INVESTING IN THE IMPROVEMENT OF ELEMENTARY SCIENCE EDUCATION

JULY 27, 2007

Inverness Research Associates

This is a presentation made by Dr. Mark St. John to the staff of the members of the United States House of Representatives who are part of the STEM Caucus (Science, Technology, Engineering and Mathematics Education Caucus). The briefing was held in the Rayburn Office Building in Washington, DC on July 27, 2007. Also presenting were Harold Pratt and Dr. Jerry Pine.

Inverness Research Associates

- Study investments in the improvement of education
- Long history (three decades) of studying elementary science programs
- Now involved in helping to create a consortium in San Francisco Bay Area that supports improvements in elementary science education
- Want to advocate today for targeted federal support for the improvement of elementary science education

Inverness Research Associates is a research group that is based in the small town of Inverness, CA just north of San Francisco. Under the leadership of Dr. Mark St. John, the group has been involved in the study of educational improvement efforts for the past thirty years. It is important to note that Inverness has focused its efforts on understanding the investments that outside agencies and foundations make in the improvement of K-12 education. Inverness has studied many different initiatives that have focused on elementary science education and has had the opportunity to document the progress of over a dozen school districts who have undertaken multi-year elementary science reform efforts.

Main Messages

- Elementary science education is important
- Current status in the US – weak
- Good programs are achievable
- A domain that is "investable"
- Federal investment is critical
- Role of the federal investment is to create capacity for ongoing improvement

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here are several main messages I would like to convey today. One is that elementary science education is a very important domain of education. It not only sets the foundation for later science learning, but it also develops key intellectual skills, attitudes and habits of mind. Although this domain is important, it is not in good shape. The teaching of elementary science in this country can fairly be described as weak, or even very weak.

This is unfortunate because this is a domain where it is possible to achieve high-quality instruction on a large scale. Work over the last three decades has shown us how to engineer high-quality programs in all kinds of settings. There is no reason for poor instruction except the lack of will.

This is also a domain where external investment can bring strong returns in terms of benefits to teachers and students. More than any other STEM domain (middle school science, high school science, and mathematics at all levels), I would argue that we know how to design and implement high-quality large-scale programs. And the federal investment is critically important to creating those programs. This is a domain where federal

money, in partnership with state and local money, can create what we call an "improvement infrastructure" for elementary science education. This improvement infrastructure can effectively support local counties and districts in creating and sustaining high-quality elementary science programs. Thus, there is an important federal role in helping states, counties and local districts gain the capacity for ongoing improvement in elementary science education.

In what follows I will elaborate and emphasize each of these messages.

Elementary Science Education is Important

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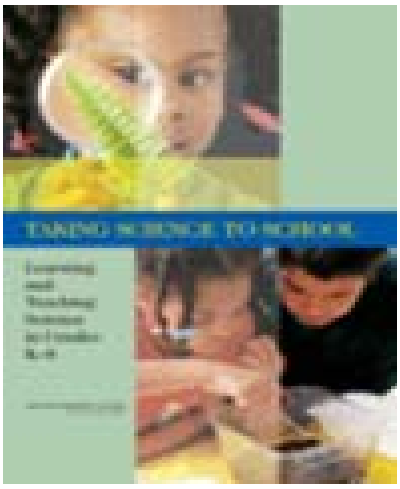
There is increasing consensus today about the importance of science education to the nation's well being. Perhaps no other time since the Sputnik era has the nation realized the danger of having inadequate opportunities for its students to learn mathematics and science. Moreover, science education is not only important to the nation, but also to the well-being of each individual as they educate themselves for their future careers.

Research



Taking Science to School: Learning and Teaching Science in Grades K-8

Committee on Science Learning,
Kindergarten through Eighth Grade,
Richard A. Duschl, Heidi A. Schweingruber,
and Andrew W. Shouse, Editors

There has been a great deal of research over the last three decades that has helped us understand what science is and how it should be taught. The National Academy has published many different important summaries of research with the most recent one focusing on learning science in grades K-8. I will not detail all the research that is relevant to making the argument that elementary science is important, but I have attached to this presentation an appendix with at least a few informative and important references.

Potential Benefits of Elementary Science Education

- Foundation to further science learning
- Foundation to further intellectual development
- Contribution to literacy
- Engagement and excitement in school

Perhaps one might summarize the research in the following way. First, elementary science provides a critically important foundation to the learning of science in later years. It may well be a mistake to think that students can simply skip science until their adolescence and then be able to acquire the conceptual and attitudinal underpinnings of scientific thought and practice. Moreover, elementary science education, when done well, not only helps students understand science, but it also equips them with broader skills and habits of mind. The ability and propensity to ask questions, observe closely, look for evidence and make rational arguments are all by-products of rich science learning experiences at a young age.

It is also important to point out that in the last five years there has been a lot of work to show that the learning of elementary science and the learning of writing and reading can be made highly symbiotic. Writing in science journals and reading science, for example, can help students develop strong literacy skills; writing about science and reading science also helps students understand the science much better.

Finally, it is important to say that high-quality science learning experiences, which engage students in hands-on explorations, can be a strong antidote to schooling that is heavily drill-oriented and passive. Many of the best learning experiences that we have observed in our hundreds of classroom visits have occurred in elementary science lessons.

Research

> We should not overlook the likelihood that life experiences before eighth grade and in elementary school may have an important impact on future career plans. ….To attract students into the sciences and engineering, we should pay close attention to children's early exposure to science at the middle and even younger grades. Encouragement of interest and exposure to the sciences should not be ignored in favor of an emphasis on standardized test preparation…
>
> Tai, R.H.; Liu, Chrinstine Qu Liu, Maltese, Adam V.; Fan, Sitano. (2006). Planning Early for Careers in Science. *Science* (312)1143-1144.

Recently published in *Science Magazine* is a research report that points out the importance of early engagement with and interest in science. By studying those who major in science in college, this study determined that scientific interest at a young age was a better predictor of those who chose to pursue science in college than was mathematical ability. It is not only achievement that matters; rather interest in the subject is also critical. I was at a science conference in Europe recently where there was a sense of crisis in science education. But, unlike the United States, they worried not so much about achievement as the fact that many youth were coming out of school disinterested and turned off by science. I think we would do well in this country to pay more attention to this dimension of learning.

Current Status of Elementary Science Programs in the US:

WEAK

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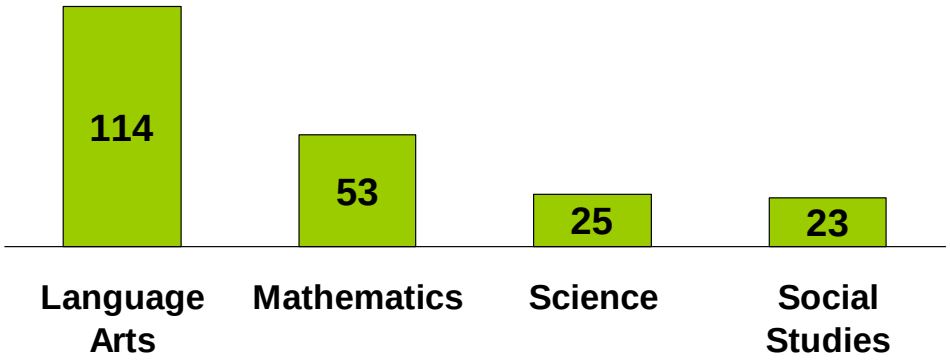
Over the past twenty-five years our research group has been engaged in many studies of science classrooms. We have had the chance to work with Iris Weiss and Horizon Research, a group that has studied the quality of science classrooms nationwide, as well as studied the quality of classrooms in NSF-funded projects. They have also documented over many years how much science is being taught in the nation's school system.

The quantity of elementary science teaching

Science is taught less than other subjects

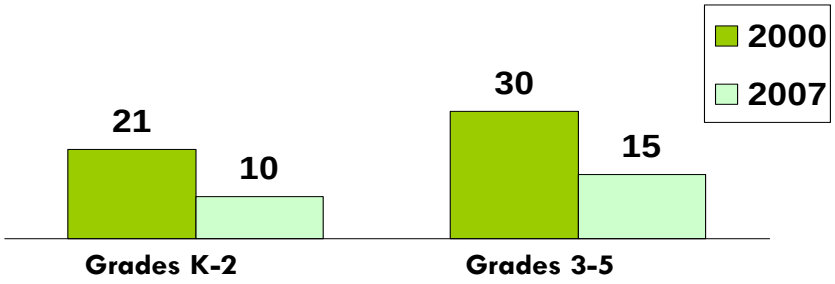


Average minutes per day of instruction

Sherri Fulp. 2000 National Survey of Science and Mathematical Education: The Status of Elementary Science Teaching

These data were gathered in the year 2000. At that point, on average, in grades K-6, science was being taught about 25 minutes per day. This is less than half the time spent on mathematics and less than one quarter the time spent on language arts.

Science instruction time may have decreased by half since 2000



Average minutes per day of science instruction

Sherri Fulp. 2000 National Survey of Science and Mathematical Education: The Status of Elementary Science Teaching and *Bay Area Consortium for Improving Science Education*

In a recent study carried out in the San Francisco Bay Area, over one hundred school districts were surveyed about their elementary science programs. These districts reported much less science being taught than evidenced in the 2000 national study. On average in the earliest grades (K-2) only ten minutes of science was being taught; in grades 3-5, the figure rises to 15 minutes.

There are two other considerations that are important to note here. One is that science is often taught at the end of the day or during that part of the year "when testing is over". The other thing to note is that these small figures are averages. That means there are very many classrooms where science is not taught at all. And, sadly, many of these classrooms are found in urban and other low SES settings where schools may be under pressure from NCLB requirements. Hence, the students who could benefit most from a high-quality science program are the ones most likely to be deprived of such an opportunity.

The Impact of NCLB

According to the new survey, the average change in instructional time in elementary schools since the law's enactment has been 140 additional minutes per week for reading, 87 additional minutes per week for math… (and)

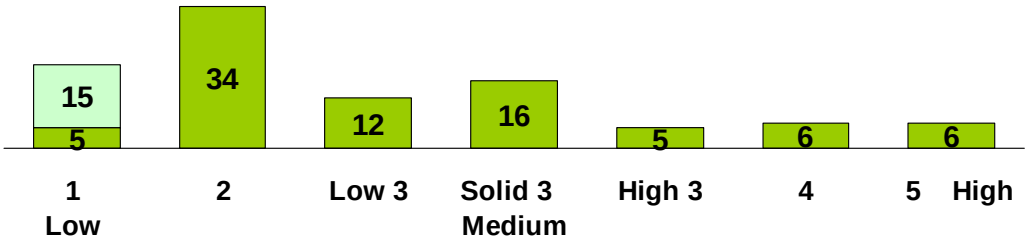
75 fewer minutes for science per week

Center on Educational Policy Report quoted in NY Times Articles, July 25, 2007

Another recent study confirms the fact that science education at the elementary levels is losing ground to other subject areas.

The quality of elementary science teaching

Most elementary science lessons are of low quality

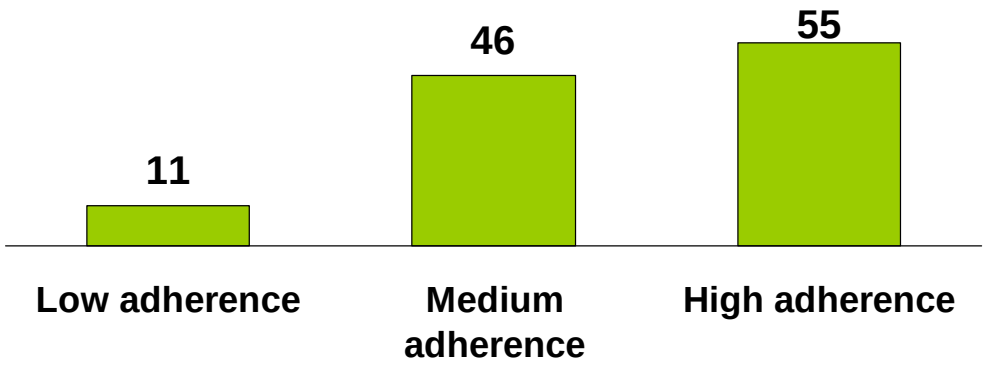


Ratings of the quality of grades K-5 science lessons (% of lesson ratings)

In a study of several hundred classrooms distributed around the United States, Horizon Research documented the quality of elementary science lessons. The scale above runs from 1 to 5. It is sufficient to say here that lessons which achieve ratings of 4 and 5 are very good science lessons that are motivating, accurate and intellectually demanding. These are classrooms you would want for your own children. Yet only 12% of the lessons that were studied fell into these two categories.

At the other end of the spectrum, lessons that were rated as 1 or 2 are lessons that were either very flawed, or they are lessons that lack engagement, accuracy, and/or significance. Over fifty percent of all lessons fell into this category. These are not classrooms you would want for your own children.

Lesson quality depends on adherence to the district program and its instructional materials

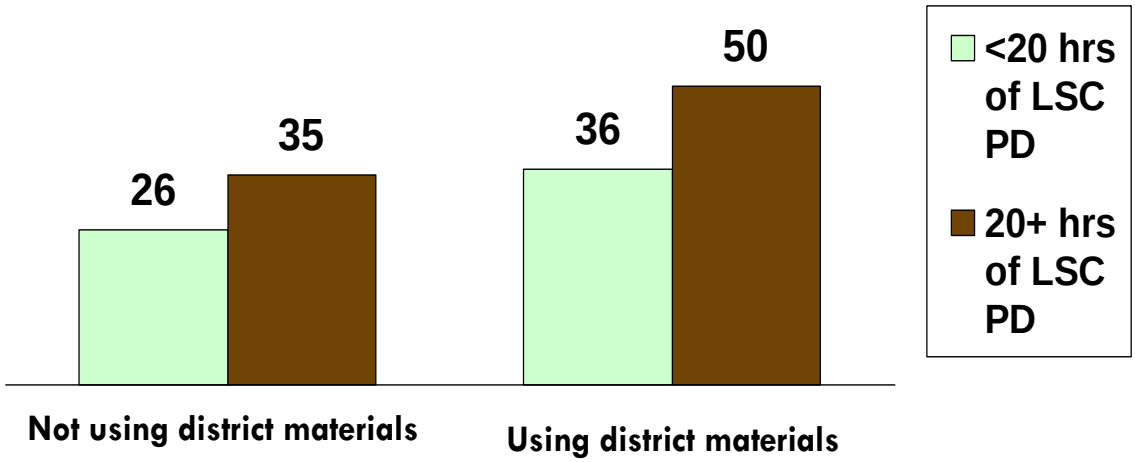


Iris Weiss. Research on Professional Development for Science Teachers (Presentation, 2006)

In their study of NSF's Local Systemic Change (LSC) initiative, Horizon research was able to compare elementary science lessons that did and did not use district-designated materials. Those classrooms that did not use materials, or did not use them as designed, were not rated highly; only 11% of these lessons were rated to be high in quality. By contrast, those teachers who used well-designed materials in the way they were intended were much more likely to be rated highly.

There is an important message here: good materials matter a lot in elementary science. The use of good materials as part of a district program greatly improved the quality of science teaching. Unfortunately, the vast majority of elementary classrooms do not have this level of support, and teachers are forced to improvise lessons and gather their own materials. And, unfortunately, only about 11% of them can be expected to produce high-quality lessons for their students.

Lesson quality is associated with both PD and use of district-designated materials



Percent of lessons receiving high ratings

Iris Weiss. Research on Professional Development for Science Teachers (Presentation, 2006)

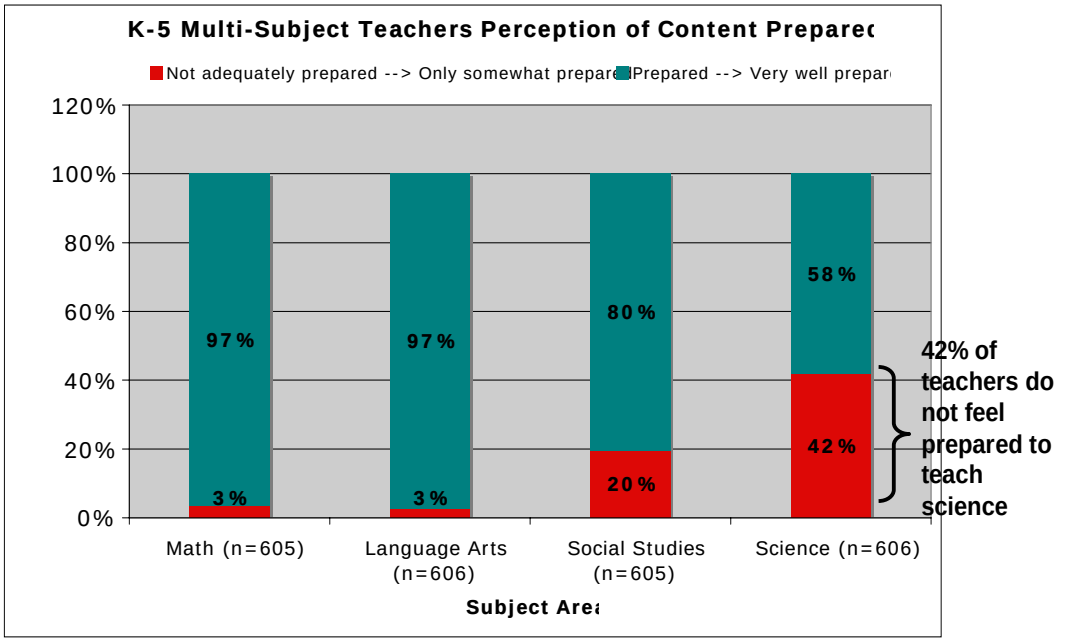
This graph makes an additional important point—that professional development also matters. The bar on the far right shows that teachers who use high-quality materials in a disciplined way AND who receive more than 20 hours of professional development are rated the highest in terms of quality. In fact, fifty percent are rated as having high-quality lessons. By contrast, those who do not use the district-designated materials, and who have received less professional development (less than 20 hours) are only half as likely to be rated highly.

The point here is that the combination of professional development and the use of well-designed materials greatly increases the likelihood of teachers producing high-quality lessons.

The supports for teachers of elementary science

We know that teachers who are well-supported are much more likely to produce high-quality science lessons. So the question becomes: how well are U.S. teachers supported in their efforts to teach elementary science education?

Many elementary school teachers feel unprepared to teach science

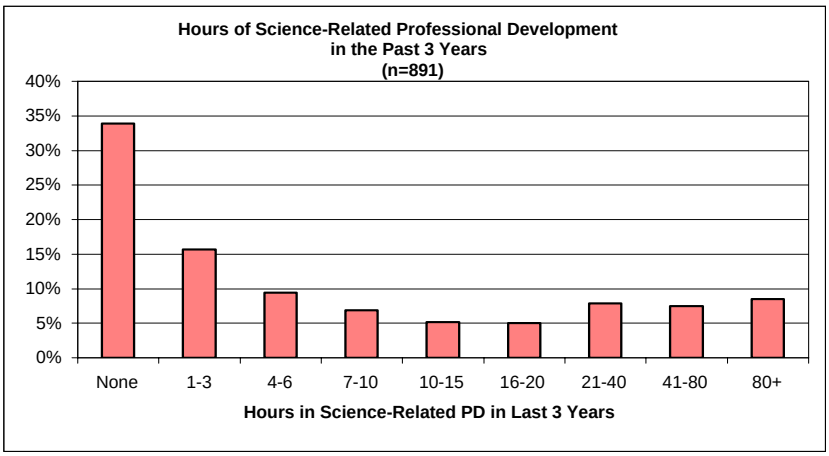


Bay Area Consortium for Improving Science Education

In the recent study of Bay Area school districts, over one thousand elementary school teachers were surveyed about their needs for support. Importantly, they responded that science was their subject area of least confidence. Forty-two percent of all elementary school teachers admitted that they did NOT feel prepared to teach science well. These results are consistent with earlier national studies that document a similar lack of confidence and preparation in elementary science teaching.

Most teachers receive little professional development

- 35% of teachers report having NO science PD over the last 3 years
- 60% of teachers report having had less than 6 hours of science PD over last 3 years

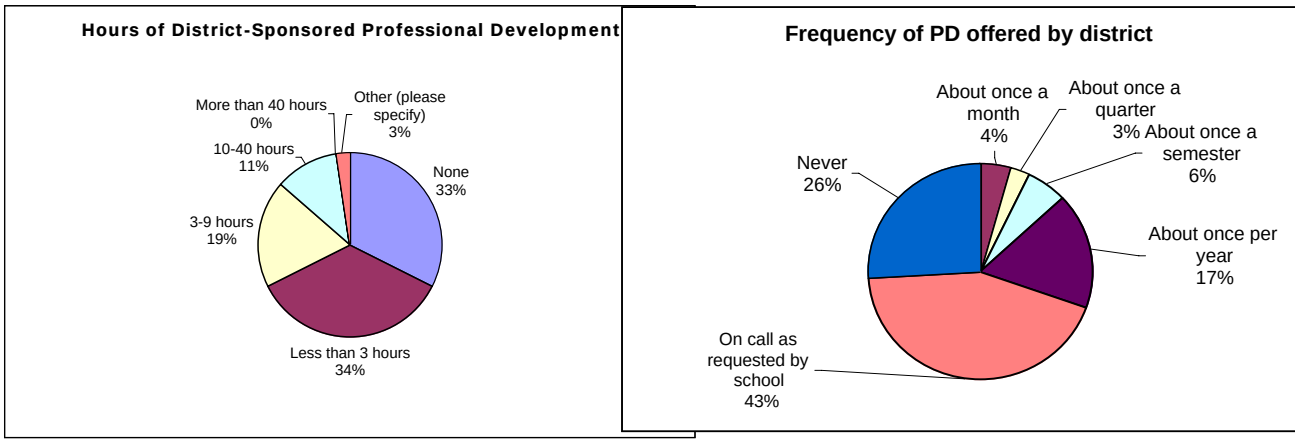


Bay Area Consortium for Improving Science Education

In the study of Bay Area districts, over one third of the teachers received NO professional development in science in the last three years. Over 60 percent of teachers received less than 6 hours over the last three years. But it is also interesting to note that there are smaller numbers of teachers who received large numbers of hours of professional development. These are teachers who had the opportunity to engage in intensive multi-year NSF-funded professional development programs. There are fewest teachers who receive 10 to 20 hours of professional development per year. This is currently a professional development situation where there are "haves" and "have-nots".

Most districts provide little professional development

- Most county offices provide no to minimal science PD
- Over 60% of districts surveyed offer no or very little (<3 hrs) PD and very infrequently

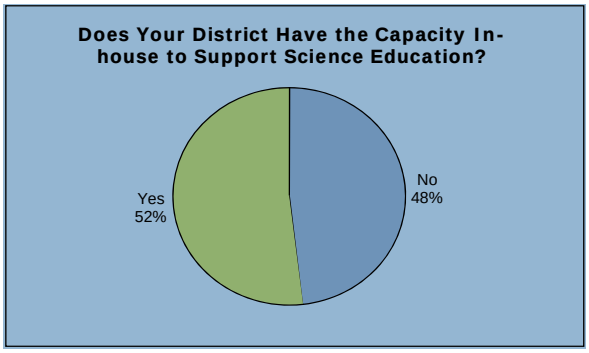


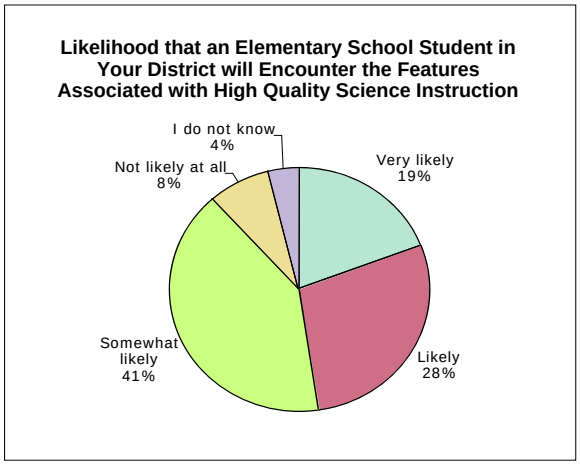
Bay Area Consortium for Improving Science Education

One reason for the lack of teachers' involvement in elementary science professional development is that districts do not offer it. In the Bay Area, which is not atypical of the rest of the country in this regard, neither counties nor districts provide much professional development in elementary science.

Districts and counties are unable to provide the needed supports to their teachers

- 48% of districts indicate they cannot support science education in-house





- About half the districts do not think their students are likely to encounter high quality science instruction.

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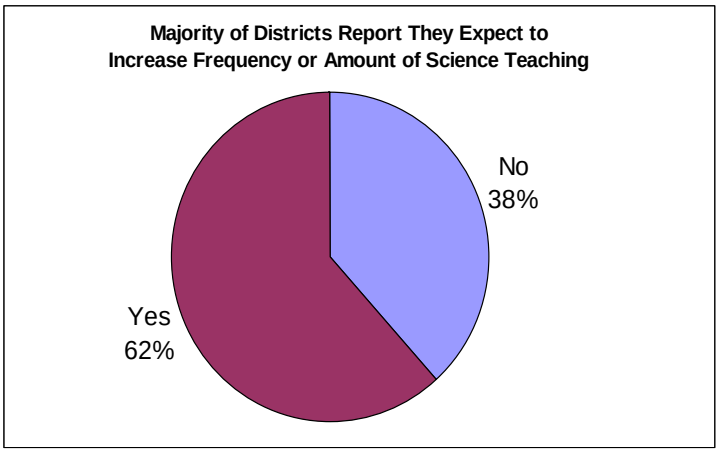
Most districts and counties do not offer professional development because they lack the capacity to do so.

Over the past decade, with the increased emphasis on reading and mathematics, many districts have lost their elementary science specialist, and counties have similarly lost their professional development leaders in elementary science.

The net result is that over half the Bay Area districts are not confident that their students will encounter high-quality science learning experiences. Again, from our experience of studying elementary science education around the country, this unfortunately is an all too common sentiment.

Growing Receptivity to Efforts to Improve Elementary Science Education

- Current opportunity with curriculum adoption and state science assessments



- Improvement strategies:
  - "increase time on science"
  - "use science resource teachers"
  - "leverage passionate science teachers"
  - "more PD with new curriculum"
  - "seek science grants"
  - "integrate science with math/L.A."

Bay Area Consortium for Improving Science Education

And yet there is some good news. Because of the adoption cycle, and because science is now factoring into the NCLB requirements, districts are interested in improving their elementary science programs. While they do not have the internal capacity to do so, they are eager to participate in larger efforts that can help them support their teachers in providing better science instruction at the elementary level.

Good Elementary Science Programs are Achievable on a Large Scale

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Often there are educational experiments that study promising strategies at a small scale. Once proven, the hope is that such strategies can "scale up". Elementary science has a different history. There are many examples of school districts that have instituted and sustained elementary science programs that are coherent, high-quality, and district-wide.

Key Supports Teachers Need

- Curriculum
- Instructional Materials and Support Centers
- Professional Development
- Assessments and Feedback
- Leadership and Mandate

There is no secret about what it takes to install a strong elementary science program. A good well-rounded curriculum that is supported by well-designed instructional materials is the centerpiece. These materials in turn need to be supported by district or regional **science materials centers** that assures teachers will have the materials they need to teach science.

A wide range of professional supports is also key so that teachers have the opportunity to learn how to teach their science kits, develop deeper understandings of content, become expert in facilitating student inquiries, learn how to use science journals, and become better at assessing their students' learning. Teachers also need good assessments and other ways to get feedback on their teaching. Finally, teachers need to be supported by strong science leaders and also administrators who can help them improve their practice and make the case for science in their districts. The administrative leader in the district needs to make science a priority and establish a clear mandate for its teaching.

With these elements in place, high-quality elementary science instruction becomes a high, rather than a low, probability event.

Districts where strong elementary science programs have been established

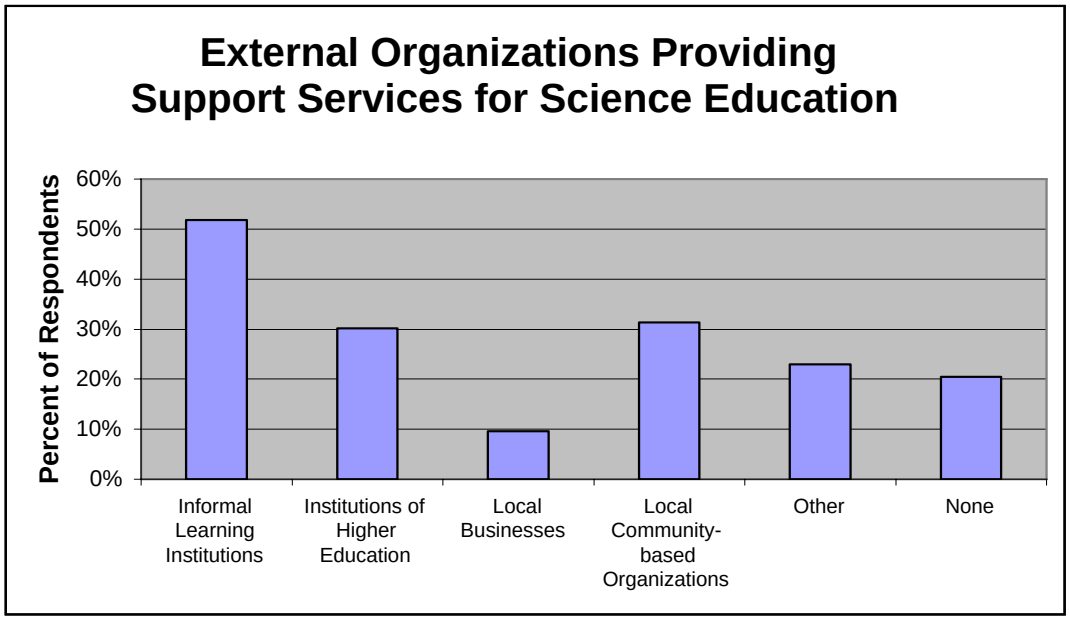
- Pasadena, Ca
- El Centro, CA
- Buffalo, NY
- Seattle, Wa
- Oneida, TN
- Las Vegas, NV
- Gilbert, AZ
- Highline, WA
- Anchorage, AK
- Mesa, Az
- Jefferson County, Co
- San Francisco, CA

The districts on the left are all districts that we have studied in the last twenty-five years. All have succeeded in establishing high-quality elementary science programs.

The districts on the right also succeeded in creating district-wide elementary science programs and many have assumed national leadership roles, providing a model and assistance for many other districts.

The case of Gilbert, Arizona is an illuminative one. They started out as a typical district where elementary science was taught in a haphazard way, if it was taught at all. With the help of nearby Mesa, Arizona, and with a strong local science leader working at the district level, Gilbert began to put the key elements in place. Once a foundation was set, Gilbert was able to successfully compete for an NSF LSC grant. Five years later, Gilbert students now receive a steady daily diet of hands-on science.

Key Role of Outside Improvement Organizations



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There is another important point to be made here about providing districts with help as they seek to support their teachers in improving elementary science instruction.

Science is fortunate because there are many external organizations that have both science and pedagogical expertise in teaching science. There are over 300 science museums in the United States capable of helping support districts and teachers. There are many more universities and colleges who have expertise and interest in helping schools. There are also other agencies, labs, and centers that are available to help. Together these organizations provide a kind of national infrastructure that can be utilized in creating the supports that districts and teachers need if they are to be successful in improving elementary science education.

The Role of the Federal Investment in Elementary Science Education

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The improvement of elementary science in the United States will require external investments that are additional to the normal state and district spending. But we argue this is a domain that is high invest-able. The federal government can play a key role in helping create the national infrastructure needed to support states and districts in doing the work of improvement.

The Federal Role in Education

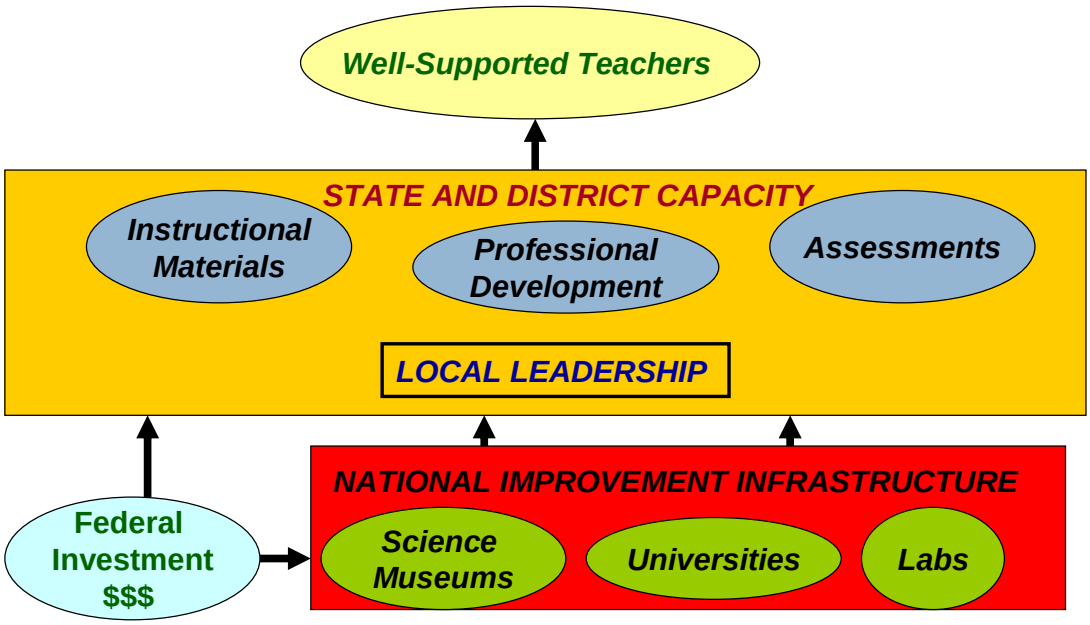
- ~ 7 % of all funding for K-12 education
- Two key functions of federal funding
  - To ensure equity and access
  - To create capacity for ongoing improvement

The K-12 educational system in the United States is an enterprise with a total cost in the realm of $500 billion dollars. Only about 7 or 8 percent of this cost is borne by the federal government.

To my mind, the federal government has two critical roles to play. One is to ensure equitable opportunity to learn for all students. The other is to help create the national capacity so that education can continue to improve its quality and effectiveness.

Elementary science education is a domain within which federal investment can greatly advance both of these goals.

The Logic of the Federal Investment



As evaluator, we are always looking for the "logic model" or "theory of action" that links investments to benefits. This diagram shows in broad terms the theory of action for the federal investment in elementary science education. The logic goes like this:

If you want student achievement in elementary science, we know that we need well-supported teachers. This, in turn, means that we need to have states and districts that are capable of providing teachers with the critical supports of good curriculum, well-designed instructional materials, professional development, good assessments, and, above all, strong local science leadership.

What is needed, then, is what we call a "national improvement infrastructure" for elementary science. This infrastructure, like a physical infrastructure (e.g., electrical grid, etc.), needs to be robust, ongoing, and well maintained. But rather than helping in operating the system, this

improvement infrastructure can provide ongoing support for the continual improvement of elementary science education. Comprised of science museums, universities, national labs, and other agencies, the improvement infrastructure is always seeking new ways to help build the capacities of states and districts so that they can effectively support teachers in improving their science instruction.

Hence the federal role is not to do science education. It is not even to take on the responsibility of local improvement of science education. Rather the federal government has the role of creating and maintaining a **national improvement infrastructure** which, in turn, can continuously help states and districts help their teachers.

Supportive Federal Efforts in the Past

- NSF: Local Systemic Change Projects (LSCs)
- NSF: Center for Urban Science Education Reform (CUSER)
- NSF: State, Urban and Rural Systemic Initiatives (SSI, USI, RSI)
- NSF: Instructional Materials Development
- NSF: Curriculum Implementation Centers
- NSF: Math Science Partnerships (MSPs)
- Dept of Ed: Eisenhower – national, state and local

In the domain of elementary science there have been many important and successful federal programs in the past. Each of these programs has pursued slightly different strategies but they all have had the effect of supporting the creation and operation of a national improvement infrastructure.

The Federal Investment: Cost parameters

- To build and sustain an elementary science program
  - ~ $500 per teacher per year
  - ~ $25 per student per year
- Funds to be shared by outside partners and districts
- Costs for the entire United States
  - $1B per year
  - Federal Cost (50%) - $500 million per year
  - Focus on 50% of districts - $250 million per year
- Need for steady long-term funding

Let me say something about the level of investment that is needed to make a significant difference to elementary science teaching in the United States. Based on past initiatives we can estimate that it takes roughly $500 per teacher per year to develop a strong science program in a school district. This is equivalent to $25 per student per year. (Note that total education spending per student is around $7,000 per year.)

If the federal investment were 1 billion dollars per year, this would theoretically allow full development of elementary science programs in every district simultaneously. This is clearly too ambitious a goal, and not practical given the limited current capacity of the national improvement infrastructure.

If the focus was on half the districts in the U.S., (those most needy), and if the federal contribution were limited to 50% of the cost (with states and districts matching it), the cost per year would fall to $250 million. Even one

half or one quarter this amount would allow for significant improvement work to proceed.

What is equally important to the amount of total investment is the time scale. Too often we have tried to invest large amounts of money for short periods of time with the hope of "fixing the problem". I believe that the idea of investing in infrastructure presents a different and more promising approach. Investments in infrastructure require steady and cumulative investment. It is better to have smaller amounts invested over longer periods of time. The goal is not to fix the problem once and for all, but rather to develop an enduring national capacity for ongoing improvement and support.

Promising Strategies for the Federal Investment

- Regional and state-level consortia
  - Districts, improvement organizations, funders
- Professional development infrastructure grants
  - LSC model
- Curriculum development and curriculum implementation centers
- Teacher leadership networks (a lá NWP)
- Capacity building grants for districts and improvement organizations

The strategies to be pursued matter as much as the total amount of federal investment. Fortunately, much has been learned from previous investments about the best ways to use federal dollars to build state and local capacity. The strategies shown here are complementary and focus on different elements and configurations of capacity.

Regional and local consortia can bring together museums, universities, counties, school districts and local funders to create effective support systems for local schools and teachers. (We are currently working on one such Consortium in the Bay Area.)

The NSF LSC initiative provided a good model for developing strong district-level science leadership capacity and full implementation of high-quality curriculum.

The NSF curriculum development and curriculum implementation centers have proven essential in helping districts learn about and have access to well-designed instructional materials.

The National Writing Project (NWP) has been a model federal program that each year supports nearly 10,000 teacher leaders in helping another 100,000 teachers per year improve their teaching of writing.

Finally, in an effort to build a strong national improvement infrastructure, the federal government can support work that seeks to build the capacity of the key improvement organizations involved in supporting states and districts. This work can involve organizational development, professional development, research and evaluation.

Finally, it is important to note that federal agencies such as NSF, NASA, and the U.S. Department of Education need to have the time and resources to carefully plan and pursue long-term developmental strategies such as these. It makes little sense to quickly design RFPs based on a singular notion or idea. The development of sound infrastructure requires thoughtful planning and steady investment.

Main Messages

- Elementary science education is important
- Current status in the US – weak
- Good programs are achievable
- A domain that is "investable"
- Federal investment is critical
- Role of the federal investment is to create capacity for ongoing improvement

So, I end with my same main messages. Elementary science education is important – too important, in fact, to tolerate the current weakness in our national educational system. It is a domain with a proven track record and good knowledge base for replicating successes. It is a domain where federal investment is important and where such investment can bring high rates of return. This work will require years of steady effort, but it is very likely to bring tangible benefits to millions of students. I urge Congress to support the NSF, Department of Education and other agencies in making targeted and strategic investments in elementary science education.