstraction and complexity of a concept should be coordinated with the cognitive development of students. And, the sequence in which students encounter concepts is important, as some concepts are prerequisite to others. For example, the concepts of mass and volume should precede the introduction of density. When the conceptual challenge is interesting and the timing is appropriate, students engage the topic with zeal. Even so, mastery of the concept takes time. This applies to kindergartners trying to figure out why one wood block needs nine paper clips to sink while another identicalsized block sinks with only six paper clips on board, as well as research meteorologists pondering what triggers lightning to strike or what causes a thunderstorm to collapse in a heat burst.

Physics First

Some issues in science education are wrangled over endlessly: which came first, the chicken or the egg?; if everything is matter or energy, what is shadow?; what should be taught first, physics or...? Unlike the first two questions, the question of when to teach physics has stubbornly resisted consensus. For me, however, the answer is straightforward: physics first. By first, I mean first grade. Physics is too large and too important to postpone until high school. Physics is the branch of science that provides the anchors against which the other disciplines pull for explanatory models and confirmation. Where the positioning of physics in the high school curriculum escalates to the level of a philosophical battle, it may indicate that opportunity has already been missed. To me physics first means start with the five- and six-year-olds, spending quality time guiding them to experience and describe the properties of objects and materials, and to discover what happens when they interact. Then comes physics second, moving students into operational experiences with force and energy–magnets, bulbs, sounds, pushes and pulls. Follow this with physics third, discovering relationships between interacting objects and systems. And then physics fourth, with the introduction of the particulate nature of matter and the conditions under which matter experiences transformations. Physics fifth brings an introduction to mathematical models and a new logic for displaying, thinking about, and explaining phenomena. In this scenario, as students enter high school, the notion of physics first has lost its gravity. Too late for physics first, just the next level of the encounter and new concepts to deepen an already substantial body of physics knowledge.

Making the World Safe for Conceptual Science

If trying to teach too much results in teaching too little, what can be done? As always, it depends. Two factors stand out as impeding factors: accountability testing and systemic anarchy. The first affects early science education most dramatically. No Child Left Behind has leveled it sights on literacy and mathematics performance. In the rush to achieve Adequate Yearly Progress scores, science has gotten trampled. Typically, primary students receive a few minutes of science instruction per week; intermediate students less than two hours. You can't even water ski if the boat doesn't leave the dock. As a result, science instruction essentially starts in the middle grades, and that is too late.

The systemic anarchy stems from the fact that science standards are developed by states. This results in a particularly incoherent national policy for science education. What has emerged is a de facto competition between states to produce the most rigorous, most comprehensive catalog of standards for each grade level. It is daunting to imagine water skiing at the speed required to cover the expanse of content suggested by the standards.

In order to teach for conceptual understanding, we will have to proceed more slowly and reach for greater depth. This means teaching fewer topics, an idea that makes educrats gasp. But teaching less will provide students with a far better understanding of science, preparing them better for both advanced study of science and thoughtful, engaged citizenship. Teaching less would require a minor but important change in testing policy. States could keep their comprehensive standards in place, but school districts would choose which science topics to teach, and then teach them in depth. The district would declare which standards their students will be accountable for, and the state would provide a test that examines those topics. The test could then probe for deeper content knowledge as well as functional understanding of the particular habits of mind that characterize the scientific enterprise.

Accountability is a thorny issue. The fates of teachers and schools ride on students' performance on state-authorized tests in the areas of language arts and math. At the elementary level, poor performance can result in teacher dismissal and school restructuring. Consequently, schools allocate most of their instructional resources to reading and writing. The content subjects–science, social studies, physical education, and the arts–lose out to skill development. Accountability under NCLB in science is still half a decade in the future unless science testing is mandated earlier when the law is reauthorized in 2008. Some forward-looking states and school districts are teaching and testing science, but even in these places there are no consequences for weak student performance in science. Sea changes in science education will require significant policy shifts at the highest levels, accompanied by incentives and coherent guidelines for world-class science teaching and learning. In the meantime, high-quality science instruction will thrive only in isolated locations with insightful leadership. While elementary science languishes generally, I, and my like-minded colleagues, continue to work diligently to help concerned educators around the country create a vision of deep conceptual science learning and implement it in their schools and districts.

In Summary

Some years ago Mesa Arizona performed a sweet little informal assessment of their science program. Mesa had diligently implemented an active-learning science program that was subscribed to by about half of the elementary schools in the district. When the sixth graders advanced to junior high school, they were presented with a menu of options for "elective" courses. Science was one of the electives. When the electives were tallied, more that 95% of the students from active-learning schools chose science. Fewer that 5% of the students from schools with traditional textbook-based programs chose science.

Resource Note: FOSS is a comprehensive K-8 science curriculum. The program is designed in three strands–life, earth, and physical science–for each grade level. The content and investigation methodologies increase in complexity as the curriculum advances through the grades.

FOSS K–8 Program Scope and Sequence

Grades 6 – 8 (Thinking processes: Inferring, Relating, Organizing, Comparing, Communicating, Observing)

Life Science	Physical Science	Earth and Space Science
Human Brain and Senses	Electronics	Planetary Science
Populations and Ecosystems	Chemical Interactions	Earth History
Diversity of Life	Force and Motion	Weather and Water

Grades 5 – 6 (Thinking processes: Relating, Organizing, Comparing, Communicating, Observing)

Life Science	Physical Science	Earth Science	Scientific Reasoning and Technology
Food and Nutrition	Levers and Pulleys	Solar Energy	Models and Designs
Environments	Mixtures and Solutions	Landforms	Variables

Grades 3 – 4 (Thinking processes: Advanced Organizing, Comparing, Communicating, Observing)

Life Science	Physical Science	Earth Science	Scientific Reasoning and Technology
Human Body	Magnetism and Electricity	Water	Ideas and Inventions
Structures of Life	Physics of Sound	Earth Materials	Measurement

Grades 1 – 2 (Thinking processes: Beginning Organizing, Comparing, Communicating, Observing)

Life Science	Physical Science	Earth Science
New Plants	Solids and Liquids	Air and Weather
Insects	Balance and Motion	Pebbles, Sand, and Silt

Kindergarten (Thinking processes: Comparing, Communicating, Observing)

Life Science		Physical Science	
Trees	Animals Two by Two	Wood and Paper	Fabric

Developed with National Science Foundation support

Full Option Science System FOSS

Mesa was preparing a scientifically literate student population. Those youngsters entered their middle years expecting to continue their study of science. Doubtless a significant number of those students went on to pursue science and science-related careers. And more important, they had been steeped in science inquiry, able to think effectively about science issues, and imbued with a trust for scientific evidence and respect for the scientific process.

We have an enviable reputation for scientific excellence in this country. American scientists lead the march to the frontier of discovery, and American universities train the most gifted candidates from around the world. But with precollege science education in stagnation, will we continue to be the standard bearer? Consider: at this time there are more honors students in China than there are students in the United States. American economic vitality, prestige, and creative problem solving rest, in part, on the excellence of the science and technology base. The next generation of leadership scientists is in residence in our schools right now. Will they be water skiers or SCUBA divers?

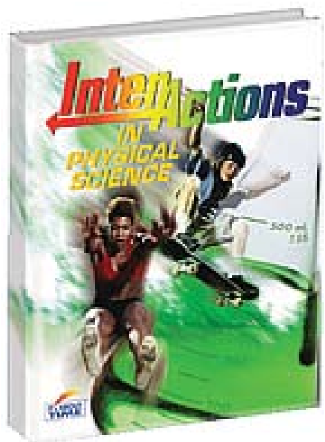
Each module includes a detailed teacher guide, a kit of carefully crafted student materials, original reading materials, multimedia resources, and strategies for integrating science notebooks and assessment activities into the science inquiry. For more information about the design, philosophy, and implementation of the FOSS program, please visit our Lawrence Hall of Science FOSS Website <www.lhs-foss.org>.

Larry Malone is codirector of the Full Option Science System program at the Lawrence Hall of Science, University of California at Berkeley, where he has been engaged in elementary and middle school science curriculum development and professional development for 42 years.

Interactions In Physical Science

Fred Goldberg and Sharon Bendall

Interactions in Physical Science [i,ii], is a one-year physical science course for middle school students. The primary developers of the curriculum[iii] had three main goals in mind: to provide a substantive and coherent physical science course based on both national and state standards; to base the curriculum on a pedagogy guided by recent research on how students learn; and to prepare students for success in their high school science and math courses which would enable them to become scientifically literate citizens. Interactions went through extensive pilot and national field-testing over five years before it was published in its final form in 2006.



InterActions is hierarchical, with topics and skills developed in a structured progression organized around important science themes: interactions, conservation of energy and mass, Newton's Laws, and Atomic Molecular Theory (small particle theory).

As the curriculum progresses, students work to complete wall maps about interactions and energy.

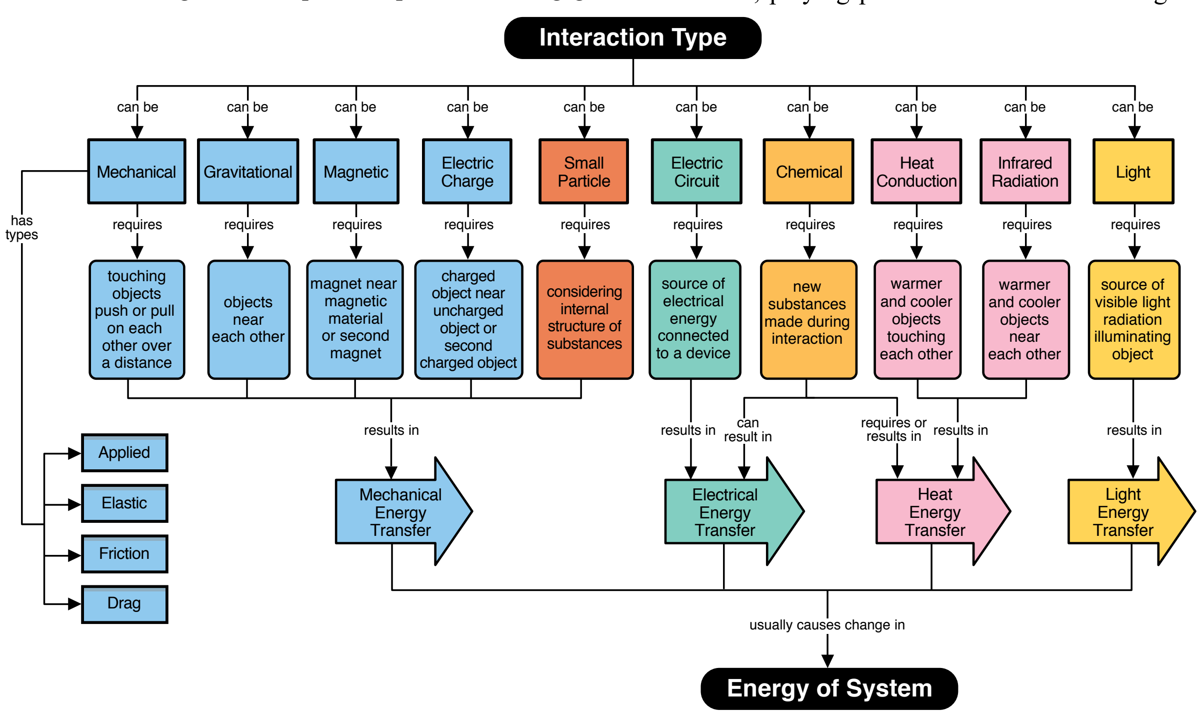
The pedagogy of *InterActions* is based on guided inquiry, with direct instruction occasionally used to extend the ideas covered.[IV] Specific activities are designed to help meet specific learning goals; these are generally particular ideas or sub-ideas included in both national and state standards. Activities are designed and structured around the following general learning principles derived from research on learning:

- Students build new knowledge based on what they already know
- Complex ideas need to be developed over time with appropriate scaffolding
- Student learning is mediated through social interaction
- Students need to practice norms both of science and learning communities: good ideas are based on evidence and involve consensus; and students have respect for others' ideas and take responsibility for their own learning

The curriculum is divided into units and chapters, each chapter consisting of a series of five types of activities based on a learning-cycle approach aimed at developing a set of important ideas.

The most common type of activity is *Developing Our Ideas*. In these activities students share initial ideas, perform hands-on experiments and/or simulation explorations to gather evidence to test their initial ideas, respond to a series of making sense questions to help them connect their developing ideas with their evidence, and then reach a class consensus.

Much of the pedagogy involves students working in small groups. The curriculum provides extensive scaffolding in helping students develop skills at participating in group discussions, following directions, playing productive roles when the group is performing



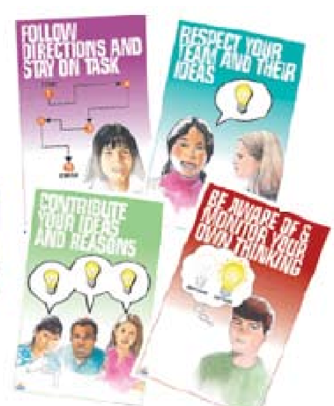
experiments, and monitoring their own thinking. Special posters and prompts within the texts explicitly address these skills.

Experience and research indicate the critical importance of helping teachers understand pedagogy and content development that may be different from their prior experiences. *InterActions* addresses this by providing a three-volume Teacher Guide, a comprehensive online resource with many videos of experiments and good implementations, and an extensive professional development program of workshops and online tutorials. The workshop series consists of seven workshop days over an academic year. In the workshops, teachers do activities from the curriculum and learn how to implement the *InterActions* pedagogy through a series of special activities focusing on understanding both how students learn and the teacher's role in promoting that learning. For further information about the Interactions curriculum, other supporting materials for students (a science fiction reader, a board game, and an engaging website), and the professional development materials, visit http://www.interactionsinfo.net/.

During the development of *Interactions,* two student impact evaluations were conducted. In a 2001 comparison study involving classes using an early version of *InterActions* and control classes (about 2200 students total), the *InterActions* students did statistically better on multiple choice questions and on open response questions on science and nature of science content. In 2004, a Force and Motion content assessment was administered to about 1900 students in 9th grade classes, where about half the students had used *Interactions* the previous year and half the students had used other physical science curricula. Students who had *InterActions* in 8th grade did significantly better on the assessment than students who did not.

Interactions was developed for middle school students. Another project that was inspired both conceptually and pedagogically by *Interactions* was *Physics and Everyday Thinking* (PET) and *Physical Science and Everyday Thinking* (PSET).[v] These two curricula were also developed with NSF support[vi] and are being published by It's About Time. Each is intended to be a one-semester course (75-hours of classroom instruction), appropriate for prospective and practicing elementary and middle school teachers, as well as for college-level students needing a general education physical science course. The PET course content focuses on the themes of interactions, conservation of energy and Newton's Laws. The PSET course, which includes both physics and chemistry, focuses on the same themes plus atomic-molecular theory. Specially designed computer simulators are used extensively in both curricula during class and as part of web-based homework.

Each curriculum uses a guided inquiry pedagogy similar to that used in *Interactions*, and is based on the same learning principles. However, unlike *Interactions*, both PET and PSET also include a series of Learning About Learning activities, in which students are asked to reflect on their own learning, the learning of young children (using videos from classrooms where students are discussing physics and chemistry ideas), or the learning of scientists (the history and nature of science). Substantive on-line teacher guides and separate teacher resource CDs provide information to help faculty implement PET and PSET. A supplementary text also includes material that teachers could use in elementary classrooms.[vii] The results of pre/post conceptual tests during field-testing of both PET and PSET show significant growth in students' understanding of the physical science content. For further information about PET or PSET, visit http://petproject.sdsu.edu/ or http://psetproject.sdsu.edu/.



[i] The development of Interactions in Physical Science was supported by National Science Foundation grants ESI-9812299 and ESI-0138900.

[ii] Published by It's About Time, Herff Jones Education Division. See http://www.its-about-time.com. Early field test versions of the curriculum were called *Constructing Ideas in Physical Science*, or CIPS.

[iii] Fred Goldberg and Sharon Bendall, San Diego State University, Patricia Heller, University of Minnesota, and Robert Poel, Western Michigan University.

[iv] Topics included in state standards but not national standards are typically addressed through activities that include more direct instruction.

[v] PET was developed by Fred Goldberg, San Diego State Uni-versity, Steve Robinson, Tennessee Technologi cal University, and Valerie Otero, University of Colorado-Boulder. PSET was developed by Goldberg, Robinson and Otero, as well as Rebecca Kruse, Southeastern Louisiana State University, and Nephi Thompson, San Diego State University.

[vi] Grant 0096856.

[vii] *Elementary Science and Everyday Thinking* (ESET) consists of a set of activities and associated teacher guides covering several different topical areas in physical science. Many of the activities are similar to the ones that are included in the movies the PET and PSET students view as part of their Learning about Learning activities. ESET is also published by It's About Time.

Fred Goldberg, Professor of Physics, and Sharon Bendall are both at San Diego State University and members of the Center for Research in Math and Science Education. Goldberg was the PI and Bendall a co-PI on the project that developed the Interactions curriculum. Goldberg was also PI of the project that developed PET and PSET.

Active Physics

Arthur Eisenkraft

NASA is planning a moon habitat where people will live for extended periods of time. Recognizing that the colonists must exercise, NASA has asked for physicists to create, adapt or invent a sport that can be played on the moon. The proposal for this moon sport should include a description of the rules and regulations of the sport, a comparison of the laws of physics on the Earth and moon and a newspaper article describing a championship match for this sport for the people back home on the Earth.

This is one of the monthly challenges that high school students get involved with in *Active Physics*. The act of inventing a sport that can be played on the moon would stretch professional physicists, college graduates and high school students. Although we may hold different expectations for each group in terms of the mathematics and detail of the physics principles, all will be involved in learning and applying physics to their solutions.

Physicists may have a good idea as to where they would start in creating a proposal for a moon sport. They probably know something about sports and certainly know both the applicable physics and moon factors (e.g. one-sixth the gravitational field strength of the Earth, no air outdoors, large temperature variations and much smaller than the Earth.) Before reading further, readers may want to pause for a few moments and map out how their favorite sport would have to be modified for play on the moon.

How do high school students who do not know physics or information about the moon succeed in creating the proposal? *Active Physics* guides students and helps them learn and apply physics. The program is built on research results from studies in cognitive sciences[1], student assessment[2], student engagement[3], and problem-based learning[4]. It supports inquiry in the classroom and meets the expectations of the National Science Education Standards[5], the AAAS Benchmarks[6] and state frameworks from across the United States.

The "sports on the moon" unit follows the same format as all of the monthly chapter challenges. After being introduced to the challenge, students develop the criteria that are needed for success on the project. For example, what percentage of points of the final project should go to the comparison of physics on the Earth and moon, what percentage to the rules and regulation of the sport and what percentage to the newspaper article? Furthermore, how many physics factors should be included to earn all credit for Earth/moon physics comparisons? The initial criteria set on day one will be revisited before the final proposal is due. The task of setting the rubric clarifies the requirements and provides a window onto students' initial ideas about the project.

Each physics topic is introduced using a 7E instructional model[7]. Students are asked "What do you see?" in a physics cartoon illustration (drawn by a celebrated MAD magazine cartoonist).

For example, what does the cartoon on the next page tell you? Is this what you would expect on the moon? Is it different than what you experience on the Earth? In the cartoon shown, students can see that it appears to be difficult for someone to push a cart on the moon while it is comparatively easy for someone to lift the same item. The activity will help students explain the differences between mass and weight. The distinction is much easier for students when discussing objects on the moon than a similar discussion for objects on the Earth.

The use of the cartoon engages students while also eliciting their

Figure 1

prior understandings. Research results strongly support eliciting students' prior understandings as an introduction to any lesson. In addition, visual learners as well as English language learners and special needs students are able and willing to participate in class discussions about what they see in the cartoon while these same students become hesitant when asked a verbal question. It has been encouraging to witness increased class participation from the cartoons and disappointing to find that some physics teachers see a cartoon and conclude that this lesson will not include meaningful physics because a cartoon exists.

The "What do you see?" is followed by a "What do you think?" question. In the lesson about friction on the moon, students are asked "How do frictional forces on the Earth and Moon compare?" Their answers reveal what they may remember about friction in general and how they may relate this to friction on the moon. The purpose of this question is not to reach closure, but rather to find out about students' prior understandings.

Figure 2

The 7E Instructional Model

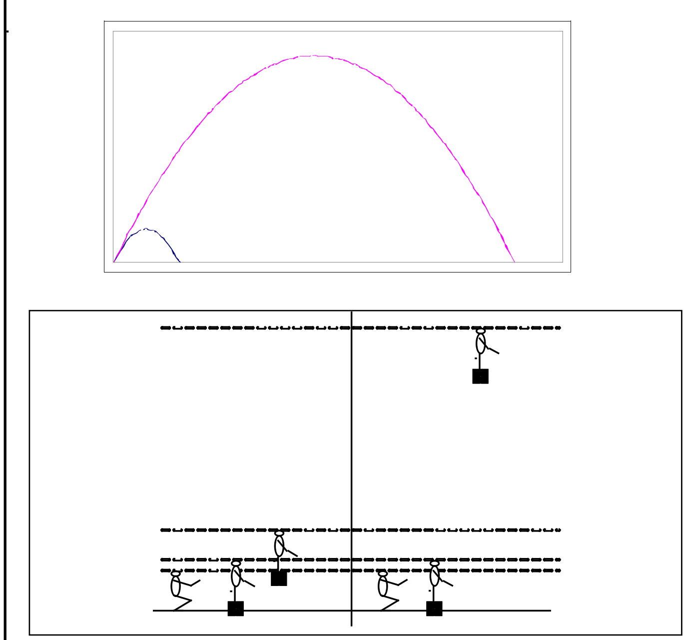
ENGAGE → ELICIT → EXPLORE → EXPLAIN → ELABORATE → EXTEND

EVALUATE

The students then embark on an activity. In the friction activity, students first get a kinesthetic understanding of friction by walking across the room and noting the direction of the push of their feet as they move forward. They then quantitatively measure the frictional force by pulling a box of sand at a constant velocity on a smooth table. After graphing the results of multiple trials, students are able to conclude that the frictional force is proportional to the weight of the box. They are then guided back to an earlier activity, where they learned that objects have one-sixth the weight on the moon. They are then able to conclude that the frictional forces on the moon will be one-sixth the frictional forces on the Earth. Most physics lessons would end with this analysis of physics. *Active Physics* students must then transfer this knowledge to their chapter challenge and their sport for the moon. The activity shows that people will be slipping and sliding all over the Moon. Students must respond to this discovery by creating adaptations to sports to take into account the decrease in friction. Will the players on the moon wear different shoes (Velcro shoes?) or will the shuffleboard court be longer or roughed up? Will baseball players still slide into second base?

In a similar fashion, students learn other concepts. Each lesson begins with "What do you see?" and "What do you think?" followed by an activity. The activity is then interpreted, explained and referenced in a discussion of the relevant physics concept. That concept learning is then tested with traditional problem sets followed by a transfer of learning as students further adapt their sport to take into account their new knowledge of physics. These activities help students explore trajectories on the moon, jumping on the moon, mass versus weight on the moon, and the period of a compound pendulum on the moon (which relates to walking and running.)

Figure 3



Comparison of a home run (top) and comparison of jumps (bottom) on the Earth and Moon as completed by students during the corresponding activities in *Active Physics*.

The chapter challenge is then completed by each student team. The strength of the model is that students take ownership of the physics as they creatively transfer the content of the chapter into an original adapted sport. When they present their sport to the class, the members of the class note how the physics is applied to each new sport. In this way, the class gets to review the content multiple times in different contexts. Learning takes place while completing the activities but additional learning takes place during the transfer from activity to challenge. Students are motivated since they are working on original products and, even though all students have expertise with respect to friction or trajectories on the moon, each group has unique expertise as to how the physics can be adapted in their sport. Finally, the sport allows students to take pride in their interests and/or culture with Latino students choosing soccer with their favorite Brazilian or Colombian teams or other students choosing sports which are meaningful to them like skateboarding or NASCAR.

After the "Sports on the Moon" unit is completed, the cycle is repeated with other monthly chapter challenges. Students design an improved safety device for a car as they learn Newton's laws. Students create an entertaining light and sound show for their friends as they increase their expertise in waves and light. Students assemble appliance packages that can be used in developing nations or in disaster relief environments where electricity is supplied by wind generators with power and energy limitations. Students develop a model of the atom or the nucleus for a science museum exhibit as well as create something related to the exhibit that can be bought in the museum gift shop. All of these challenges are real challenges in that adults get paid to perform them. Students in *Active Physics* never ask, "Why am I learning this?" because they are constantly reminded of the challenge and recognize that the content of the course will help them in their execution of the challenge.

Figure 4

- •Challenge
- •Activity level
  - –What do you think?
  - –For you to do
  - –**For you to read (This is your traditional program)**
  - –**Physics Talk (This is your traditional program)**
  - –Reflecting on the Activity and the Challenge
  - –**Physics to Go (This is your traditional program)**
  - –Stretching exercise
- •Mini challenge–engineering design
- •Challenge Project–Problem Based Learning (Transfer of knowledge)

It is useful to contrast the traditional physics textbook and its approach to learning with the *Active Physics* text with its attempt to bridge research in learning and practice in the classroom. In both traditional texts and *Active Physics*, there is content (For You to Read), equations (Physics Talk) and homework (Physics to Go). In *Active Physics*, students also have a challenge to frame the content, an opportunity for teachers to elicit prior understanding (What do you think?), a need for students to transfer their knowledge at the activity level (Reflecting) and the chapter level (challenge project). In addition, *Active Physics* has opportunities for additional inquiry activities for highly motivated students (Stretching) and a connection to engineering design (mini-challenge and in the challenge project.)

Active Physics is an NSF supported project that was first conceived and developed by physicists and physics teachers under the auspices of AAPT and AIP. Its major goal is to increase the number of high school physics students exposed to quality physics instruction and it has been meeting that goal as students of all ability levels have been introduced to physics for the first time. No longer need high school physics be limited to the strongest academic students. No longer should the physics community be satisfied with 30% of high school graduates taking a physics course. We now have almost all students in Boston High Schools, Los Angeles High Schools and a host of other cities and districts enrolled in a physics course and finding out that they can do physics and appreciate physics through the *Active Physics* challenges..

More information about *Active Physics* can be found at www.its-about-time.com

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Minds•On Physics: Redefining Physics Instruction

Bill Leonard

The Minds•On Physics (MOP) project started in 1989 with a proposal to the National Science Foundation (NSF) to develop activities for high school physics instruction. The activities would be rooted in educational and cognitive research results, especially those from studies of expert-novice differences, formative vs. summative assessment, metacommunication, alternative conceptions, and cognitive overload. After 2 NSF grants and 15 years of development, the program is a full, one-year curriculum with more than 180 activities covering traditional topics such as motion, interactions, and conservation laws, and not so traditional topics such as entropy and relative motion. The activities are published in 6 volumes by Kendall/Hunt, each of which has an accompanying Teacher's Guide. Most of our time on the project is now spent doing implementation workshops.

The target audience for Minds•On Physics are juniors and seniors in high school taking college prep physics. The typical course is algebra based, with an emphasis on solving problems, lots of problems. The goal of MOP is to address one of the major shortcomings of traditional high school courses: Most students develop superficial, formula-driven approaches to solving problems and develop little or no conceptual understanding and no appreciation of the hierarchical nature of physics ideas and principles.

The best way to describe the Minds•On Physics materials is to look at the features that make it special.

• *Activities first!* A typical lesson begins with an activity, with little or no reading or lecturing beforehand. Students struggle with ideas on their own, giving teachers lots of useful formative feedback about what students do and don't understand.

• *Minimal reading*. After each activity or set of activities, there is some reading, usually about one or two pages per activity. The readings summarize, prioritize, and organize the ideas and issues students struggle with in the activities.

• *Retains the feel of calculus while being algebra based.* Physics is intrinsically calculus based, and it can be difficult to make the transition to algebra based without resorting to assertions and superficial results. This, in turn, makes superficial and formula-driven approaches inevitable, because a student literally cannot understand where the formulas come from. MOP does not use calculus, per se, but it has the elements of calculus nonetheless. For instance, velocity (vs. time) is shown to be the slope of position vs. time, and displacement (during a time period) is shown to be equal to the area below velocity vs. time between two instants of time. Further, many common formulas, such as position as a function of time for constant acceleration, are not asserted, but derived, without using calculus.

• *Extensive teacher support materials*. Rather than "Teacher's Editions" of the student activities books, each volume is accompanied by a Teacher's Guide. For each activity, this includes three or four pages of suggestions to help teachers prepare a lesson. Also included are answers with short explanations to every question, with commentary of what students' answers might mean. Answer sheets tailored to each activity further simplify implementation. In all, there are over 2000 pages of support materials.

• *Additional assessments included*. New instructional methodologies require new ways of assessing students, so the Teacher's Guides include hundreds of questions that teachers can use during activities, on tests and quizzes, etc. As a result, teachers and students get even more feedback about what students do and don't understand.

• *Based on educational and cognitive research*. MOP activities pull together multiple strands of research into how people learn. For instance, the materials address students' prior knowledge and conceptions, help students make the transition from novice to proficient problem solver, discourage formulaic approaches to solving problems, and encourage students to structure knowledge.

• *Shifts focus of instruction from problems to analysis of prob lem situations*. Only about 20% of MOP activities specifically ask students to solve problems. The bulk of activities help students develop the conceptual foundation and array of reasoning skills needed to solve problems expertly, so students learn how to learn and they improve conceptual understanding, reasoning and analysis skills, while improving problem solving.

• *Stresses metacommunication (i.e., communicating about communication, learning issues, pitfalls, etc.)*. Talking to students about how to learn, the role of language in learning, and how to modify traditional roles for teachers and students are examples of way to increase student engagement, involvement, and motivation. These and other forms of metacommunication help students become reflective, self-evaluative learners, and make students more responsible for their own learning.

• *Encourages new roles for teachers and students*. The primary job of the teacher is no longer to be an authority and pass along information to students; it is to model students and help them overcome learning barriers. Lectures become focused and target issues raised during activities. Students are no longer sitting passively trying to decipher what the teacher saying; instead they are actively working with the language, concepts, and principles, and learning how to learn.

• *Effective when done in small-group format*. When students are working together on an activity, language issues, prior conceptions, and reasoning are even more manifest, so communication is improved more quickly and more efficiently.

• *Carefully sequenced.* Prior knowledge is provided in prior activities. Further, a progression of goals takes students from naïve beginners to efficient and proficient problem solvers as they: (1) confront their own conceptions; (2) relate concepts to other concepts; (3) apply concepts and principles to problem situations; (4) organize and prioritize concepts and principles; and (5) solve problems without using formulaic approaches.

• *Suitable for multiple contexts*. Although the materials are designed for college-prep level high school physics (i.e., juniors and seniors), many activities have been used at other levels, in cluding 8th and 9th grade physical science, as supplements to college physics, and in graduate level teacher preparation courses. This is possible primarily because the materials are fundamentally a set of questions, and thus, the teachers decide the depth of answers and discussion appropriate to the context. The program has also been used in bridging programs in South Africa, to help underprepared black University students get ready for college.

With its emphasis on inquiry and process skills, MOP aligns well with the National Research Council's *National Science Education Standards* (1996). However, at the level of states and large school districts, where standards tend to be the union of traditional content standards and the new process standards, MOP often falls short. One reason is that MOP has pared down its content to accommodate the development of process skills, while state and local standards have not done so. Another reason is that when the national standards were put into practice at the state and local levels, "activity" often became synonymous with "lab", and MOP has no formal lab activities. If you are a University faculty member, you might think, So what, but meeting state and local standards is a huge hurdle for instructional programs below the college level, in part because schools are usually not allowed to buy materials with public funds unless they meet the standards. The end result is that while many teachers love the program, few districts have adopted MOP. The most notable exceptions are Grand Rapids, MI, Chicago, IL, and Fairfield County, VA. In the first of these, adoption was possible because the local content standards were minimal; in the other two, MOP was adopted alongside a traditional text. Thus, until local standards fully align with the national standards, especially in terms of content coverage and what is meant by activity, it is unlikely that any inquiry-based curriculum will be able to compete on a national scale with more traditional textbooks, at least in the college-prep (high school) physics market.

Of course, there are no formal standards for undergraduate and graduate level physics instruction. Many of the pedagogic principles and findings gleaned from K-12 instructional revision are indeed applicable above the high school level. Thus, the national standards would apply as well. However, the context is different enough that it is highly debatable exactly what college physics instruction should look like. While the prevailing instructional method–lecture–has been slow to evolve and most available texts remain in a traditional style, there has been some progress. Several recent texts have made efforts to incorporate researched instructional methods, use a more student-centered approach, and include metacommunication and metacognitive elements. Furthermore, classroom response systems make it possible to engage in meaningful and productive formative assessment practices, even in large assembly situations. The primary impediments to educational reform at the university level are exactly the same impediments as at every other level, namely, instructor and administrative inertia. Change is hard, and it requires time, money, and will. Written curricular materials, classroom technology, and instructional strategies are just tools to be used by an interested instructor. As with carpentry or any other profession, materials and tools can be well or poorly used. Giving instructors at all levels the time, motivation, and mental space to first realistically assess their own skills and then improve them remains the greatest challenge to educational reform.

The bottom line is that while exemplary materials such as Minds•On Physics are necessary to stimulate improvements in science instruction, they are not sufficient. Reform will remain slow in coming until instructors and institutions desire change. The MOP approach has shown that we can radically change the form of materials and the roles of students and teachers without sacrificing learning. It is an existence proof that the traditional approach is not the only approach. We look forward to ever increasing adoption of MOP as more people become dissatisfied with the traditional approach, and we are here to help them implement it.

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For more information about Minds•On Physics, please contact Bill Leonard at 413.545.0442 or wjleonard@physics.umass.edu.Information is also available at http://umperg.physics.umass.edu/projects/mop and http://umperg.physics.umass.edu/resources/mop.

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Modeling Instruction for K-12 Science Education

David Hestenes

The Modeling Instruction Program (David Hestenes, PI) is an evolving, research-based program for high school science education reform continuously supported by the NSF from 1989 to 2006. The name Modeling Instruction emphasizes making and using conceptual models of physical phenomena as central to learning and doing science. Adoption of "models and modeling" as a unifying theme for science and mathematics education is recommended by both the *National Science Education Standards* (NSES) and the NCTM math education standards as well as AAAS Project 2061. However, no other program has implemented it so thoroughly.

The *Modeling Program* has evolved through several stages with progressively broader implications for science education reform. From its inception, the program has been concerned with reforming high school physics teaching to make it more coherent and student-centered and to incorporate the computer as an essential scientific tool. Recently it has expanded to embrace the entire middle/high school physical science curriculum.

Stage 1: Foundations for Modeling Instruction. Principles and designs for *Modeling Instruction* were initially developed and tested (1980-89) by David Hestenes and his graduate students Ibrahim Halloun and Malcolm Wells. Success of full-scale implementation in university physics and (especially) high school physics provided foundations for further development and dissemination.

Stage 2: Modeling Workshops for high school physics reform.

With NSF support, intensive summer "*Modeling Workshops*" were held to inspire and enable inservice physics teachers to adopt the Modeling approach to instruction. Initially a local effort in Arizona (1989-92), the Workshops were soon extended to a nationwide program (1994-99). More than 200 teachers from almost every state in the country attended intensive 4-week Workshops on two successive summers that thoroughly reformed the standard one-year high school physics course. A follow-up survey found that *more than 90% of the active teachers still use the modeling pedagogy that they learned in the Workshops!*

Stage 3. Cultivating physics teachers as leaders of science education reform.

During Stage 2 many teachers reported that they were in demand in their schools for what they had learned about science pedagogy and the use of technology in science teaching. So, without changing the science content of the Workshops, the emphasis was broadened from reform of physics instruction to cultivating physics teachers as leaders of reform in science teaching with technology in their schools.

Stage 4. Institutionalization at Arizona State University (ASU).

This began in 1995 when the Modeling Workshops were adopted as courses in *Methods of Physics Teaching* for preservice as well as for inservice teachers. *Half* of the inservice physics teachers in Arizona have taken at least one Modeling Workshop. This has established common ground for a community of teachers committed to science education reform. Within this community there has emerged a number of exceptional teachers dedicated and able to serve as leaders of reform.

Stage 5. Physics graduate program for life-long teacher professional development.

Teacher demand for high-quality professional development stimulated expansion of the Modeling Program into a full-blown graduate program expressly designed to meet the needs of physics teachers and lead to a *Master of Natural Science* (MNS) degree in physics teaching. All courses are given in the summer and lodging is arranged to make the courses accessible to teachers throughout the nation. The curriculum includes pedagogical training in five Modeling Workshops for high school physics as well as an array of contemporary physics and interdisciplinary courses taught by senior research faculty.

Responses from both teachers and professors have been overwhelmingly positive. Unanimous support from the ASU physics department led to incorporation in the official ASU catalog. Each summer since it was established, the program has attracted an average of 150 teachers from across the country. The *North Central Accreditation Academic Program Review Committee* evaluating the ASU physics department reported in May 2005: "One of the important ways that ASU is currently elevating science education in Arizona is its unique *Master of Natural Science* (MNS) program for in-service teachers. There appears to be no comparable program at any other university in the United States, and it stands as an exemplary model of how physics departments can improve high school physics education."

Stage 6. Interdisciplinary teacher professional development in the sciences.

Driven by teacher demand, expansion of the MNS graduate program to serve inservice teachers of chemistry, physical science and mathematics is well underway (biology to be included later). According to AIP data, 80% of physics teachers are required to teach these related subjects, for which typical academically narrow preservice training has left them unprepared. Even more than university faculty, high school physics teachers need a broad interdisciplinary science background. A comprehensive graduate professional development program is the only feasible way to acquire it.

On the other hand, AIP data shows that 70% of high school physics teachers are crossovers recruited from other disciplines. Graduate professional development goes a long way toward rectifying this situation. Perhaps the single *most encouraging finding* from our extensive experience with inservice high school physics teachers is that the vast majority of them are able and eager to be excellent teachers. Though they are seriously under-prepared in pedagogy, physics and technology, after three summers in the modeling program they are as effective in physics teaching as physics majors.

Viability of a comprehensive graduate professional development program requires buy-in from all academic science departments. However, for the program to thrive and realize its potential to revitalize science education in the local schools, *leadership at the highest levels of the university administration is essential* to ensure commitment of adequate resources and to establish partnerships with local school districts.

Stage 7. K-12 science curriculum reform for the 21st century.

The current MNS Program already has in place the academic resources and the broad involvement of committed teachers needed to attack the central problem of K-12 science education reform: to design and deliver a pedagogically sound, integrated, math/science curriculum framework for the 21st century. Sufficient funding to support this complex enterprise has not yet been arranged.

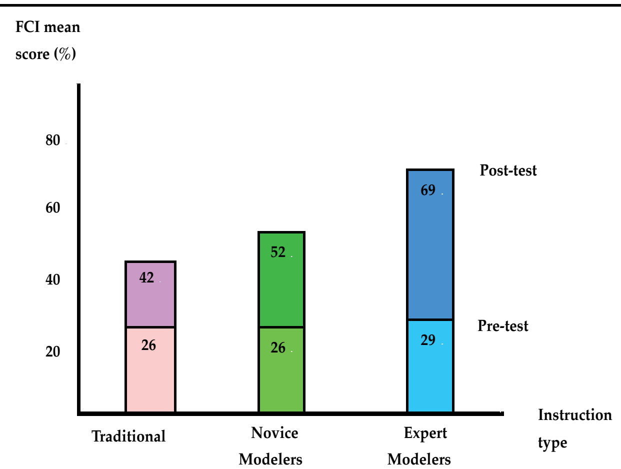
How good is Modeling Instruction?

The most widely used and influential instrument for assessing the effectiveness of introductory physics instruction is the *Force Concept Inventory* (FCI). The Modeling Program has accumulated FCI data on roughly 30,000 students of 400 physics teachers in high schools, colleges and universities through the United States. This large data base presents a highly consistent picture, supporting the following conclusion:

In comparison to traditional instruction, under expert modeling instruction high school students average more than two standard deviations higher on the FCI.

Figure 1 summarizes data from a nationwide sample of 7500 high school physics students involved in the Modeling Instruction Project during 1995–98. The average FCI pretest score is about 26%, slightly above the random guessing level of 20%, and well below the 60% score which, for empirical reasons, can be regarded as a *threshold* in the understanding of Newtonian mechanics. Fig. 1 shows that traditional high school instruction (lecture, demonstration, and standard laboratory activities) has little impact on student beliefs, with an average FCI posttest score of 42%, still well below the Newtonian threshold.

Figure 1



FCI mean scores under different instruction types

High school teachers participating in the Modeling Instruction Program begin a shift from traditional instruction to modeling instruction in their first three-or four-week summer workshop. After their first year of teaching, posttest scores for students of these *novice modelers* are about 10% higher, as shown in Fig. 1 for 3394 students of 66 teachers. For 11 teachers identified as expert modelers after two years in the Program, posttest scores of their 647 students averaged 69%. Since that time, numerous expert modelers have recorded posttest averages exceeding 80%. These are among the very best results reported for high school and even college physics.

Impact of Modeling Workshops on teachers.

Extensive and repeated interviews, surveys, testing and observations support the following conclusions:

- The physics content knowledge of most teachers is increased substantially by the Modeling Workshops. When beginning the Workshops, about a third of the teachers score below Mastery Level on the FCI (> 85%). Within the next year nearly all of them improve to Mastery Level.
- Modeling Workshops have been extremely successful in inducing transformations from *traditional* (teacher-centered) instruction to *constructivist* (student-centered) instruction in full accord with the *National Science Education Standards*. Nearly all of the participating teachers now use the constructivist Modeling Method for all or most of their physics teaching.
- 75% of Modeling Workshop graduates responded immediately and enthusiastically to a follow-up survey between 1 and 3 years after they had completed the program. More than 90% of them reported that the Workshops had a highly significant influence on the way they teach. 45% report that their use of Modeling Instruction continued at the same level, while another 50% reported an increase. Only 5% reported a decrease.
- The most important factor in student learning by the Modeling Method (partly measured by FCI scores) is the teacher's *skill in managing classroom discourse*. That, of course, depends on the teacher's own ability to articulate the models clearly and explicitly as well use them to describe, explain, predict and control physical processes. Although the Modeling Workshops cultivate such skills and nearly all participants improve significantly, it takes many years to reach a high level of proficiency. We estimate that perhaps 20% had the background to reach a high level by the end of the workshops. The rest need a long-term program of professional development to reach their full potential.
- Since initial development of the modeling workshops, an active group of 1500 teachers in 48 states and a few other nations have put the curriculum to use in secondary classrooms. They remain in contact through the Modeling listserv run by Jane Jackson. Workshops have been conducted at some 30 universities and colleges throughout the country, so the Modeling Project is truly national in scope and impact.

Conclusion: University Programs to Cultivate Teacher Expertise.

Ultimately, all reform takes place in the classroom. Therefore, the key to reform is to *cultivate teacher expertise*. The need is especially critical for high school physics and chemistry teachers, because they are in the best position to set the level and tenor of science in their schools and serve as local leaders of education reform. *Above all, teachers need opportunities for professional growth and a supportive school environment.*

Lifelong professional development is as essential for teachers as it is for doctors and scientists. It takes at least a decade to reach a high level of expertise in any profession. Few teachers have adequate opportunities for sustained professional development, and many have an inadequate background in science to start with, so most remain far from reaching their full potential as teachers. The NSES emphasize that "coherent and integrated programs" supporting "lifelong professional development" of science teachers are essential for significant reform. It states that "The conventional view of professional development for teachers needs to shift from technical training for specific skills to opportunities for intellectual professional growth." Such a program cannot be consistently maintained and enriched in any locality without dedicated support from a local university.

The MNS program at ASU has demonstrated how university physics departments can lead the way in creating effective professional development programs, an essential prerequisite for broader K-12 science education reform. For advice and assistance in establishing a comparable program elsewhere, contact jane.jackson@asu.edu.
Details about the MNS program at ASU and extensive information about the Modeling Instruction Program, including publications and reports supporting claims in this article and addressing related issues in science education, are available at the project web site: http://modeling.asu.edu/.

David Hestenes (Distinguished Research Professor of physics at Arizona State University) is founder of the Modeling Instruction Program.

Reformed-Based Physics Teaching: An Inquiry Approach

Dave Pinkerton and Betty Stennet

The Biological Sciences Curriculum Study (BSCS) is in the last stages of development of a 3-year multidisciplinary science program for high school. *BSCS Science: An Inquiry Approach* represents a new generation of instructional materials for high school science. This program, funded by the *National Science Foundation*, helps students develop an in-depth understanding of the core concepts in physical science, life science, earth-space science, and inquiry as articulated in the *National Science Education Standards* (NSES) (National Research Council [NRC], 1996). Students using BSCS Science: An Inquiry Approach integrate major concepts in science across disciplines and across time in relevant, social contexts. The design of the program is strongly supported by recent research in learning (Bransford, Brown, & Cocking, 2000; Pellegrino, Chudowsky, & Glaser, 2001).

Students engaged in BSCS Science: *An Inquiry Approach* address questions in the core sciences for three years. The three levels of the program address all the high school-level NSES using the conceptual framework

Figure 1: Frameworkfor BSCS Science: An Inquiry Approach.

Units	**Major Concepts Addressed at Each Grade Level**		
	Level 1	**Level 2**	**Level 3**
Science As Inquiry	Abilities necessary to do and understandings about scientific inquiry with a focus on:		
	•Questions and concepts that guide scientific investigations	•Design of scientific investigations •Communicating scientific results	•Evidence as the basis for explanations and models •Alternative explanations and models
Physical Science	•Structure and properties of matter •Structure of atoms •Integrating chapter	•Motions and forces •Chemical reactions •Integrating chapter	•Interactions of energy and matter •Conservation of energy and increase in disorder •Integrating chapter
Life Science	•The cell •Behavior of organisms •Integrating chapter	•Biological evolution •Molecular basis of heredity •Integrating chapter	•Matter, energy, and organization in living systems •Interdependence of organisms •Integrating chapter
Earth-Space Science	•Origin and evolution of the universe •Origin and evolution of the Earth system •Integrating chapter	•Geochemical cycles •Integrating chapter	•Energy in the Earth system •Integrating chapter
Science in a Personal and Social Perspective, Science and Technology	•Personal and community health •Natural and human-induced hazards •Abilities of technological design	•Population growth •Natural resources •Environmental quality	•Science and technology in local, national, and global challenges •Understandings about science and technology

The following standards are addressed throughout grade levels and units
- Science as a human endeavor
- Nature of science
- History of science

shown in figure 1. This program provides high school students and teachers nationwide with a research-based alternative to the traditional sequence of biology, chemistry, and physics that is rigorous, focused, and coherent.

Results from field tests suggest that students from a large range of ability levels, from college preparatory students to those with special needs, can be successful with the program. Teachers share many success stories of how students with a range of ability have succeeded in classrooms using *BSCS Science: An Inquiry Approach.*

First, the performance of 1,550 individual students on pre- and posttests were tracked. Tests were developed for 14 chapters, seven per grade level. The results demonstrate strong and statistically significant gains in student achievement. Average student gains at both ninth- and tenth-grade levels were between 20 and 25 percent.

Second, a key goal was to evaluate whether students of different ability levels benefited from the curriculum. Results show that classes of "general ability," "high ability," and "mixed" each demonstrated a significant increase from pretest to posttest independent of the ability level of students.

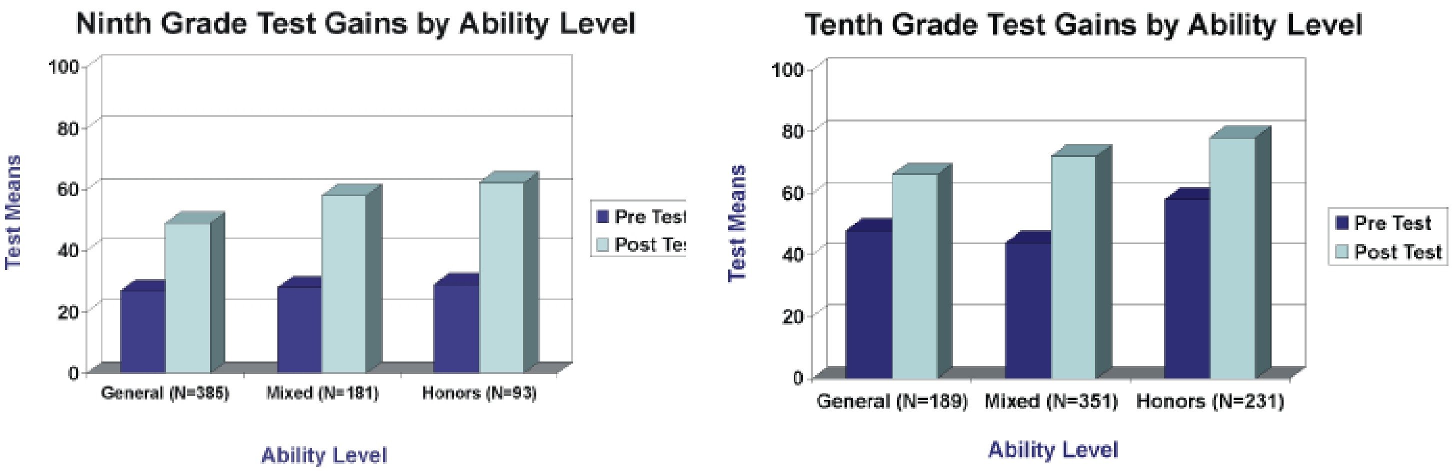


Figure 2: Field test results from portions of Level 1 and Level 2 of the program.

Outcomes of the program

National field tests of the program have demonstrated its effectiveness. Among the findings, two major results highlight the quality and effectiveness of the instructional materials for improving student achievement (figure 2, Coulson, 2002).

The effectiveness of the program is currently being tested in a large-scale, randomized, controlled experiment with several high schools in Florida that have adopted Level 1 of *BSCS Science: An Inquiry Approach.* This research is funded by a grant from the

Engage	These activities mentally engage the students with an event or question. Engagement activities help students make connections with what they know and can do.
Explore	Students work with one another to explore ideas through hands-on activities. This exploration provides a set of common experiences for all learners. Under the guidance of the teacher, students begin to clarify their understanding of major concepts and skills.
Explain	Students construct explanations of the concepts and processes about which they are exploring and learning. Teachers clarify students' understanding of concepts and help them develop skills.
Elaborate	These lessons challenge students to apply what they have learned to a new situation and to build on the students' understanding of concepts in ways that extend their knowledge and skills.
Evaluate	Students assess their own knowledge, skills, and abilities. These lessons also allow teachers to evaluate students' progress and inform instruction.

Figure 3: The salient features of each *E* of the BSCS 5E instructional model.

Department of Education.

Key aspects that have made the program successful

A key aspect of the program is that laboratory activities are integral to learning science content and inquiry skills. The labs do not appear in a separate (and often viewed as optional) book, but rather are included as an integral part of the learning sequence. The tight coherence between content and active learning experiences helps students know, think, and apply the major understandings of science. Classrooms with this environment blend results from research on learning with the on-the-ground realities of schools to create best practices (Kimmelman et al., 1999; Singer et al. 2005).

This program integrates features of research-based, active learning classrooms as naturally as it integrates life science, physical science, and earth and space science. Cognitive development strategies in the program include: the BSCS 5E instructional model (described in figure 3); embedded literacy strategies tied to student readings; multiple forms of representation; metacognition using student notebooks as a tool; questioning strategies designed to engage higher order thinking skills; activities directly targeted to student misconceptions; collaborative learning; and balanced assessments.

In BSCS Science: An Inquiry Approach, each chapter proceeds through a cycle of activities based on the BSCS 5E instructional model. According to the model, each E represents an important part of the sequence through which students progress to develop their understanding. The BSCS 5E instructional model naturally supports the program's inquiry focus. The combination of the 5E model with a strong assessment-oriented design provides opportunities for learning and conceptual change in students, which leads to an improved understanding of science (Bransford, Brown, & Cocking, 2000).

Unique aspects of the program

Two aspects of this program are unique: essential design principles

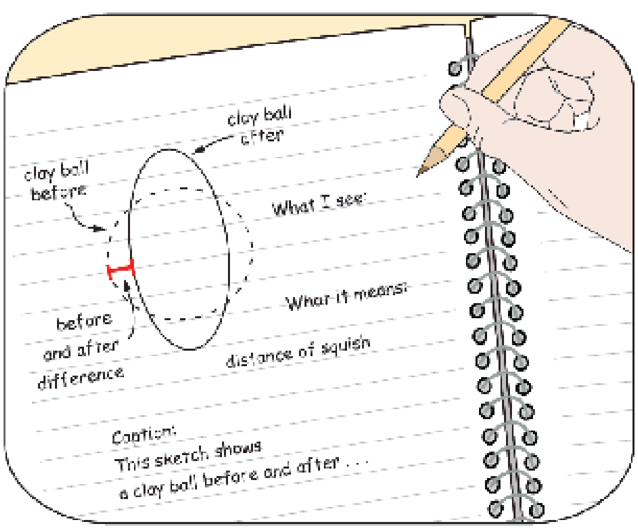


Figure 4: Highlight comments and caption in student notebook.

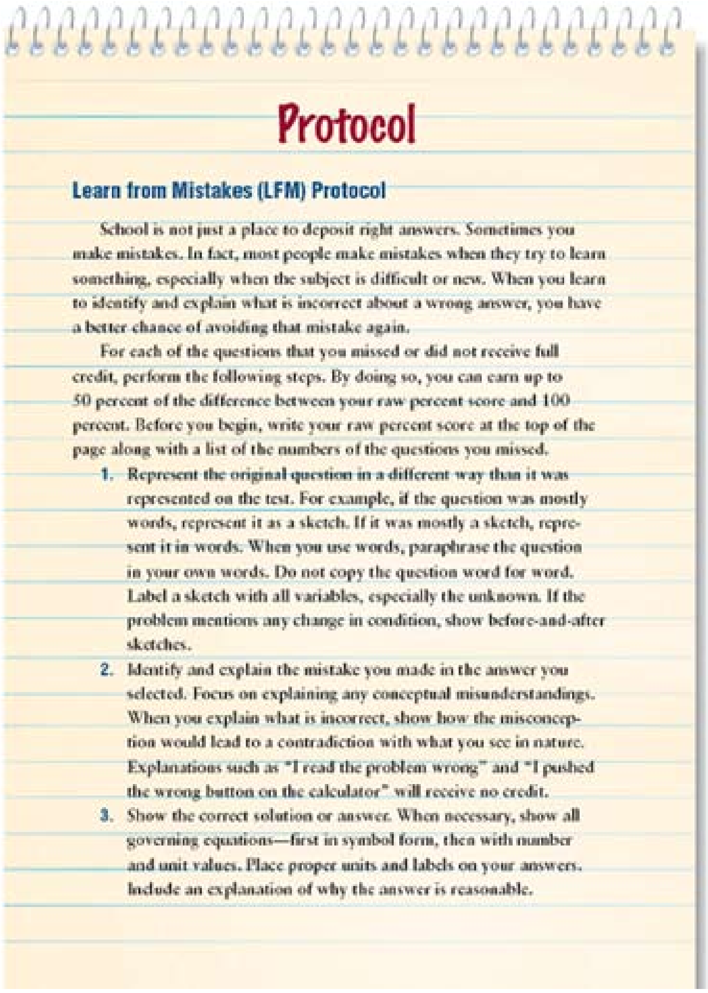
guided each phase of development, and findings from learning research were integrated into the lesson structure. The essential design principles used to develop this curriculum were the BSCS 5E instructional model, understanding by design (Wiggins & McTighe, 1998), and the *National Science Education Standards*. Together, these principles applied to curriculum design generate a program that is focused, rigorous, and coherent, all reported aspects of materials that increase student achievement and long-term learning, self-monitored.

BSCS Science: An Inquiry Approach applies findings from learning research to orchestrate each lesson. Primarily, this orchestration takes the form of making a select family of literacy strategies explicit and integral to the day-to-day progress through the 5E instructional model. These literacy strategies elicit prior knowledge, foster expert-like conceptual structures, and teach metacognitive habits of the mind. Three examples provide illustration.

Including highlight comments and captions on figures, tables, and sketches occurs in each chapter throughout the program. Students generate highlight comments as short phrases to capture the essence of *what they see* and *what it means*. For example, one lesson on force pairs asks two students to place a ball of clay between books they hold. Next, they tap the books together to model a collision and then examine the amount of squish recorded in the ball's shape. The lesson structures students' thinking by first requiring them to write down what they see and link it to a sketch they have made. After this explicit reference to evidence, students interpret what they see by making a brief statement of what it means. Once students check their understanding, they write a caption. Captions translate the highlight comments into a coherent paragraph constructed of cause and effect statements. The caption is a succinct record of student understanding at that point in time. It encourages students to link evidence to explanations–an essential aspect of inquiry (figure 4).

Another unique literacy strategy is used often to help students monitor their learning. The Think-Share-Advise-Revise (TSAR) strategy is often used after students generate highlight comments and a caption. In this reflection and communication strategy, students first *think* about the answer to some curricular prompt. In the prompt above, students write highlight comments and a caption. Students do this as individuals, thus expressing their individual preconceptions. Next, student pairs share what they have written. They use their work as a prop in explaining their initial ideas. After they *share*, they *advise* each other on how to improve each response. Finally, they revise their original response based on the feedback in the share out. Along the way, students record what happens in their notebooks, which teachers can use as formative assessments.

After several activities in a chapter in which students generate highlight comments and share their thinking by using TSAR, they are in a position to demonstrate knowledge and understanding. This program uses several performance-based evaluations (class presentations, investigation design, role playing). But it also uses



Protocol

Learn from Mistakes (LFM) Protocol

School is not just a place to deposit right answers. Sometimes you make mistakes. In fact, most people make mistakes when they try to learn something, especially when the subject is difficult or new. When you learn to identify and explain what is incorrect about a wrong answer, you have a better chance of avoiding that mistake again.

For each of the questions that you missed or did not receive full credit, perform the following steps. By doing so, you can earn up to 50 percent of the difference between your raw percent score and 100 percent. Before you begin, write your raw percent score at the top of the page along with a list of the numbers of the questions you missed.

1. Represent the original question in a different way than it was represented on the test. For example, if the question was mostly words, represent it as a sketch. If it was mostly a sketch, represent it in words. When you use words, paraphrase the question in your own words. Do not copy the question word for word. Label a sketch with all variables, especially the unknown. If the problem mentions any change in condition, show before-and-after sketches.
2. Identify and explain the mistake you made in the answer you selected. Focus on explaining any conceptual misunderstandings. When you explain what is incorrect, show how the misconception would lead to a contradiction with what you see in nature. Explanations such as "I read the problem wrong" and "I pushed the wrong button on the calculator" will receive no credit.
3. Show the correct solution or answer. When necessary, show all governing equations—first in symbol form, then with number and unit values. Place proper units and labels on your answers. Include an explanation of why the answer is reasonable.

Figure 5: Sample Learn from Mistakes protocol

conceptually based multiple choice tests. These tests are an important reality in schooling. In this program, we use a structured learning protocol to help students learn from mistakes on these tests. The protocol is called Learn from Mistakes (LFM).

Figure 5 explains the essential features and the sequencing of the LFM protocol. The overriding inquiry concept conveyed to students by the LFM protocol is that acquiring knowledge is always a process. The process often involves situations in which knowledge is not understood completely or accurately. But with time and an insistence on linking evidence to new understanding, learning can develop.

Suggestions for successful implementation

Two preliminary results emerge from studying field test teachers and the few schools that have adopted parts of this program. First, teachers who implement successfully tend to use the teacher edition as it is designed. That design includes rich support for teacher logistics such as detailed materials lists, advanced preparation, and extensive background information for out-of-discipline teachers. More significantly, the teacher edition provides within each step of an activity coherent rational and practical suggestions for teaching so that students construct their own knowledge.

Secondly, teachers who understand the BSCS 5E instructional model and the philosophy of the program exhibit high fidelity of implementation. Teachers who fostered a climate of inquiry in their classrooms where students felt safe in expressing their ideas and explaining their thoughts and where students could build their own knowledge through time were the most successful with the program.

Lessons learned in developing the program

Two important lessons from development should be shared with the physics education community. The first lesson is the need for ongoing and intensive review, both formal and informal. In developing this program, feedback was solicited systematically. For example, field test teachers provided extensive descriptions of their experiences and offered suggestions, which were incorporated into the final product. Evidence from field test student pre- and posttests helped developers modify lessons. Each chapter was reviewed by content experts and text editors twice before publication. Annual advisory board meetings took advantage of the expert feedback from the larger science and science education community. Our development process depended on these frequent formal and informal reviews.

The second lesson we learned is the need for several versus a single design conference. Certainly, the overall framework of the program was laid out in the early stages of development. In this framework, we decided the general division of content and inquiry-based organizing principles to use for each level of the program. For example, Level 1 broaches characteristic properties, Level 2 force and motion, and Level 3 energy transformations and disorder. This framework remained constant throughout development. But within each level, BSCS held design conferences to establish the way this framework would manifest. Thus, the writing team positioned themselves to learn from each previous development experience as they moved forward. This learning process made the final three-year program coherent, rigorous, and focused.

Conclusion

Reformed-based physics curricula can be successfully developed and implemented. To do so requires a clear understanding of how people learn. That understanding leads to teaching students the skills to do scientific inquiry in the context of science content. The BSCS 5E instructional model structures curriculum development so it fosters learning inquiry and content. Along with explicit literacy strategies integral to content activities and richly annotated teacher pages, student achievement increases in both science content and science as inquiry.

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Dave Pinkerton and Betty Stennett are science educators with BSCS. They are part of the team of curriculum developers working on BSCS Science: An Inquiry Approach. Currently Levels 1 and 2 of the program are available commercially through Kendall Hunt Publishing (www.kendallhunt.com). Level 3 of the program will be released in 2008. For more information about the program or BSCS please visit www.bscs.org.

Physics Teacher Education Coalition

Section on Teacher Preparation

Corporate Funding of Physical Science Teacher Preparation Programs

The total National Science Foundation budget for Education and Human Services in 2007 was 797 million dollars. This money was spread among a wide variety of important programs to improve science education. For example, 9.77 million dollars was requested for the Robert Noyce scholarship program for future science teachers. Since most of the funding for physics research comes from the United States government, it is natural for scientists seeking to improve teacher preparation to look to federal programs to fund teacher preparation programs. In this section of the newsletter, we examine three programs that use another source of funding. In 2006, U.S. corporations donated money and services that totaled 13.77 billion dollars to various charities. Teacher recruitment and preparation are an important public issue. Corporations that direct some of their charitable giving toward teacher preparation not only do good work, but are also rewarded with positive media coverage.

Our first article discusses the role of private funding in the founding and growth of the very successful UTeach program at the University of Texas. More information on UTeach can be found in the Fall 2005 edition of this newsletter and in a recent article in Science (Science 316(5829): 1270-1277, 1 June, 2007). The second article is written from the corporate viewpoint and discusses IBM's extensive Transition to Teaching Program. The final article discusses the experiences of the Physics Department at Seattle Pacific University in working with the Boeing Corporation.

John Stewart is an Assistant Professor of Physics at the University of Arkansas. He has a long association with Arkansas' PhysTEC project and is currently editor of the ComPADRE PTEC collection.

Raising funds for UTeach

Michael Marder

Origins of UTeach

I have watched the preparation of teachers of mathematics, science, and computer science grow in the College of Natural Sciences from a small pilot in the fall of 1997 to a highly regarded program today called UTeach with over 480 students and 70-75 graduates per year. The goal of these remarks is to lay out the role of external fundraising in achieving this goal.

Prior to the founding of UTeach, the University of Texas at Austin was putting out 15-20 math teachers and 10-15 science teachers per year. The math department had worked hard to create special courses for future teachers, which helped explain why more teachers came out of math than all the sciences put together. In all cases it was up to students to complete their degree and take largely unconnected coursework in the College of Education in order to be recommended to the State for certification to teach.

Private funding played an essential role in the founding and development of UTeach. In 1997 Jeff Kodosky, who came to Austin originally as a graduate student in Physics and went on to become the co-founder of National Instruments, had a discussion with Mary Ann Rankin, Dean of the College of Natural Sciences, about the need for more and better teachers. Kodosky offered a small initial gift that made it possible to bring together a small group of award-winning secondary teachers, and they spent several weeks in the summer of 1997 outlining a program in which students would be attracted to teaching through early field experience, and would be able to complete a degree in their discipline and teaching certification together in 4 years. To the partial astonishment of those who had drawn up the plan, the Dean decided to start the program right away, and hired Mary Long, a member of the planning team, to get it going. Midway through the semester, she looked for a faculty member to assume leadership, and I became involved at that point. Over the remainder of the year we developed a close partnership with the College of Education, and settled many of the final details to create UTeach.

Private donors continued to play a major role as UTeach developed. Their significance was even greater than the funds they contributed might indicate. Faculty are usually so busy conducting research and teaching that they rarely conceive of a new university function. Donors and friends of the university are not trapped within a sense of inevitability about what the university accomplishes, and as individuals who may have founded companies they know what it is like to create organizations from scratch. UTeach benefited greatly from such influence. In addition to Jeff Kodosky, we received early gifts from Harry Lucas, who heads the Educational Advancement Foundation. The goal of this foundation is to promote the use of active learning techniques, and the fact that UTeach students in their first class were using kits to teach inquiry lessons to elementary school kids made us an attractive seed project for Lucas to support.

Groups managing fundraising

As time went on, UTeach obtained support from more and more individuals and public and private foundations; the list of contributors currently numbers over 50. There were two groups of people largely responsible for soliciting and managing the donations. The first was the Development Office in the College of Natural Sciences. Early in the development of UTeach, Dean Rankin made clear that raising funds for UTeach was to be one of their highest priorities. The amount of assistance they have provided has varied from time to time, but there have been periods when UTeach has had a professional fund-raiser working for us half time or more. They made contact with individuals, provided first drafts of applications to private foundations, and gently nudged us to provide personalized letters of thanks after funds arrived. In contrast to federal agencies such as the National Science Foundation, private foundations and individuals usually ask for much less paperwork but more personal contact. It is not uncommon for the process to involve the prospective donor in visiting classes, interviewing students, and trying to obtain an honest appraisal of the strengths and weaknesses of the program on a first-hand basis. UTeach students have always been the best possible advocates for us; we have never given them directives of any type on what or what not to say, and have never regretted having the chance to introduce them to prospective donors.

In addition to the Development Office, we established a UTeach Task Force, composed of members of the College of Natural Sciences Advisory Board who heard about UTeach and were interested in supporting it. All of the members had experience in the business world, and had contacts in Austin and across Texas that no professors could match. They also were able to provide advice on matters ranging from branding to the presentation of our accounts on spreadsheets that continues to be invaluable. Dean Rankin is a member of the Task Force, and personally always has been very engaged in raising funds for UTeach as well.

Categories of funds

The funds we raised for UTeach can be divided roughly into four groups: Individual and private foundation seed funding, federal grants, contributions to endowment, and institutional funds.

Individual and private foundation seed funding: A set of private gifts was instrumental in starting UTeach, and yet presented a problem, because if we were to use it to fund core activities such as instructor salaries, fluctuations in funding at any time could cause the enterprise to collapse. We decided that the best way to make regular use of such gifts was with program elements that could safely grow or shrink without placing basic operations at risk. The main element of this sort was the Internship Program. We pay UTeach students $12/hour to work with educational nonprofit organizations ranging from tutoring at-risk youth to helping create educational software. The future teachers benefit because they can support themselves financially in a fashion more closely tied to their career than by flipping burgers. Organizations such as Breakthrough or AVID benefit through individuals they do not have to pay. The recipients of the mentoring, tutoring, or other services have the benefit of wonderful role models. It is relatively easy to adjust the amount spent each year in fairly painless ways. Eligibility for internships can be restricted to students at earlier or later stages in the program, and one can adjust the number of summer internships made available. Foundations immediately see the benefits of their gifts to this program, and there are no adverse consequences if the gift is not renewed.

Federal grants: UTeach has been awarded 3 NSF grants: a Collaboratives for Excellence in Teacher Preparation and two rounds of Noyce Scholarships. The Collaboratives for Excellence in Teacher Preparation grant was over a million dollars, which created again the challenge of gaining maximum benefit from the funds without placing basic operations at risk when they inevitably terminated. We employed the funds mainly in two ways. The first was release time and course development support so that all courses taught in the College of Education especially for UTeach could be improved. The second was for program evaluation. The demands of the National Science Foundation for information about characteristics and numbers of students were greater than those of previous funders. Gaining the ability to gather these data was very important in the development of UTeach. The National Science Foundation also introduced us to a national community of organizations working to improve teacher preparation.

Contributions to Endowment: Five years into the development of UTeach, we had gathered enough evidence that UTeach was meeting its goals that Jeff Kodosky offered $5,000,000 as a lead gift to start a UTeach endowment. This gift followed years of personal involvement and inspection of the program from the inside. Many additional contributions have now been obtained, and the endowment currently has a value of approximately $9,000,000 yielding around $400,000/year in largely unrestricted income that can be used for program support. The significance of this source of funds is hard to overstate. There is a collection of essential activities in UTeach that cannot be paid from the university's instructional budget. These include stipends for cooperating public school teachers, tuition reimbursements for students in their first two courses, the internship program, and support for our graduates in their first two years of teaching. Endowment funds allow us to smooth over rises and falls in foundation gifts and also make it increasingly unlikely that changes in university administration could lead to a substantial scaling back of the program.

Institutional funds. The largest single donor to UTeach–although one might not normally think of things this way–is the university itself. Year after year the provost, Sheldon Ekland-Olson, agreed to allow new faculty hires, and to allocate operating funds so the program could grow in response to student demand. Permanent institutional funds are the key to making an educational program permanent, and nothing could substitute for them except for complete funding from endowment.

Closing Thoughts:

Universities bring together people concerned about the future of a community. When individuals or private foundations give money to an educational program, most of them are hoping for a relationship with it. University programs to improve teaching acquire the double weight of concern for the university and concern for the public school system. The risk in accepting external funds, including funds from Federal grant programs, lies in creating a great seed project that withers away when each particular source of external funding vanishes, as it always must. The great benefit lies in the possibility of creating something really new and necessary. Because of a constant awareness of the tension between these two possibilities, external donations to UTeach have been a completely positive experience, and are responsible both for the program's creation and its current strength.

Recently, a $125 million donation from ExxonMobil has created the National Math and Science Initiative, and one of the two programs this initiative will support is the replication of UTeach. At least 10 more universities will now have the chance to develop teacher preparation programs like ours. They too will need to start right away raising additional external funds, and we hope their experience will be as positive as ours has been.

Michael Marder is an Associate Professor of Physics at the University of Texas–Austin and Co-Director of the UTeach Program (For more information on UTeach, see http://uteach.utexas.edu). Dr. Marder is a Fellow of the American Physical Society. His primary research interest is the mechanics of solids, particularly the fracture of brittle materials.

Transition to Teaching

Robin Willner

"[The IBM candidates] bring wonderful knowledge and experience–real world experience, and they bring a lot of career exploration. Many of them have participated in programs in the community, or through IBM, that have allowed them to see what it looks like on the other side of this process. They have an idea of what it would be like to go back to school and what it would be like to actually be a teacher."

~ Susan Phillips, Dean, School of Education, SUNY, Albany

If you talk to our most successful business and community leaders, you will learn that they have few priorities higher than innovation. At IBM for example, *"Innovation that matters for our company and for the world"* is one of our core values; we work to put this value into action every day to remain competitive as we create new technologies and services that make a difference for our customers around the globe.

In education, innovation is imperative if students are to meet the increasingly complex demands of the global economy. Only by designing and implementing new strategies and by creating new tools and resources can we help our students achieve at higher levels. Schools alone cannot be the breeding ground for innovation; businesses and community organizations will play a critical role in igniting innovation in education.

To that end, IBM, as an extension of our efforts in education improvement, announced in September 2005 that we would help address the critical shortage of math and science teachers by leveraging the brains and backgrounds of some of our most experienced employees.

The Transition to Teaching program enables IBM employees, who are interested in second careers in education, to become certified math and science teachers. Through Transition to Teaching, IBM employees can engage in both online and more traditional courses and are offered a leave of absence for student teaching. Participants also are provided with online mentoring and support throughout the process.

IBM initiated Transition to Teaching for a number of key reasons: to address the severe shortage of math and science teachers; to help raise the math and science achievement levels of our nation's youth and prepare them for the demands of the global economy; and to respond to the needs of IBM's growing force of mature workers.

Why Transition to Teaching?

IBM launched Transition to Teaching in response to what we believed to be two important and converging trends: the need for teachers, especially in math and science; and the unique characteristics of the Baby Boomer generation.

Education. For the last 15 years, improving public schools around the world has been IBM's top social priority. As a business, we know that our enterprising spirit and economic strength depend most heavily on the ability of our schools to prepare our young people to become the responsible citizens, productive workers and visionary leaders of the coming Innovation Economy.

Through strategic grantmaking and public policy work, IBM has made significant and comprehensive impacts on education improvement in the United States and around the world. Our $75 million-plus Reinventing Education program is demonstrating how technology can help spur and support school reform efforts around the world, while our KidSmart Early Learning Program integrates new interactive teaching and learning activities using the latest technology into the pre-kindergarten curricula in more than 50 countries. IBM also supports literacy through Reading Companion, which uses cutting-edge speech-recognition technology to help both young children and adults learn to read. Through these programs and many more, IBM engages our technology, technical expertise, and our people throughout the world, allowing us to leverage our greatest strengths for the benefit of the communities in which our employees live and work.

IBM's Transition to Teaching was a natural progression of our work in education. Our efforts had highlighted the importance of the classroom teacher to student learning, and all of our programs included teacher professional development as an integral component.

We also recognized that new economic demands required new thinking about what we should do to improve our schools. According to the U.S. Department of Labor, jobs requiring science, engineering and technical training will increase dramatically in the future. The U.S. produces only about 100,000 engineers each year, far fewer than those graduating in other countries, including India and China. To remain economically competitive, the U.S. needs to grow its pipeline of engineers and other qualified IT workers. To prepare young people for these jobs, the U.S. faces the need for 2 million teachers–and a critical shortage of math and science teachers.

Retiring Workers. Simultaneously, IBM recognized that 76 million Baby Boomers are approaching traditional retirement age, with many reporting they plan to continue working in fields where they can give back to their communities. This generation will be the healthiest and best educated group of 60-somethings ever to walk the earth. They will be eager to continue to be productive and contribute to society, and they will have the mental and physical capability to do so. A recent study by Civic Ventures/Met Life Foundation found that 53% of Americans ages 50-70 plan on second careers, and a full 50% of Americans ages 50-70 are interested in taking jobs that help improve the quality of life in their communities.

IBM knew that its tradition and reputation as a workplace of choice would enable us to prepare for and capitalize on a successful demographic transition over the next decade. IBM has always invested wisely and continuously in our employees. This includes a tradition of diversity, which extends to mature workers and would provide a foundation for a new approach to the career cycle. Focus groups around the country told us that our employees were interested in second careers as teachers– but they felt that the process was daunting. IBM also has a history of innovation in adapted work styles and schedules and involvement in public policy.

The Program. IBM launched Transition to Teaching program in January 2006, in the United States. All employees who met specific criteria could apply to participate. Participants did not need to be Baby Boomers; they could be employees seeking a mid-career change.

IBM's criteria focused on those employees who had the best opportunity for success. This was not a program to rid the company of poor performers. Criteria for eligibility includes 10 years of IBM service; a record as a top performer; a bachelor's degree in math or science or a degree in a related field, and some experience teaching, tutoring or volunteering in a school or other children's program. The program also requires management approval as is the case with a large number of IBM human resource initiatives.

While Transition to Teaching is open to IBMers anywhere in the US, we also focused special programming and support in New York and North Carolina. These states were chosen because both have significant shortages of math and science teachers. Additionally, these are the two states that have the largest IBM populations and where many employees live after leaving IBM. In North Carolina and New York, IBM partnered with institutions of higher education to design pathways for IBMers. These were options that met the state requirements for certification and met IBM's recommended model for preparation. In New York, IBM developed partnerships with the State University of New York (SUNY) and the City University of New York (CUNY). In North Carolina, IBM developed partnerships with the University of North Carolina at Charlotte, the University of North Carolina at Chapel Hill, and North Carolina State University.

The models included information and pathways for candidates in these states and would reduce the time it took to place qualified teachers in classrooms. The models also would include pre-service training, student teaching and in-service mentoring and would encourage the use of online curriculum, as well as completely online university programs.

IBMers were free to enroll in any existing certification program and apply for the financial incentives from IBM. IBM Corporate Community Relations Managers and Human Resources staff provided support and direction for applicants, but each participant was responsible for selecting and enrolling in an approved teacher preparation program and assuring that they could complete certification requirements within three years.

Recruiting Participants. Transition to Teaching recruitment began soon after the program specifics were announced company-wide in November 2005. The program received significant fan-fare both within and outside the company for its innovation in education and workforce development, receiving more media hits than any other IBM program or solution announcement that year. The value in advertising in print media alone for this positive story was $2.3 million.

To recruit IBM employees, IBM Corporate Community Relations and IBM Human Resources worked closely together to develop materials and host information sessions at IBM locations around the country to inform interested employees about the program. One such publication, *Straight Talk on Teaching*, was designed to help IBM employees, who are considering participating in the Transition to Teaching program, understand both the rewards and the potential challenges of a second career in teaching.

Transition to Teaching Today

Today 85 U.S. employees are participating in online course work, more traditional courses, and online mentoring while remaining at the company. IBM is reimbursing participants up to $15,000 for tuition and stipends, as well as offering a leave of absence of up to four months for student teaching. This is the first time that IBM has provided tuition reimbursement for courses that are not job-related, representing a long-term investment in our communities and labor force of the future. Participants must agree to complete their preparation and begin teaching within 3 years. If they decide not to complete the program, they can remain at IBM but must repay any funding they have received.

Participant Snapshot. While IBM began with our largest states, New York and North Carolina, the reality was that every participant in the program was unique. Each had a different recall of math or science; some have had a little pedagogical preparation, and others had none. In the end, there was not a single way to group participants–other than that they started their certification work in 2006. Currently we have employees in 17 states–the largest participating in NY, followed by NC, GA, TX, VT, AZ MA, MI, matriculating at 30 different universities. No two are the same.

Amazing IBMers are entering this program. Their enthusiasm to take applied math and science back into the classroom is inspirational. The following is a snapshot of our current participants:

- Age range: 37-60
- Male 57%; female 43%
- White 73%; Black 21%; Asian 2%
- Varied work experiences: Engineers 25%; Computer Science 21%
- 69% want to teach math; 31% want to teach science
- 44% plan to teach for 10 years or more; 38% between 3-9 years
- 50% plan to teach in middle school; 50% high school
- 83% plan to supplement income with a pension, spouse income or investments

The vast majority of participants cited as their reason for going into teaching the value of education to society (33%), while nearly a third (31%) expressed their desire to work with young people. Fifteen percent said that they simply wanted to change careers. As the most important factor for participation, almost half (46%) stated the ability to keep working while going through the program; a third (33%) highlighted IBM's financial help, and 10% singled out the program's vast choice and flexibility. The most common comment among the participants was a great appreciation to IBM for the Transition to Teaching effort.

Ongoing Program Support. Participating employees are receiving extensive support through a web site IBM developed specifically for the program at www.ibm.com/ibm/transitiontoteaching. The Transition to Teaching web site includes background information for prospective participants, as well as teaching resources. A password protected site for actual enrollees provides online mentoring and forums so that participants across the country can hear from national experts on the most important issues in K-12 public education, ask questions, muse about the differences in corporate and educational cultures, vent, and share successes.

There are currently four Transition to Teaching mentors available through the web site. All are consultants from the Center for Teaching Quality, a research-based advocacy organization committed to improving student learning, who provide advice and direction to the participants. Two of these consultants are second career teachers, so they are well aware of the issues involved in transitioning to a new career. Collectively, they have a great deal of experience in building virtual learning communities, working with novice teachers and moving into teaching as a second career. As the participants navigate through their certification programs, the mentors are ready to listen to their concerns and open up a dialogue on issues around becoming a teacher.

Our participants are now networking and learning from one another. Conversations around topics of interest in the teacher-preparation pipeline have begun, including preparing for work with students with special learning and language needs, teaching in a climate of high-stakes testing, and the challenges of engaging and motivating students. The goal is to connect participants and providing support as they make this major life change.

What We've Learned

IBM has earned a lot about state certification and is working to make sure that a second career person has a different route than an 18-year-old to becoming a teacher. We are focusing on eight states (CA, GA, MA, MD, MN, NC, NY, and TX) where we think public policy work can and will effect this agenda. In each state, we are beginning to see new flexibility in their second career programs, and we are working to focus on exactly what skills a new teacher needs to master. We want programs to provide everything necessary for the success of our employees' new students, but nothing more. We are also investigating new incentives and public/private investments to encourage second career teachers.

Transition to Teaching is beginning to make its mark on the national and state levels. The U.S. Department of Education has highlighted Transition to Teaching as part of the Administration's new program to enhance competitiveness In California, we are working with the Governor's Education Advisory Committee and the State's P16 Advisory Committee to expand second career programming. We are also seeing significant new initiatives in other states, as well as interest from many companies to initiate similar programs.

Internationally, the program is making its mark as well. Following an IBM proposal to Prime Minister Tony Blair to replicate the Transition to Teaching program in the United Kingdom, a Steering Group chaired by IBM has been developed to implement a similar program in England. Five other companies are joining IBM on the steering group: Cisco, Lockheed Martin Aerospace, Astra Zeneca, BT and KPMG. They will be joined by representatives from the Confederation of British Industry, the Association for Science Education, the Teacher Development Agency, the Sector Skills Council for Science Engineering and Manufacturing Technologies and the Department for Education.

We hope that our new effort in education improvement will encourage other businesses, community organizations, as well as schools themselves, to bring greater innovation to education. IBM knows that Transition to Teaching will only make a difference if it is allowed to scale. As in the United Kingdom, IBM already has spoken with a dozen U.S. companies about their interest in creating a similar program.

If 100 other U.S. businesses initiated similar efforts, placing 100 of their mature workers with math and science backgrounds into K-12 schools, then that would result in 10,000 new math and science teachers–every year. The impact on education could be extraordinary.

Robin Willner is Vice President for Global Community Initiatives at the IBM Corporation.

Back to the Future: An IBMer's dream coming truethrough Transition to Teaching

IBMer Vickie Szarek, now a student teacher at Garner Magnet High School, was one of Transition to Teaching's first participants.

Twenty-seven years ago, Vickie Szarek thought about becoming a teacher. Then she married an IBMer and began a series of work-related moves. During this time she completed graduate work at NC State and a BS in Computer Information Systems at Florida Atlantic University in Boca Raton. She eventually became an IBMer and has been with the company for eighteen years. Still, Szarek never lost her desire to teach, even taking teacher certification courses in Florida until she was transferred back to North Carolina.

"I was beginning to think about retiring when I saw an article on Transition to Teaching," recalls Szarek. After being accepted into the program, Szarek applied to NC State for a slot in their NC Teach program, an accelerated curriculum for teachers interested in lateral entry.

Support from Szarek's IBM manager was crucial to her success in the program. "While all of the classes were offered at night or on the weekends, at the beginning it was difficult to balance working at IBM with often needing to leave work early to make it to a five o'clock class and then come home and do fifty pages of reading."

But Szarek's dedication remained and now, after a year of juggling school and IBM, she has taken a leave of absence from IBM and is in the classroom full-time. "I am currently on a leave of absence from IBM and student teaching at Garner Magnet High School — and I LOVE it!" she says.

Szarek began by observing science teacher Martha Ghali's classes, and quickly began teaching on her own. "My husband keeps telling me to wipe the smile off of my face," laughs Szarek. "I spend my days working on science labs and other activities to try to reinforce material — it is great!"

"She is earning the students' respect and teaching them content in great, innovative ways," says Ghali. "I have taken a few of her ideas and used them in my other classes, which is the best part of working as a team. We can share ideas and come up with new ways to help the students learn."

On June 1 Szarek will return to IBM, where she will continue working while interviewing for teaching positions across the county. Once she finds the right school for her, she will resign her position at IBM and begin her new career as a teacher.

And for other late-career IBMers, Transition to Teaching might also be the perfect opportunity at the perfect time. "IBM has shown genuine courage in being the first of many–I hope–businesses taking an interest in how they can positively affect our public schools by providing and supporting highly qualified employees to consider a career change into teaching," says NC Teach's Grant Holley. "I would strongly encourage IBMers with an interest in teaching to take advantage of this wonderful program."

Leveraging Corporate Support for Science Education Reform at Seattle Pacific University

Eleanor Close

I. INTRODUCTION

Corporate interest in the improvement of K-20 education is significant. When ExxonMobil recently announced the creation of the National Math and Science Initiative, a $125 million non-profit program, academics devoted to the professional preparation of math and science teachers took careful notice. This initiative did not arise in a vacuum. During the last twenty years, a series of national reports has warned about the precarious state of precollege math and science education in our country. Although every report has been discussed extensively by academics and pundits, few have had a more visible impact on larger policy than the 2005 National Academy of Sciences report "Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future." A confluence of factors have contributed to the magnitude of the impact: a changing political climate in Washington, with increasing emphasis on programs to improve student achievement; a growing recognition that the number of graduates with expertise in science, math, engineering, and technology (SMET) produced in the US every year is inadequate to meet the long-term needs of the country; as well as a long list of quantitative measures of scientific productivity that are consistent with a shrinking US footprint. There is an additional reason for the widespread impact of this report. The report was written by a committee that was chaired by a business leader, included several business leaders, and was written for an audience of business leaders. As academics, we can leverage and direct corporate interest in the improvement of science education at all levels to support innovative programs.

In a previous article in the summer 2006 newsletter, my colleagues Lane Seeley and Stamatis Vokos made the case that collaboration among faculty in the discipline departments and the School of Education is necessary for the creation and refinement of exemplary teacher education *programs* (which include but are not restricted to exemplary *courses* for teachers). In this article, I will present the case study of Seattle Pacific University's continuing collaboration with corporate foundations. Our hope is that other Departments of Physics will recognize the benefits that such a close collaboration can afford them, and will also be warned about different expectations shared by academia and federal funding agencies, on one hand, and some corporate foundations, on the other.

II. PARTNERSHIP BENEFITS

In September 2004, the Department of Physics and the School of Education at Seattle Pacific University (SPU) were selected by the Boeing Company to develop a collaborative model of teacher preparation. Since that time, Boeing has continued to support the deepening collaboration between the Department of Physics, the School of Education, and local school districts. This support was leveraged by SPU and gave rise to an additional $1.5 million in funding for a major research and development effort, and was ultimately responsible for SPU's selection as a Primary Program Institution for PhysTEC (Physics Teacher Education Coalition).

Beginning in 2004, the Boeing Company has provided a continuing grant to support the project *A Collaborative Preparation Model to Increase the Math and Science Competence of K-12 Pre-Service Teachers.* Among the long-term objectives of this local initiative are: (1) to increase the number of well-qualified math and science teachers prepared at SPU; (2) to design and implement a coherent, research-driven program for pre-service teachers in math and science that results in deep content knowledge in the technical area, curriculum and pedagogy; and (3) to create a partnership between teacher educators, researchers, school administrators and master teachers in the areas of math and science that improves the education and retention of K-12 teachers.

To this end, the Boeing Company has provided partial support for a Resident Master Teacher, Lezlie Salvatore DeWater, who has become an integral part of the teacher preparation and enhancement program at SPU and a liaison between the teacher education efforts of the Department of Physics, the Science Education program in the School of Education, and the science education reform initiatives in Seattle Public Schools. This funding has enabled the Department of Physics to secure the remainder of the necessary funding for the full-time position in the form of support from the National Science Foundation and the College of Arts and Sciences at SPU.

Collaboration on the Boeing proposal helped develop a strong partnership between the Department of Physics and the School of Education. This partnership has led to the establishment of a joint School of Education/Physics tenure track faculty position in science education, a position currently held by the author. Working as a team, the Resident Master Teacher (Lezlie DeWater) and the author are responsible for the development and implementation of special science content and methods courses for pre-service teachers. Pre-service teachers, therefore, are immersed in the blending of subject matter knowledge and pedagogical content knowledge. We have also developed reformed general science courses for non-majors offered through the Department of Physics to incorporate the results of physics education research.

DeWater's connection with Seattle Public Schools has led to professional development opportunities both for pre-service teachers at SPU and for SPU faculty. As part of the elementary science methods course, pre-service teachers are required to attend one of the excellent workshops offered by Seattle Public Schools on Expository Writing and Science Notebooks (see http://www.inverness-research.org/reports/ab2005-09_Rpt_SeattleNotebks_ElemSciWriting.htm), and to implement strategies from the workshops in their student teaching assignments. They have the additional opportunity to attend Seattle Public School's Initial Use workshops for the elementary science curriculum kits adopted by Seattle and many of the surrounding school districts. SPU physics faculty regularly attend these and other workshops with the Seattle Public Schools Inquiry Based Science program, allowing us to stay current with the science program in local schools as well as to nurture relationships with science program personnel and local science teachers.

As mentioned above, initial support from the Boeing Company was instrumental in obtaining additional funding from the National Science Foundation. In spring of 2005 the Department of Physics began a five-year, 1.5 million-dollar NSF Teacher Professional Continuum (TPC) program *Improving the Effectiveness of Teacher Diagnostic Skills and Tools*. The project has two primary goals: (1) to help teachers of physical science in grades 5-10 develop deep subject matter content understanding, extensive pedagogical content knowledge, and flexible curricular content knowledge, and (2) to develop research-based resources that assist teachers and teacher educators in constructing a diagnostic classroom environment to formatively assess the evolving understanding of their students in the topical areas of properties of matter, heat and temperature, and physical and chemical changes.

In this partnership-based project, the SPU Department of Physics and School of Education work together with FACET Innovations, LLC., a Seattle-based educational research and development company dedicated to the improvement of learning and teaching in K-20 science. The partners of this project work with the Seattle, Bellevue, and Spokane school districts (three of the four largest school districts in Washington State).

The TPC project includes the development and implementation of special courses for in-service teachers, offered both during the academic year and as intensive summer courses. In addition to these courses, SPU physics faculty teach special science content and pedagogy workshops for in-service elementary teachers in Educational Service District 105, headquartered in Yakima, Washington. These workshops are supported through the Washington Leadership and Assistance in Science Education Reform (LASER) program, which is funded in part by the state and the Boeing Company.

In recognition of the previously described Department of Physics work in teacher preparation, SPU was chosen in 2006 as a Primary Program Institution by PhysTEC, a joint program of the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics. As part of this program, we have established a Teachers Advisory Group (TAG) with representatives from the Seattle, Bellevue, Issaquah and North Shore School Districts as well as from the Catholic Archdiocese of Seattle. The TAG allows us to further our collaborative relationships with local schools and develop a deeper understanding of the needs of teachers in local districts.

The collaboration between the Department of Physics and the School of Education has also led to the establishment of a Science Education Task Force at SPU. Faculty from the Department of Physics and School of Education meet quarterly to coordinate programs and map out future plans to enhance both pre-service and in-service science teacher education at SPU. Current work includes recruitment of exemplary in-service science teachers to serve as mentors for SPU student-teachers; discussion of ways to coordinate course offerings in physics and education that complement and build on one another; and exploration of the possibility of a general science major for pre-service middle school teachers.

In summary, continuing corporate support of the Department of Physics at SPU has allowed us to add faculty to our department; strengthen and extend existing relationships with the School of Education and with local school districts, and create new relationships; improve our course offerings for pre-service teachers and non-science majors; enhance our teacher preparation and professional development programs for both pre-service and in-service teachers; secure NSF support for research and development in the area of K-12 physics education and teacher professional development; and obtain additional support for physics teacher preparation through the PhysTEC program. These developments have had enormous positive impact on our department, and will continue to shape our path into the future.

III. THE CLASH OF EXPECTATIONS

Q. *How many physics faculty does it take to change a light bulb?*

A. *Physics faculty…change?*

Any authentic collaboration tends to change all members involved. Collaboration with industry in support of science education reform requires academic faculty to recognize that many corporate foundations expect large-scale impact (i.e., a large number of participants involved in a program) on short time-scales. Recently, our Department had the benefit of a visit by the Executive Director of the charitable foundation of a major transnational corporation, which extensively funds math and science education projects around the world. We were all impressed very favorably by the broad perspective that the Executive Director brought on issues of common interest in teacher education and enhancement. It was also clear that there were differences in our outlooks, in both grain-size and time-scale requirements. A telling insight of the corporate mentality was the Executive Director's statement that the majority of sales income for this corporation every year comes from products that did not exist twelve months earlier. The whole ethos of the corporation is based on innovation and rapid, widespread implementation of new programs.

Many research-based university programs in science education reform, viewed from the industry point of view, represent the antithesis of such an outlook. University perspectives are often based on time-scales informed by experience in teacher education and professional development. In most, if not all, experience of university faculty (including the author), it has taken a long time (sometimes as long as ten years) to develop teachers' deep subject matter content knowledge, extensive pedagogical content knowledge, and flexible curricular content knowledge. Frequent changes in leadership and subsequent changes in direction of science reform efforts in school systems relax these systems very quickly back into a pre-reform state. As Melba Phillips once quipped, "The problem with the problems in science education is that they don't stay fixed." The practical results of these differing perspectives is that university programs typically affect dozens of teachers, often on five- to ten-year time-scales, while the furthest time-horizon for industry support of a project is typically three years and the support may be contingent on much larger-scale program impact (e.g., hundreds or thousands of teachers). Given these differences, corporate support of a university program may be difficult to secure, however compelling the research case for the effectiveness of the program may be.

There is plenty of room for productive compromise between these two perspectives. Many university programs for teachers will benefit from recognition of the dire, immediate national need for well-prepared teachers (not just in content but also in pedagogical skill). On the other hand, it is only through constructive, ongoing engagement with industry foundations that corporate expectations of immediate large-scale results in science education can be moderated and the recognition may develop that the preparation and development of professional teachers does not lend itself easily to standard business models.

ACKNOWLEDGMENTS

The efforts described in this article are the results of intensive ongoing collaboration among all members of the Department of Physics at SPU, present and past. In addition to the author, Tom Bogue, Lezlie Salvatore DeWater, John Lindberg, Lane Seeley, Stamatis Vokos, Michael Witiw, Hunter Close, and Pamela Kraus have each played major and distinct roles in all aspects of the program. Bill Rowley, Dean of the School of Education and Frank Kline, Associate Dean for Teacher Education, have been invaluable partners in all our efforts. Our own Dean, Bruce Congdon, has been an indispensable supporter of our Department.

We gratefully acknowledge the support of the National Science Foundation through Grants ESI 0455796 and DUE 0310583, the Boeing Company, the Huston Foundation, and the PhysTEC project of APS, AAPT, and AIP.

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Eleanor Close is an Assistant Professor of Physics and Science Education at Seattle Pacific University. Seattle Pacific University was recently named as a new PhysTEC site. Ms. Close will be deeply involved in SPU's teacher preparation efforts.

Browsing the Journals

Thomas D. Rossing

• Resistance to certain scientific ideas derives in large part from assumptions and biases that can be demonstrated experimentally in young children and that may persist into adulthood, according to a review in the 18 May issue of Science. Both adults and children resist acquiring scientific information that clashes with common-sense intuitions about the physical domain. Babies know, for example, that objects are solid, persist over time, fall to the ground if unsupported, and do not move unless acted upon. The problem with teaching science to children is not what the student lacks, but what the student has, namely alternative conceptual frameworks for understanding the phenomena covered by the theories we are trying to teach.

• The April issue of *American Journal of Physics* has a resource letter on "Physics and society: Energy" that provides a guide to the physics-related literature about energy and society. One way to teach energy and society is to develop an entire course devoted to the topic. Another way is to insert energy-and-society topics into a more general physics course. Journals, textbooks, and websites are referenced on a variety of topics including fossil fuels, global warming, nuclear power, fusion power, renewable resources, wind, photovoltaic, and geothermal energy, and energy storage.

•Teacher turnover, which is "spiraling out of control," is estimated to cost the nation more than $7 billion a year, according to a story in the June 20 issue of *Education Week*. A study by the Washington-based National Commission on Teaching and America's Future says that despite the staggering expense, virtually no school district has systems in place to track or control such turnover. Turnover costs are based on expenses incurred to recruit, hire, and train teachers. The report recommends that the federal government make retention of highly effective teachers a focus of the No Child Left Behind Act, which is up for reauthorization this year.

•"Three or four golden rules of lecture" is the title of an article in the April issue of *The Physics Teacher* by a recent recipient of the AAPT award for excellence in undergraduate teaching. Rule 0: Reinvent as little as possible. Learn from your peers, read the literature. Rule 1: Emphasize conceptual understanding and qualitative reasoning throughout the course, especially on the exams. Rule 2: It is OK to lecture less, because they are not listening anyway. Rule 3: Class morale is vital. If the students learn some physics but leave class hating the subject, we have failed.

•The impact of teaching assistants on student retention in the sciences is the subject of an article in the March/April issue of the *Journal of College Science Teaching*. The authors present results from a survey of 2,100 undergraduates that, contrary to previous research, suggests that teaching assistants influence student retention in the sciences in multiple ways. Multiple linear regression and student comments suggest that TAs influence lab climate, course grades, and students' knowledge of science careers, all of which have an effect on students' decisions to stay in or leave science. The article presents some recommendations for TA training, mentoring, and management.

•The merits of programs aimed at attracting more women into physics should not be judged purely on enrollment statistics, argues a forum comment in the April issue of *Physics World*. Our goal should instead be to allow women to choose their career with as much freedom as possible. “Manipulating a person towards science is not any more acceptable than manipulating that person away from it.”

•“The special joy of teaching first year physics” is the subject of a guest editorial in the July issue of *American Journal of Physics*. A number of circumstances make the first year so special. Students enter the university with great expectations, they respond to good teaching, and their learning ability appears to be at a maximum. The usual first year fare–which includes Newtonian mechanics and electromagnetism—allows them to reach great heights in science. All physics departments should capitalize on these circumstances. It is a special joy to hear from former students about the impact my physics course has made in their lives.

•“The advanced laboratory experience plays a pivotal role in undergraduate physics, yet it is often taught in isolation,” observed former AAPT president Dick Peterson in the March/April issue of *Interactions*, a new AAPT publication. Typically advanced laboratories, taught at the junior or senior level, include experiments from atomic and nuclear, condensed matter, optics, fluids or acoustics. Sometimes advanced laboratory experiences are incorporated within upper-division courses, sometimes they are stand-alone courses. To foster a continuing conversation on topics related to advanced labs, AAPT has established a listserv at www.aapt.org/advlabs. This website includes links to other valuable material on advanced laboratories.

•An article called “Nature’s guide for mentors” in the 14 June issue of Nature has an interesting discussion of mentoring and how to be effective mentors. Personal characteristics of effective mentors include: enthusiasm, sensitivity, appreciation of individual differences, respect, unselfishness, and support for other than one’s own students.

•A guest editorial “Why physics first?” by a high school teacher appears in the March issue of *The Physics Teacher*. Although one of the most common arguments for physics first is that it prepares students to study chemistry and biology, the author argues that a more fundamental reason is that it exposes more students to physics. He teaches a course in conceptual physics to ninth graders, most of whom will never take another physics course in their lifetime. How can students be considered educated without knowing how and why objects move? What heat really is? What comes out of an electrical plug? How we can explain sunsets and rainbows and echoes? How can we critically evaluate the need to stop global warming?

•A thoughtful essay on teaching for understanding appears in the May/June issue of the *Journal of College Science Teaching*. The author begins by describing a class he observed. The instructor focused on terms, theories, and mechanisms, carefully answered all student questions. About halfway through the hour, the class broke into “co-operative-learning” teams at which students reviewed their notes together, asked questions of their teammates, and discussed the assignment. During the group work, the instructor visited each group to answer question or rectify misconceptions that came up. On the surface the teacher had done a commendable job. What was missing, however, was the application of the principles in the lesson to different situations that promote understanding.

How can professors teach for understanding rather than memorization? Our ancestral scholars achieved teaching for understanding by responding to the pupils’ questions not with answers, but with other questions. A lasting knowledge can be achieved by applying a simple learning cycle, developed 40 years ago by Karplus and Their. The three phases of the learning cycle are explanation, comprehension, and application. Understanding, not facts, is what education is all about.

•The physics education systems in Holland, Russia and America are compared by a student who experienced all three in the March issue of *The Physics Teacher*. He attended elementary school in Russia and high school in Holland and the United States. In his opinion the main advantage of the American education system is the possibility to choose subjects according to your interests and your level. He found his physics classes interesting but found the problems did not require intensive thinking and standardized tests checked mainly memorization. In Russia the demands of math and science courses are very high and there is no avoiding them even if you do not plan to pursue a career in science. Dutch students focus on language, and after VWO (pre-university) school, students speak four or five languages.

•“Dilemma of a science educator” is the title of an essay in the May issue of *Physics Education*. The author says that when he was at university, the best way to get a decent mark in a physics practical was to rig the results. There was no way–using the apparatus provided–to get anything like the answer in the textbook. Components were missing, instrument needles were sluggish with rust, batteries were flat and crocodile clips were bent beyond usefulness. But as students mysteriously produced ever more accurate results, there was no reason for the lab technicians to check on the quality of the apparatus. And so the vicious circle continued. The way to pass was to work backward. First you looked up the answer in the book, then drew the appropriate straight-line graph and scattered some points around it, then finally you deduced what readings you should have taken.

There are many examples in research. About 100 years ago, Robert Millikan devised a wonderful experiment to measure the charge on an electron–by placing charged oil drops into an electric field. Millikan used this method to show that charge does not vary continuously, but instead goes up and down in steps–those steps being the charge on one electron. Millikan’s method was sound, but, just to be sure that he quelled potential doubters, he was choosey about the results he published. According to a Wikipedia article on this issue, this selectivity ‘enabled Millikan to quote the figure that he had calculated e to better than one-half of one percent; in fact, if Millikan had included all of the data he threw out, it would have been to within 2%.

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