Creating a Well-prepared Science, Technology, Engineering and Mathematics (STEM) Workforce: How Do We Get from Here to There?

April 2009

Creating a Well-prepared Science, Technology, Engineering and Mathematics (STEM) Workforce: How Do We Get from Here to There?

Symposium Summary

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February 2, 2009
Sacramento, California

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California Teacher Advisory Council (Cal TAC)

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Center for the Future of Teaching and Learning (CFTL)
California Council on Science and Technology (CCST)

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CalTAC
California Teacher Advisory Council

Letter from Cal TAC, CCST and CFTL Leadership

On February 2, 2009, a group of California science and mathematics teachers, policy makers, researchers, and representatives from business, industry, and higher education met to consider how California could do a better job of preparing today's students for the future STEM – science, technology, engineering and mathematics – workforce. The Symposium was co-sponsored by the California Council on Science and Technology (CCST) and the Center for the Future of Teaching and Learning (CFTL), as well as the California Teacher Advisory Council (Cal TAC).

Cal TAC is a group made up of highly accomplished teachers who are working to bridge the gap between theory and practice so that educational policy decisions can be made with a keen ear toward the practicalities and realities of authentic classroom experiences. These award-winning teachers volunteer their time at both the state and local levels to ensure student success in science, mathematics, technology, and engineering.

The following summary report captures the major issues considered by symposium participants as well as the ways in which California can work effectively toward strengthening STEM teaching and learning. Presented against the backdrop of voices from the classroom from members of Cal TAC, two main themes emerged: the need for appropriate and meaningful assessments of science and math teaching and learning to guide instruction, and the need for professional development to deepen subject matter knowledge and encourage artfully taught, inquiry-based learning in the science classroom.

These themes grew out of deeply held beliefs about what constitutes powerful science teaching, a set of concerns about California's economic future and a compelling rationale for immediately attending to good teaching in science and mathematics. As the report notes, "high-caliber science and math education pays many dividends. It not only imparts precisely the critical thinking and problem-solving skills that modern business and industry need to compete in the global marketplace, but also promotes the rational decision-making that yields thoughtful, productive citizens." We agree.

We hope you find this report a useful resource in your efforts to improve leadership, teaching and schools. To see this and other timely reports related to quality teaching, please visit CCST's and the Center's websites at www.ccst.us and www.cftl.org.

Sincerely,

Anne Marie Bergen
Chair, Cal TAC

Margaret Gaston
President, CFTL

Susan Hackwood
Executive Director, CCST

Executive Summary

On February 2, 2009, a group of California science and mathematics teachers, policy makers, researchers, and representatives from business, industry, and higher education met to consider how California could do a better job of preparing today's students for the future Science, Technology, Engineering, and Mathematics (STEM) workforce. The meeting was co-sponsored by the California Council on Science and Technology (CCST) and the Center for the Future of Teaching and Learning (CFTL), as well as the California Teacher Advisory Council (Cal TAC).

The STEM workforce is one on which the state — and the nation — will depend for innovation and economic prosperity. Unfortunately, as keynote speaker Bruce Alberts noted, decades of warnings about the erosion of quality science and math education have gone unheeded, both nationally and in California.

Progress in Science and Math Education Requires Empowering Our Best Teachers

Dr. Alberts observed that high-caliber science and math education pays many dividends. It not only imparts precisely the critical thinking and problem-solving skills that modern business and industry need to compete in the global marketplace, but also promotes the rational decision-making that yields thoughtful, productive citizens. The bad news is that most science and math education in California (and throughout the United States) falls far short of this potential, driven in part by tests that measure memorization and familiarity with definitions rather than any type of understanding or ability. The tests, in turn, are dictating textbooks and classroom practices that conspire to bore disinterested students – many of whom are turning away from science and math in droves, before they ever have a chance to discover how exciting and relevant these subjects can be.

The Need for STEM Workers is Increasing, but the Supply is Shrinking

Susan Hackwood, CCST's Executive Director, provided an update on the current status of California's STEM workforce. She noted that despite projected growth in science and technology occupations, the supply of graduates in these fields is shrinking. California and the United States need a competent, creative science and technology workforce to stay competitive and advance innovation, but both the state and the nation remain far from being able to produce this type of skilled workforce. Doing so will require boosting the development of skilled human talent that powers innovation, which in turn will require improving the economic environment and institutions that support innovation, while also responding to the changing global marketplace.

Tomorrow's STEM Workforce Requires a Supply of STEM-Discipline Teachers Today

Margaret Gaston, CFTL's President and Executive Director, briefed the group on the current status of STEM teaching and learning in California. Based on state tests, overall student achievement in science and math has been on the rise, yet California lags behind national averages in both science and math tests administered to 4th and 8th grade students. She noted that reversing these trends will require meeting three major challenges:

- Creating an adequate supply of STEM-discipline teachers;
- Making sure those teachers are fully prepared with a deep understanding of subject matter content and sound pedagogical skills; and
- Distributing them evenly across schools and districts, so that every child has a chance of being in a classroom with a great science or math teacher.

Building a System, Creating Connections for Effective Professional Development

When CFTL and CCST joined forces to launch Cal TAC in 2005, they were creating a California version of a similar national model that convened teachers to bring real-world classroom experience – the "wisdom of practice" – to policy makers and others whose decisions affect the quality of science and math education. At the STEM Workforce symposium, teachers joined policy makers, business and industry representatives, researchers, and representatives of institutions of higher education in small group discussions to consider more system-wide approaches to improving the future STEM workforce.

Two main themes emerged from these discussions: the need for appropriate and meaningful **assessments** of science and math teaching and learning in the K-12 system, and the need for **professional development** to encourage artfully taught, "inquiry-based" learning in the classroom.

The Lessons of a Flopping Fish

Mid-way through the Symposium, Cal TAC's Chair, Anne Marie Bergen, gave participants a quick lesson in how to engage students in scientific inquiry. Around the conference room, Symposium participants could be seen peering intently into their palms, where a translucent plastic fish flopped and curled. The room buzzed with speculation and chuckles. Was body heat making the fish move so convincingly? Moisture? A combination of both? Neither?

Ms. Bergen had asked the meeting participants to perform some of the tasks she routinely asks of her elementary school science students: observe, compare, speculate, hypothesize, and discover. She asks herself, "How do I hook them, connect with them?" Quoting Dr. Anthony Witham, she said,

> "Teachers who inspire perceive their task not as one of implanting facts, but to place the subject in front of the learner and through enthusiasm, imagination, and inventiveness, awaken the appetite of the learner."

The urgent task of awakening the appetite of California learners for science and math education occupied Symposium participants throughout the meeting. In each of the presentations and discussions, they identified specific opportunities to work together to redefine science and math education, in the hopes of building something stronger and better than what currently exists. As new state policies are being considered and evaluated, bringing together the voices of knowledgeable and accomplished teachers, business and industry representatives, and policy makers — as the Symposium did — is an essential step in that process.

Introduction

In 1957, the Soviet launch of the world's first orbiting satellite profoundly challenged America's view of itself as the world leader in both space technology and missile development. Reflecting the national mood, then-Congresswoman Clare Booth Luce described the satellite's beep as "an intercontinental outer-space raspberry to a decade of American pretensions that the American way of life was a gilt-edged guarantee of our national superiority." The shock of Sputnik unleashed a competitive spirit that galvanized the U.S. space program, leading to the creation of NASA the following year.

In the decades since, investments in science and mathematics education as a foundation for American competitiveness have waxed and waned. Since at least the early 1990s, various task forces and committees have been sounding the alarm that American students are not receiving the academic preparation and encouragement that are prerequisites for innovative work and contributions in science, technology, engineering and mathematics (STEM). These concerns are particularly acute in California, home to Silicon Valley and several major scientific research laboratories.

On February 2, 2009, a group of California science and mathematics teachers, policy makers, researchers, and representatives from business, industry, and higher education met to consider how California could do a better job of preparing today's students for the future STEM workforce. (A complete list of attendees is provided in Appendix A.)

The Symposium was co-sponsored by the California Council on Science and Technology (CCST) and the Center for the Future of Teaching and Learning (CFTL), as well as the California Teacher Advisory Council (Cal TAC). CCST is a nonpartisan, impartial, not-for-profit corporation established 20 years ago to offer expert advice to the state government and to recommend solutions to science and technology-related policy issues. CCST's core support comes from California's major post-secondary institutions, which provide important backing, support, and resources to CCST. CCST is governed by a Board of Directors composed of representatives from its sponsoring academic institutions, from the corporate and business community, as well as from the philanthropic community. Together, these members are helping both the public and private sectors find answers to the important science and technology-related issues facing California.

CFTL is a public, not-for-profit organization dedicated to strengthening teacher development policy and practice. With its research partners, the organization promotes effective teacher development through data collection and analysis, state and national policy and legislative initiatives, and models for effective practice.

CCST and CFTL joined forces to form Cal TAC in 2005 as a means for bringing real-world classroom experience — the "wisdom of practice" — to policy makers and others whose decisions affect the quality of science and math education in California.

Symposium Goals and Structure

The Symposium organizers' main goal was to spark a conversation about how best to prepare students at every stage in the public school system — from K-12 through community colleges, 4-year institutions, and universities — to be ready for careers in STEM fields, from the perspective of business and industry.

In addition to producing students ready for careers in STEM fields, a related goal was to ensure that California's public school system also yields students who are "STEM-literate." STEM literacy describes the majority of students who may not proceed to advanced study or careers in STEM fields, but still have enough background and preparation to understand basic scientific and mathematical concepts and to use this understanding in their work in other fields, as well as in their daily and civic lives.

More immediately, the Symposium organizers hoped to foster a greater understanding among policy makers about the impact that education policies have on actual classroom practice and the importance that professional development has for teachers of science and mathematics.

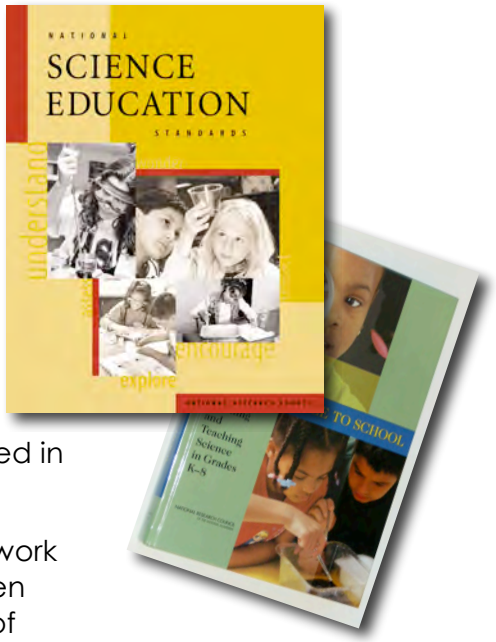
The Symposium was organized to provide forums for both information and discussion. During the morning sessions, several speakers set the stage for more detailed small-group discussions in the afternoon.

- Bruce Alberts, Professor of Biochemistry and Biophysics at the University of California, San Francisco (UCSF) and Editor-in-Chief of *Science* magazine, delivered the keynote address, reflecting on how **progress in science and math education requires empowering our best teachers** and heeding advice from the "shop" floor.
- Susan Hackwood, CCST's Executive Director, provided an update on the **current status of California's STEM workforce**.
- Margaret Gaston, CFTL's President and Executive Director, briefed the group on the **current status of STEM teaching and learning in California** and moderated a subsequent panel discussion.

Following these presentations and a reflection by Cal TAC's incoming chair, Anne Marie Bergen, participants broke into small groups to consider what teachers need to know and be able to do to ensure student success in math and science, as well as specific suggestions for strengthening California's teacher development system in ways that support math and science education.

This Symposium summary provides highlights from each of the presentations and from the small group discussions that followed. It is designed to capture key points and suggestions generated by Symposium participants, so that others who were not present at the meeting may join them in the essential work of increasing the pool of California students who are drawn to STEM disciplines and apply an understanding of scientific and mathematical concepts in both their civic and work lives.

Bruce Alberts: Progress in Science and Math Education Requires Empowering Our Best Teachers



Bruce Alberts may be forgiven for sounding a bit impatient about renewed calls for improving science and math education. Between 1993 and 2005, he served back-to-back terms as President of the National Academy of Sciences, presiding over several efforts to redefine science education. These included *National Science Education Standards*, first published in 1996, and *Taking Science to School: Learning and Teaching Science in Grades K-8*, published in 2007.

Instead of taking the recommendations from the Academy's work and reports to heart, Dr. Alberts said, the United States has been asleep, even as the world changes around it. Our only hope of remaining a world leader is to maintain our status as the continual source of the most innovative scientific ideas — and of the new technologies that they generate.

Key Points: Progress in Science and Math Education

- A broad consensus has emerged about the value of "inquiry-based" science education and the standards that would put this type of education within reach of all students.
- Inquiry-based science education fosters an aptitude for critical thinking and problem-solving that precisely matches the workforce skills that U.S. business and industry need and want.
- In spite of this, most current science education across the United States falls far short of inquiry-based science education standards.
- The current science testing and assessment system drives science education away from inquiry-based standards and aspirations, because it is both cheaper and more efficient to test for knowledge of science terminology, rather than true understanding and ability.
- To move closer to the standards, Dr. Alberts calls for:
    - Making science education more exciting
    - Developing quality assessments
    - Seeking and listening to the "ground truth" of classroom teachers
    - Making a science out of science education, in a spirit of continuous improvement

Science Education for All: Benefits for Business, Industry, and Democracy

Dr. Alberts argued for yet another wake-up call: one that focuses on science education for everyone. Through science education geared to *every* student, three ambitious goals could be realized:

- All children (even those who do not become scientists) could acquire the problem-solving, thinking and communication skills that scientists develop through their training – skills that many businesses and industries prize.
- This broadly disseminated "scientific temper", in turn, would sprinkle scientifically trained people throughout many different professions and communities, yielding the rationality and tolerance that are essential for civic discourse, wise decision-making, and a democratic society in general.
- By casting the widest possible net for talent, the United States could then generate new scientific knowledge and technology.

Inquiry-based Science Education: We Know What To Do, But We're Not Doing It

Dr. Alberts provided Symposium participants with a good news/bad news take on the current state of science education in California and across the country. In the "good news" column, a great deal of consensus has emerged about what is broadly termed "inquiry-based" science education and its expectations for students. The four main strands (which, Dr. Alberts emphasized, are equally important) are that students should be able to:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations;
- Understand the nature and development of scientific knowledge; and
- Participate productively in scientific practices and discourse.

These skills reflect an aptitude for critical thinking and problem-solving that happen to match precisely the workforce skills U.S. business and industry deem important for their workforce in general — not only for those engaged in STEM-specific pursuits.

On the "bad news" side of the ledger, however, is the fact that most current science education across the United States falls far short of these standards. Instead of an atmosphere of excitement, discovery, and inquiry, students instead are involved in a type of science education that focuses on definitions. Dr. Alberts described this all-too-common approach as "science by mentioning." Of the four strands listed above, students are only asked to "know" scientific explanations — not to move beyond that knowledge to using and interpreting what they learn, generating evidence and explanations, understanding the trajectory of scientific knowledge, or participating in any meaningful way in scientific practice or discourse.

The Role of Testing

One culprit in the move away from inquiry-based science education and toward "science by mentioning" is the role of testing. Every state, Dr. Alberts pointed out, now requires high stakes science assessments. It is both cheaper and more efficient to test for knowledge of science terminology, rather than true understanding and ability. A good test, Dr. Alberts emphasized, would motivate good teaching and learning. Instead, we are mired in the opposite: tests that create incentives for trivializing science education. Memorizing definitions instead of discovering and exploring explanations for natural phenomena makes science boring and drives students — and thus potential scientists and innovators — away from these classes. "Real science is exciting!" Dr. Alberts said, "and *completely* different from the tests and textbooks."

A Call to Action

How can this trend be reversed? Dr. Alberts' call to action includes several key elements:

- **Make science education more exciting by teaching the "missing" strands.** Early in his keynote address, Dr. Alberts described a classroom of San Francisco kindergarteners. The children don clean white socks and walk around the schoolyard. Back in the classroom, they collect all the specks that have adhered to their socks and try to determine which are dirt and which might be seeds, examining them with a simple (and cheap) microscope. They plant both the "dirt" and the "seed" specks, testing their assumptions about which are which.

  "Imagine an education that includes solving hundreds of such challenges over the course of 13 years of schooling . . . challenges that increase in difficulty as the children age," Dr. Alberts said. " . . . I believe that children who are prepared for life in this way would be great problem solvers in the workplace, with the abilities and the can-do attitude that are needed to be competitive in the global economy. Even more important, they will also be more rational human beings — people who are able to make wise judgments for their families, their communities, and their nation."

  "The best teachers need a much larger voice in helping to steer state policies in school systems, or else we will risk making the same mistakes we've made in the past."

  Dr. Bruce Alberts

- **Develop quality assessments to measure all four strands (not just the "mentioning" portion of the first strand).** Once these assessments are developed, they should be explained to the public and made widely available, at low cost — removing some of the main impediments that now stand in their way.

- **Adopt the tenets of continuous improvement, including soliciting and respecting the "ground truth" provided by excellent classroom teachers.** Dr. Alberts pointed out that 40 years ago, the American auto industry learned from its Japanese competitors that building a better automobile depends, in large part, on listening to what workers on the assembly line have to say. The lesson that the people closest to the product know the most about it spread quickly to other

industries — but has not penetrated the educational system. "Education," Dr. Alberts said, "is one of the few parts of our society that has failed to exploit this fact." Moreover, he added, "In no state does hierarchical, top-down management do more destruction than in California, because the people making the decisions don't understand what is happening in the schools."

Cal TAC and its national counterpart were created for this reason, but the wisdom from the shop floor needs to be institutionalized, Dr. Alberts said, with a continual source of feedback from the front lines built into every level of the system (including the district level). He recounted a recent visit to Singapore — a country of 5 million people with 50 staff in the central education office dedicated exclusively to the development of science and math curriculum policies. Of these 50 staff, two-thirds are outstanding teachers who serve 3-year terms and then rotate back to the classroom, keeping the classroom perspective front and center.

- **Make a science out of science education**. The National Academies' science education initiatives harvested a great deal of valuable information about how students learn science, but it also revealed how much we don't know. New research must be focused on the classroom and must build on what teachers know. Otherwise, the nation's schools will continue to be driven by the lure of the latest magic bullet.

  Fields as diverse as medicine, agriculture and transportation have settings like teaching hospitals and field sites that allow researchers, designers and practitioners to work together to observe, explain, test, document and replicate solutions to problems. The Strategic Education Research Partnership (SERP) was proposed by the National Academies in 2003 as a way to inject this type of collaboration into education, where it is largely absent. With the support of the Bechtel Foundation, two field sites have been established to explore this type of collaboration — one in the Boston public schools focusing on middle school literacy and a second in San Francisco Unified School District focusing on middle school math and science.

  Dr. Alberts hopes that the next San Francisco project will be to center the entire curriculum of a few failing schools on inquiry-based, active science learning to see how this might affect students' motivation to learn — as well as their reading, writing, and math skills.

"Science education should have a much larger role in all school systems," Dr. Alberts concluded, "but only if it's a different kind of science education than most students are experiencing today. It will require redefining science education and using continuous improvement to make our education system much more collaborative and effective, with education research focused on real school needs."

"It will require teachers and researchers working together," he continued. "The best teachers need a much larger voice in helping to steer state policies in school systems, or else we will risk making the same mistakes we've made in the past."

Susan Hackwood: Current Status of the STEM Workforce

To illustrate the dismal state of science literacy among the general population, Susan Hackwood, CCST's Executive Director, opened her remarks with an anecdote about a popular YouTube video now circulating: the Sprinkler Rainbow Conspiracy.

In the video, a woman's voiceover expresses alarm about the rainbow she sees through her backyard sprinkler. "What the heck is going on?" she asks. "What is in our water supply, our oxygen supply, what is oozing out of our ground, that is creating this rainbow effect in a sprinkler. . . something we never saw 20 years ago?"

Although the anecdote amused Symposium participants, it also highlighted a very serious issue: if this lack of understanding and knowledge is widespread, where will California's (and the nation's) STEM workforce come from? Without effective STEM education, how will fields as diverse as energy, nanotechnology, biotechnology, medicine, genomics, and transportation be able to recruit and retain the talent workforce they will need to thrive and innovate in the future?

Key Points: Current Status of the STEM Workforce

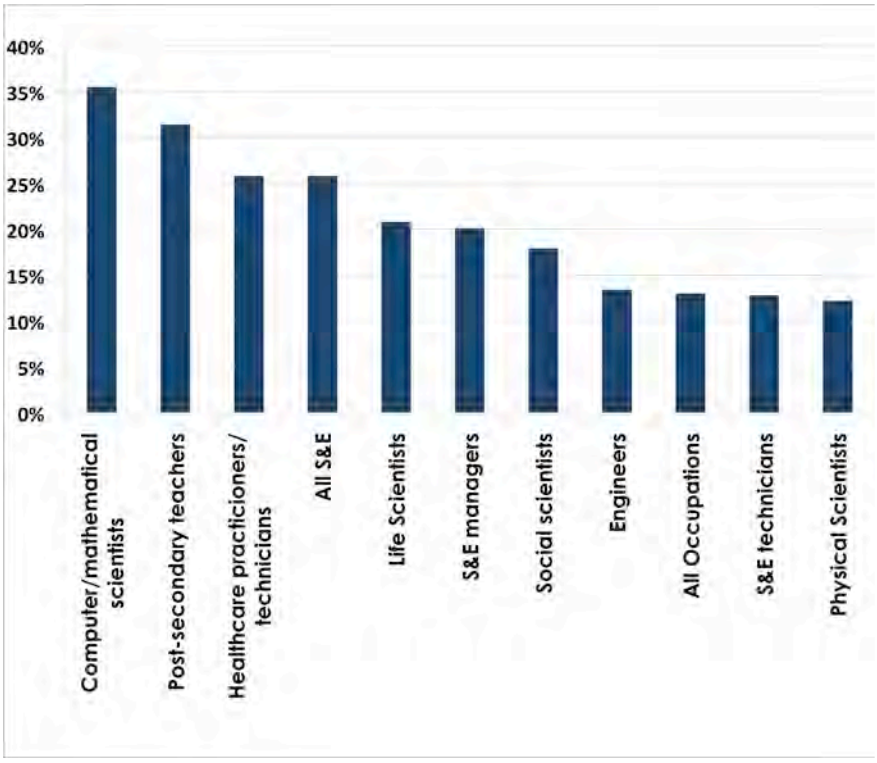
- California and the United States need a competent, creative science and technology workforce to stay competitive and advance innovation.
- Despite projected growth in science and technology occupations, the supply of graduates in these fields is shrinking.
- We are far from being able to produce the skilled workforce envisioned by *The Gathering Storm* reports and other calls for innovation and competitiveness.
- In response, we need to boost the development of skilled human talent that powers innovation.
- This will require improving the economic environment and institutions that support innovation, while also responding to the changing global marketplace.

The Need for STEM Workers

Dr. Hackwood observed that projected growth rates for the science and technology workforce exceed those of other occupations. Even if these are affected by the economic downturn or other unforeseen events, the pattern is striking: healthcare practitioners and technicians are expected to add the most new jobs between 2006 and 2016 (at a 19.8% growth rate) and computer and mathematical occupations are expected to grow the fastest (with a 24.8% growth rate). Related occupational groups (such as architecture, engineering, and the life, physical and social sciences) are likely to see double-digit growth rates as well. Indeed, of the 30 fastest growing occupations, many are science and technology-related.

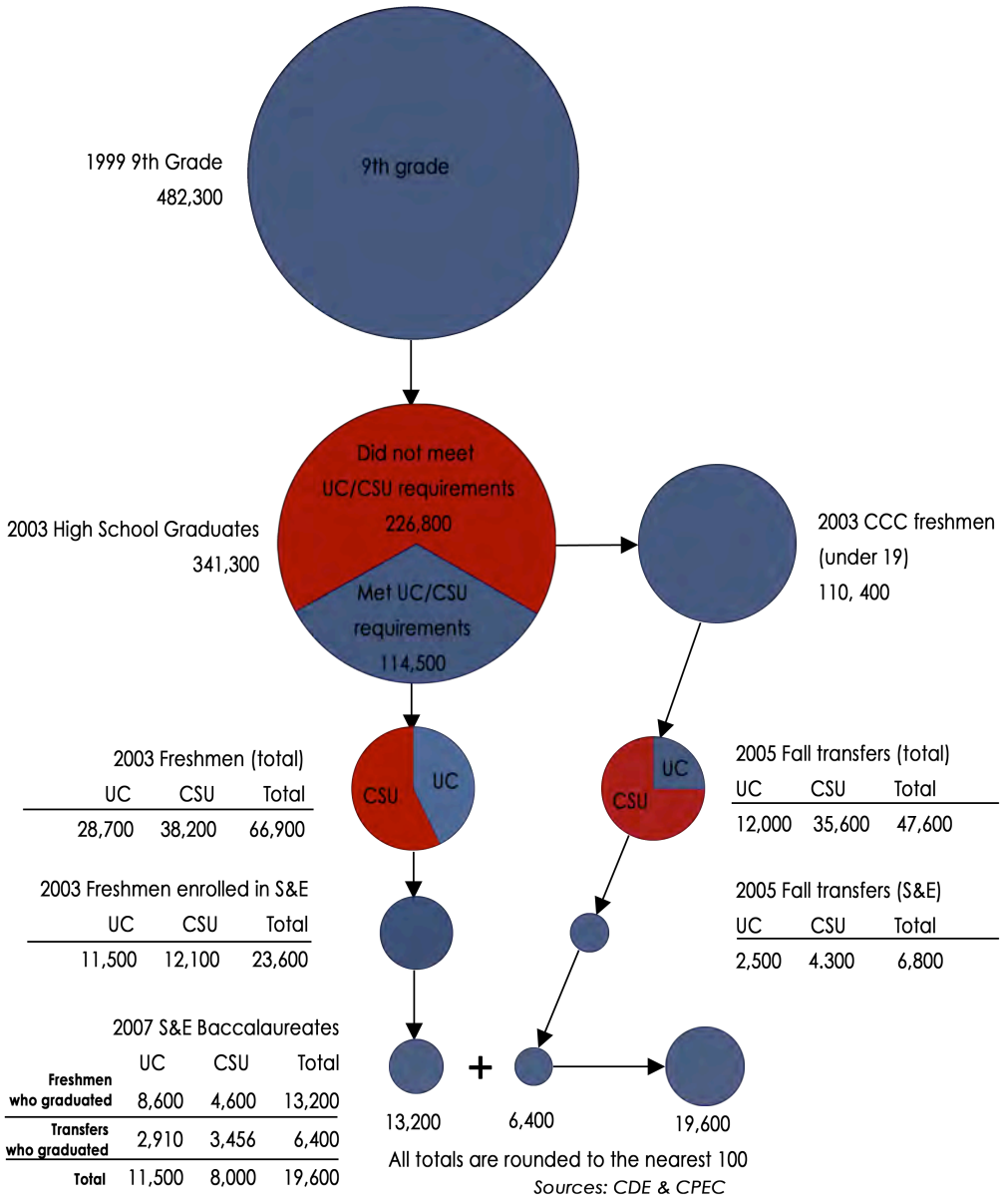
These future workers will need a blend of skills to compete effectively in a global economy, including technology skills (biotechnology, information technology, and nanotechnology), "multi" skills (the ability to operate in multi-language, multi-cultural environments), and business skills.

Quoting Ray Marshall and Marc Tucker from their 1992 book, *Thinking for a Living: Education and the Wealth of Nations*, Dr. Hackwood observed that they also will need to be able to apply a "capacity for abstract thought to complex, real-world problems — including problems that involve the use of scientific and technical knowledge — that are nonstandard, full of ambiguities, and have more than one right answer." Workers will need to have developed a high level of capacity for abstract, conceptual thinking and to communicate their ideas to diverse groups of people, working in teams.



Projected Increase in Employment for Science and Engineering and Selected Other Occupations, 2004 - 14

Source: Bureau of Labor Statistics — Science and Engineering indicators 2008



Longitudinal study of students in public school system, 9th grade through S&E baccalaureate, 1999-2007

Sources: California Postsecondary Education Commission (CPEC), California Basic Educational Data System (CBEDS)

A Shrinking Supply

Dr. Hackwood shared data on the shrinking pool of graduates in the natural sciences and engineering. In 2002 (the most recent year for which data are available), the United States was behind 15 other countries in the science and engineering degrees per 100 24-year-olds (including Taiwan, which topped the list, Finland, Lithuania, South

Korea, Australia, France and several other European countries, Canada, and Singapore).

In California, there is significant attrition at every step in the educational path between high school and college. The 19,600 science and engineering baccalaureate degrees awarded in 2007 represent only 4% of the 9th graders who became that pool of college students. Within the CSU system alone, science and engineering degrees represent just 40% of the freshmen who enrolled in these disciplines four years earlier.

Echoing Dr. Alberts' remarks, Dr. Hackwood agreed that the issue is not just how many STEM graduates are produced — although this is an important measure of progress (or lack thereof). The future workforce needs not only STEM graduates, but also graduates knowledgeable about STEM fields, even if it is not their area of expertise or day-to-day work.

Another looming factor is the demographic change that is affecting California and the United States overall. Failure to educate large proportions of the population — such as California's Latino children — has serious economic consequences; per capita income will enter negative territory by 2020 if higher wage jobs (and the skills needed for them) do not alter the trajectory in the very near future.

The Context: Innovation and Urgency

CCST prepared a California response to the national report, *Rising Above the Gathering Storm*. Both reports recommended increasing the talent pool for the future STEM workforce by vastly improving K-12 science and mathematics education. They also focus on making the United States and California the top places in the world to innovate, attracting the best and brightest students, scientists and engineers here to study and perform research. This, in turn, will require a sustained and strengthened commitment to long-term basic research that has real potential to be transformational.

Dr. Hackwood quoted Intel's Craig Barrett, who said, "The only way we can hope to compete is with brains and ideas that set us above the competition — and that only comes from investments in education and research and development." She defined innovation as the creation and application of new ideas that generate economic and social value. In the 1990s, Dr. Hackwood observed, innovation was centered on technology and its applications. Today, innovation is more dispersed: it is about new strategies, new products and processes, new business models, and new markets.

> ***"The only way we can hope to compete is with brains and ideas that set us above the competition — and that only comes from investments in education and research and development."***
>
> Craig Barrett
> Chairman of the Board, Intel

This broader view of innovation is the culmination of a more gradual shift in the sources of success for nations and economies: from *inherited* assets (such as geography, climate, natural resources, and population) to *created* assets (such as high-caliber universities and research centers, talented people, entrepreneurial cultures, networks, and vibrant downtowns that attract creative people).

Solutions

To capitalize on these trends we will need to boost the development of skilled human talent that powers innovation. This will require improving the economic environment and institutions that support innovation, while also responding to the changing global marketplace. As demonstrated by the charts and data above, we are far from being able to produce the skilled workforce envisioned by *The Gathering Storm* reports and other calls for innovation and competitiveness.

In closing, Dr. Hackwood quoted Motorola's Robert Galvin and Edward Bales:

> "While most descriptions of necessary skills for children do not list '**learning to learn**,' this should be the capstone skill upon which all others depend. Memorized facts, which are the basis for most testing done in schools today, are of little use in the age in which information is doubling every two or three years. We have expert systems in computers and the Internet that can provide the facts we need when we need them. Our workforce needs to utilize facts to assist in developing solutions to problems."

Margaret Gaston: The Current Status of STEM Teaching and Learning in California

Margaret Gaston, CFTL's President and Executive Director, noted the "twin challenge" of boosting the capacity of the workforce to engage and teach students, while also responding to the tremendous pressure to increase student achievement.

Student Achievement Trends

As Dr. Alberts noted earlier, Ms. Gaston said, the current metric for assessing student achievement — the California Standards Test (CST) — may not be the best measure of true scientific knowledge or skill. Nevertheless, it does allow some tracking over time and is the measure currently used by the public and the policy community.

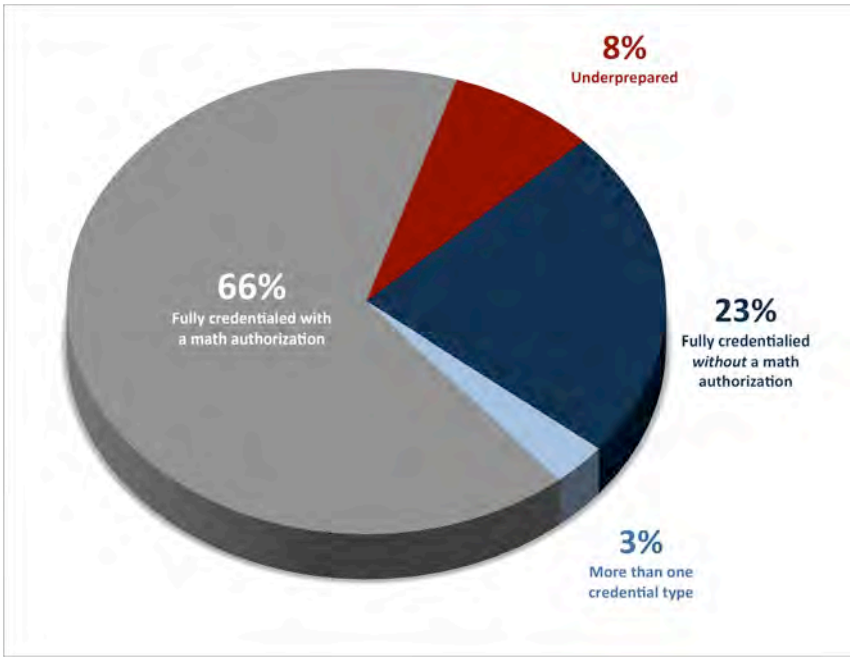
Key Points: Current Status of STEM Teaching and Learning in California

- Although overall student achievement in science and math has been on the rise, the majority of California's Latino and African-American students scored below proficient on the math California Standards Test.
- California lags behind national averages in both science and math tests administered to 4th and 8th grade students.
- Reversing these trends will require meeting three major challenges:
    - Creating an adequate supply of STEM-discipline teachers;
    - Making sure those teachers are fully prepared with a deep understanding of subject matter content and sound pedagogical skill; and
    - Distributing them evenly across schools and districts, so that every child has a chance of being in a classroom with a great science or math teacher.

With those caveats about the test, Ms. Gaston said, California students' achievement overall has been on the rise over the past 7 years, including achievement in science and math. This is particularly remarkable, she noted, because so little science is being taught — and some students receive no science instruction whatsoever.

The overall increase in student achievement in math also glosses over a persistent gap between white students and students of color: 67% of Latino students and 72% of African-American students scored below proficient on the math CST.

And California continues to lag behind national averages on the National Assessment of Educational Progress (NAEP) in science and math, administered to 4th and 8th grade students around the country.



Middle School Algebra Teachers, 2007-08

Source: California Department of Education

Teacher Workforce Trends

Ms. Gaston highlighted two aspects of California's science and math teacher workforce: the supply of fully prepared and qualified teachers, and how they are distributed.

The overall number of **underprepared teachers** — those who have not yet met the requirements for even a preliminary credential in the area they are assigned to teach — has declined by 40% (from 40,587 underprepared teachers in 1999-2000 to 15,463 in 2007-08), demonstrating that significant progress is possible. Even so, 5% of the workforce still does not hold a preliminary teaching credential; of these, half are interns.

Among novice teachers overall, 24% are underprepared, but the proportions are far higher for the STEM disciplines: 39% of high school math teachers, 38% of high school science teachers, 31% of middle school math teachers, and 33% of middle school science teachers are underprepared.

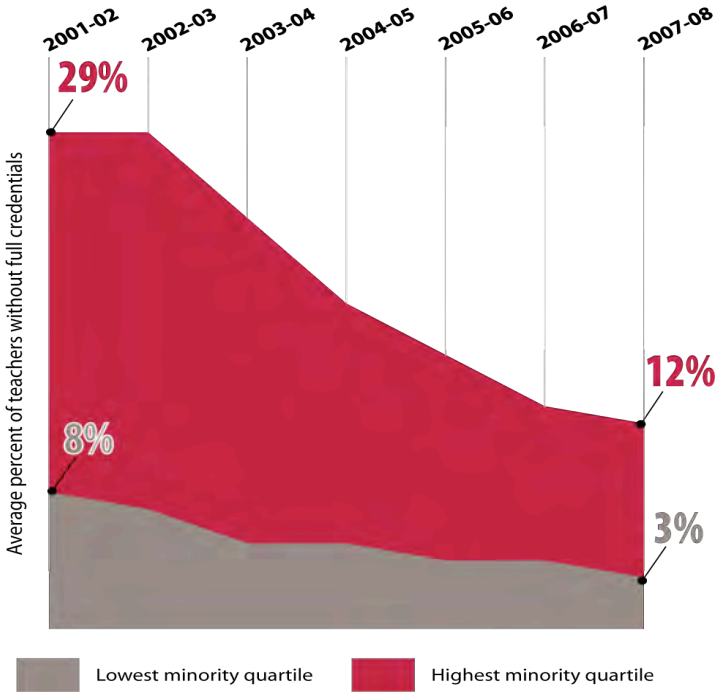
Another issue is the number of teachers who hold credentials, but are teaching **outside their fields of expertise**. In California, 12% of math teachers, 18% of physical science teachers, and 11% of life science teachers are considered out-of-field teachers. One-third of middle school algebra teachers do not hold a math authorization.

Ms. Gaston noted that it would be challenging enough for policy makers if the underprepared, out-of-field, and novice teachers were evenly distributed across schools and districts, but that is not the case. Underprepared teachers are overwhelmingly

concentrated in urban areas, serving educationally disadvantaged students. California's highest-need schools — those with the highest concentrations of poor, minority, and second-language learners — have four times as many underprepared teachers as the lowest-minority schools.

Ms. Gaston called attention to the mismatch between the supply of prepared STEM teachers and the demand for them. As Dr. Hackwood had noted in her presentation about the STEM workforce, there is significant attrition in both the University of California and California State University systems from the numbers of freshmen declaring majors in the STEM disciplines, compared to those who graduate with degrees in these disciplines.

Of those who graduate with degrees in these fields, few enter the teaching profession. The table below contrasts the number of new teaching credentials issued in math, physical science, and life science, compared to the estimated number of teachers hired the following school year (2007-08).



Minority Students Get Least Prepared Math Teachers

Source: Center for the Future of Teaching and Learning

	New Credentials (2006-07)	Estimated Hires (2007-08)	Projected Shortfall
Math	1,800	2,132	332 (16%)
Physical Science	524	879	352 (40%)
Life Science	812	1,050	238 (23%)

Number of New Teaching Credentials Issued in Math, Physical Science, and Life Science, Compared to the Estimated Number of Teachers Hired the Following School Year (2007-08)

Three Major Challenges

Summarizing the trends in both student achievement and the teacher workforce, Ms. Gaston noted three main challenges:

- The first is to **create an adequate supply of STEM-discipline teachers**, which in turn will require some of the steps outlined by Dr. Alberts to redefine science education and make science and math classes exciting and compelling. Once teachers are produced through a strong science and math education pipeline from K-12 through college, the state needs to do a better job in ensuring that they **end up in the classroom**. The temptation to work in business or industry, for financial and other reasons, is strong.
- The second is to **make sure those teachers have the subject matter content knowledge** and pedagogical skills to teach science well. Multiple subject teachers especially — those who teach kindergarten and grades1 through 8 — may lack any background in science at all and need high quality professional development to help them fill the gaps in their own knowledge.
- Third, the fully prepared, veteran and accomplished STEM-discipline teachers should be **distributed evenly** across schools and districts, so that every child has a chance of being in a classroom with a great science or math teacher.

Panel Responses

Following her presentation, Ms. Gaston invited four panelists to reflect on the trends and challenges she had described.

Karl Pister, Chancellor Emeritus, University of California, Santa Cruz (and the proud father of a middle school math teacher), brought his engineering perspective to the Symposium.

Dr. Pister explained the difference between Eulerian observers — those who examine a process from outside, focusing on its nodal points — and Langrangian observers, who experience a process from within, while moving through it. In Dr. Pister's view, the education leadership and policy makers at the state and federal levels inevitably adopt a Eulerian perspective, "looking down on the system from above and directing which way it should go."

In this comparison, the teachers and students embedded in the system are the Langrangian observers. They may understand the process best because, like the assembly line workers in Japanese car factories, they are closest to it. Yet their knowledge typically is discounted or even dismissed — even though it is essential to understanding and improving the process.

To improve science education in the ways Dr. Alberts envisioned, Dr. Pister explained, requires a shift from the current Eulerian perspective to a Langrangian one. Such a shift would examine the different factors affecting student achievement and their preparation for further education or entry into the workforce, taking into account both internal factors (such as motivation, capacity and readiness to learn, and school site conditions) and external ones (teachers, role models, the role of parents and peers, societal views).

Key Points: Panel Discussion

- **Karl Pister:** Improving science education requires a shift from the current top-down (i.e., Eulerian) perspective to a more embedded (i.e., Langrangian) one.
- **Lyn Arscott:** From the point of view of the engineering profession, we need you!
- **Beth Graybill:** Strategies for improving the future STEM workforce are an excellent fit with legislative and policy priorities.
- **Pete Arvedson:** How can we help students regain their passion for learning math and science? How can we help teachers regain and maintain their enthusiasm for math and science so they build a passion for these subjects in our students?

In the future, Dr. Pister would like to see more thoughtful attention to the other metrics that affect school systems and STEM education — those that are not directly

connected to testing and teaching, but rather to the many variables outside the classroom that affect students' willingness and ability to learn.

Lyn Arscott, a retired Chevron engineer and current President of the Society of Petroleum Engineers, reminded the Symposium attendees of the sense of urgency communicated through the National Academy of Sciences report, *The Gathering Storm,* by quoting a sampling of facts and observations from the report:

- Economists estimate that one half of U.S. economic growth since World War II was the result of technical innovation.
- Compared with other countries, the share of leading-edge semiconductor capacity owned or partly owned by U.S. companies is one-half of what it was in 2001.
- China overtook the United States as the lead exporter of its products and the U.S. now ranks 12th among developing countries in the number of broadband connections per 100 inhabitants.
- American youth spend more time watching TV than they do in school.
- Percent of undergraduates receiving degrees in the natural sciences and engineering: France – 47%, Singapore – 67%, U.S. – 15%.
- Of college students intending to major in engineering, one-third switched majors before graduating.

Together, these observations point to a major — and long-standing — problem in creating a supply of technical talent for U.S. companies and overall competitiveness. The point has not been lost on the CEOs of major corporations (many of whom were involved in *The Gathering Storm* report and committees).

The Gathering Storm conclusions and recommendations have been presented to Congress without significantly affecting funding or policy, but Dr. Arscott is guardedly optimistic that the new administration may infuse new energy as well as new funding (via the stimulus package) to the report's findings. For example, the first recommendation is to increase America's talent pool for K-12 science and math education by recruiting more teachers and paying them for four years of science education.

In closing, Dr. Arscott told the Symposium participants, "From the point of view of the engineering profession, we need you!"

Beth Graybill, Principal Consultant to the California Senate Committee on Education, encouraged the group by pointing out that the Symposium's agenda fits well with the state's legislative and policy agenda on several fronts: the focus on the economy, the

role education plays in workforce development and competitiveness, and the skills students need to be successful not only in college, but throughout their careers.

Ms. Graybill said that she was struck by the role of curiosity and interest in closing some of the achievement gaps that Ms. Gaston noted and that there also is a concern of hers and many of her colleagues. "Students are unlikely to like science and math if they're not good at it," she said, "and they're also not likely to be good at it unless they're really interested." The key variable to increasing student interest and curiosity is teachers, so the observation, for Ms. Graybill, prompts the question: "How can we get more qualified teachers into the classroom?"

One possible response, she suggested, is to try to provide opportunities for existing teachers to obtain credentials in science and math to help close the gap between supply and demand. She also discussed some budget implications — such as whether existing funds could be shifted to areas most in need, or targeted to professional development in ways that give districts more flexibility (and simultaneously increase the supply of science and math teachers by enriching the math and science content knowledge of existing teachers from other fields).

Pete Arvedson, a science teacher at La Puente High School and a member of Cal TAC, noted some of the same trends — low achievement in math and science, especially among California's minority students; students taught by science teachers with no experience with the processes of science. "How can these teachers engage students to inquire about the nature of science or be creative problem-solvers?" Mr. Arvedson asked.

He explained how when he started teaching 37 years ago, he was tremendously excited about teaching and about leading his students on the same journey of discovery that he had experienced. He was mentored by two experienced teachers who taught him something he had not learned in his college classes: how excitement really works in the classroom.

"How can we help teachers regain and maintain their enthusiasm for math and science so they build a passion for these subjects in our students?"

— Pete Arvedson

Today, more students are taking science and more science is required for graduation, yet failure rates are skyrocketing. "Many of my teaching colleagues," Mr. Arvedson lamented, "have no time in the school day to do anything beyond prepping disinterested students to take state tests."

As an example of how testing has undermined both the interest in science and student achievement in these courses, Mr. Arvedson told the group about a 9th grade class that his high school once offered — an introductory class that put scientific processes in context, setting students up for success in each of the subsequent years of chemistry and biology. When the district eliminated the introductory class in favor of a biology, chemistry and physics sequence, student failure rates escalated — but the introductory class was never reinstated, because there was no state test in place to capture the time and effort it represented, and he posited that the school and district were afraid of being penalized.

Tests, scripts, pacing calendars — all of these can combine to remove the artful teacher's individual imprint and connection with students from the classroom. "How can we help students regain their passion for learning math and science?" he asked. "How can we help teachers regain and maintain their enthusiasm for math and science so they build a passion for these subjects in our students?"

"Teachers want to be held accountable. We're not against accountability, but we want to be accountable for the right things."

— CALTAC member

In questions and comments after the panelists spoke, several Symposium participants noted the role of testing and the inadequacy of current assessment methods. Elizabeth Stage, Director of the Lawrence Hall of Science at UC Berkeley, spoke for many when she pointed out that a major factor in the poor quality and yield of current testing is the imperative to keep costs down. The result, she said, is a mismatch between how we keep score and what we are trying to accomplish. She urged the group to consider ways to increase the public's understanding of why spending more for testing is worthwhile, lamenting the fact that parents are willing to pay many times more to find out whether their child has strep throat, compared to what they are willing to pay to find out whether the same child is making academic progress. She called for building greater public will to pay for assessments and trust the judgment of teachers that more comprehensive assessments will require.

As another Cal TAC member put it, "Teachers want to be held accountable. We're not against accountability, but we want to be accountable for the right things."

Anne Marie Bergen: How Do We Get the STEM Workforce We Need?

"Teachers who inspire perceive their task not as one of implanting facts, but to place the subject in front of the learner and through enthusiasm, imagination, and inventiveness, awaken the appetite of the learner."

— Dr. Anthony Witham

Cal TAC's new Chair, Anne Marie Bergen, serves as the District Science Coordinator and teaches science for the Oakdale Joint Unified School District. She gave Symposium participants a quick lesson in how to engage students in scientific inquiry. Around the conference room, Symposium participants could be seen peering intently into their palms, where a translucent plastic fish flopped and curled. The room buzzed with speculation and chuckles. Was body heat making the fish move so convincingly? Moisture? A combination of both? Neither?

Ms. Bergen asked the meeting participants to perform some of the tasks she routinely asks of her elementary school science students: observe, compare, speculate, hypothesize, discover. She asks herself, "How do I hook them, connect with them?" And she asks the same questions about her colleagues and community.

Quoting Dr. Anthony Witham, she said,

> "Teachers who inspire perceive their task not as one of implanting facts, but to place the subject in front of the learner and through enthusiasm, imagination, and inventiveness, awaken the appetite of the learner."

With that backdrop, Ms. Bergen asked the Symposium participants to consider what could be done to prepare teachers to meet STEM workforce needs. What are the key elements, roadblocks, challenges, and possibilities?

Some of the responses are provided below:

- Reaching STEM students as potential teachers at the college level may be too late; moreover, many STEM B.S. and Ph.D. candidates do not necessarily make good teachers.
- STEM professors are role models and can either encourage or discourage students from entering the STEM teaching profession — alas, usually the latter.
- Internships and hands-on work are as important for teachers as they are for students, giving them a taste of science in action. Another participant noted that hands-on/internship modules should be added to teacher professional development opportunities, and that these generally should be made more accessible.
- Shadow opportunities (in laboratories and business/industry) also help teachers reconnect to how exciting and exhilarating math and science can be when they are applied in the workplace — and they can then communicate this

passion and excitement to their students. Leaders and school administrators have to see the value of this, too, so that they may be more likely to support it.

- Alignment needs to start in elementary school, as a K-20 project.
- We have to find ways to draw more women and minorities into science.
- The STEM workforce topic is an opportunity to have a conversation about professional development and how it could look in the future — as well as learning from models in other states (such as a South Florida program that pulls students from junior high, supports them through college, and then helps them return to teach math and science in high-poverty districts, becoming role models for other minority students).
- Another disconnect is between teacher professional development and pre-service teacher education — especially finding teacher mentors in the settings where people do their student teaching.

Building a System, Creating Connections for Effective Professional Development: Small Group Discussions and Feedback

Participants broke into smaller groups for more intensive and detailed discussions. It should be noted that the discussions were far-ranging and detailed — far more so than could be captured in this summary (which reflects mostly the main points that were reported back to the larger group of Symposium participants at the end of the day).

Key Points: Building a System; Creating Connections for Effective Professional Development

- The need for appropriate and meaningful assessments of science and math teaching and learning in the K-12 system.
- The need for professional development to encourage artfully taught, "inquiry-based" learning in the classroom.
- The need to seek and create as many opportunities as possible for bringing together the voices of knowledgeable and accomplished teachers, business and industry representatives, and policy makers as new state policies are being considered or evaluated.

Group A — Summary of Discussions

The accomplished teacher's voice is both essential, and missing. We need to help teachers become better-informed, critical thinkers by resolving the disconnect between professional development on the one hand, and what happens in the classroom on the other. Too many teachers are unprepared when they walk into the classroom and need support to deepen their subject matter content knowledge and sharpen their pedagogical skills.

Industry may provide some important clues and tools for revamping professional development. For example, Hewlett Packard (among others) uses backward mapping — envisioning a future desirable end result, and then figures out how to work towards it.

A persistent roadblock is the lack of respect for teachers as professionals. No other profession gives comparably trained and responsible professionals so little latitude in decision-making, as evidenced by a blanketed approach to scripted teaching and pacing calendars for accomplished, veteran teachers (who are not the novices who might benefit the most from these tools).

To convey some of these messages, we may need to change the messengers — e.g., having industry and business representatives go to bat for a stronger voice for professionalizing teaching, if teachers themselves are not heard (or listened to).

Regarding assessment quality: You get what you pay for! Low-cost, narrow assessments are not adequate to the task of assessing students' knowledge and skill or guiding instruction.

Group B — Summary of Discussions

Teachers and mentors have enormous influence on the paths that children take in life. All students should have the experience and excitement of hands-on discovery.

The best professional development can be provided to teachers by breaking the mold of how they were taught in the past; starting early (with pre-service) and sustaining ongoing professional development. Support from principals is key.

The gaps in the teacher and student pipelines must be better understood and discussed — with teachers at the table.

The assessment system must be overhauled, not tinkered with. It should hold students and teachers accountable for the right things. Teachers are not afraid of accountability, but it has to be for the right kinds of things.

Group C — Summary of Discussions

The No Child Left Behind Act (NCLB) cannot take the blame for all the current ills of public education; California must take some responsibility as a state, considering how public education is supported and structured.

Regarding assessment: if expectations are low — should the results be any surprise? Educating the public about the limits of the current assessment system is essential if parents are to become allies.

The disincentives to teaching science must be tackled, including the role of specialists versus generalists and the quality of elementary science education.

Group D — Summary of Discussions

The outcome to focus on is the creation of informed critical thinkers — independent thinkers capable of reaching conclusions based upon evidence, applying knowledge, using logic, and checking for relevance.

Teachers are facilitators who draw out students' knowledge and develop critical thinkers.

Standards that maximize conceptual understanding should guide teaching and learning— and should be assessed frequently.

Challenges include the fact that teachers and parents alike are intimidated by science. Parents lack knowledge about how science really works (because they too did not benefit from well-taught science). Scripts, pacing guides, and weak assessment measures may work against quality science and math education if they become proxies for the highest attainment in teaching quality. Further, fluctuations in state education spending and top-down decision-making dampen efforts to improve teaching at the school and classroom level.

Possible solutions include providing training and opportunities for teachers to become leaders, connecting policy makers to students and their experiences, finding influential champions, and cultivating more industry-education partnerships.

Next Steps

Janet English, a Cal TAC member and Director of Educational Service for KOCE-TV, noted that the Symposium represents the beginning of a conversation and wasn't designed to resolve the many issued raised. Still, she said, the group is seeking lasting solutions, not Band-aids. ("After all, band-aids fall off!" she reminded the audience.)

An ongoing theme was the consensus that the current assessment structure is not an appropriate driver of curriculum, professional development, teaching, or learning in California. Despite this and the many other roadblocks and frustrations that participants identified throughout the day, Ms. English noted that there is an opportunity to take a step back and re-define science and math education, in the hopes of building something stronger and better than what currently exists. For example, she noted, this might involve deciding what we want our students to know at the end of the 12th grade and what skills they should have; from there, deciding what students should experience at each level of their education; and then what types of professional development teachers would need in order to do an exemplary job of providing it.

On behalf of all her Cal TAC colleagues, Ms. English expressed the hope that Symposium participants would have met, and in the future will reach out to, allies in the room to work together on this important goal.

Collaboratively designed thoughtful solutions and approaches, with teachers involved at every step, are both possible and necessary — and can help move California from the Eulerian mode that Dr. Pister decried to the Langrangian, classroom-focused, ground-truth, shop-floor model he and others aspire to.

Appendix A: Attendees at the 2/2/09 Symposium

Creating a Well-prepared STEM Workforce: How Do We Get from Here to There?

Bruce Alberts
Department of Biochemistry Biophysics, University of California, San Francisco

Lyn Arscott
President, Society of Petroleum Engineers, Chevron (Retired)

Susan Brady
Department Head, Center for Science and Engineering Education, Lawrence Berkeley National Laboratory

Courtney Corda
Vice President, Science Buddies

Eilene Cross
Education Consultant, California Council on Science and Technology

Angela Diaz
Consultant, California Council on Science and Technology

Mary Donnelly-Ortega
Education Programs Consultant, Policy Development and External Affairs Branch, California Department of Education

Marilyn Edling
Executive Director, California STEM Innovation Network

Sue Elrod
Director, Center for Excellence in Science and Mathematics Education

Stephanie Farland
Senior Research and Policy Consultant, California School Boards Association

Dick Farnsworth
Education Outreach Manager, Lawrence Livermore National Laboratory

Margaret Gaston
President, Center for the Future of Teaching and Learning

Beth Graybill
Principal Consultant, Senate Committee on Education

Susan Hackwood
Executive Director, California Council on Science and Technology

Susan Harvey
Program Officer, S. D. Bechtel, Jr. Foundation

Alice Huang
Senior Councilor for External Relations, California Institute of Technology

Karen Humphrey
Administrator, California Postsecondary Education Commission

Dale Janssen
Executive Director, Commission on Teacher Credentialing

Barbara Johnson
District Director, Office of Congressman George Miller

Chelsea Kelley
Committee Consultant, Assembly Committee on Education

Stacey Kyle
Research and Policy Associate, Center for the Future of Teaching and Learning

Phil LaFontaine
Director, Professional Development and Curriculum Support, California Department of Education

Nicole Lezin
Consultant, Center for the Future of Teaching and Learning

Maria Alicia Lopez-Freeman
Executive Director, California Science Project

Michael Masterson
Project Manager and Researcher, California STEM Innovation Network

Ray Ng
Manager, Sandia National Laboratory

Rollie Otto
Berkeley Center for Cosmological Physics, University of California

Karl Pister
Chancellor Emeritus. University of California, Santa Cruz

Stephen Rockwood
Executive Vice President (Retired), Science Applications International Corporation

Diana Rude
Consultant, California Council on Science and Technology

Jeffrey Rudolph
President and CEO, California Science Center

Diane Siri
Project Director, Center for the Future of Teaching and Learning

Elizabeth Stage
Director, Lawrence Hall of Science

Jean Treiman
Executive Director, California Subject Matter Projects

California Teacher Advisory Council (Cal TAC)

Peter Arvedson
Science Teacher, La Puente High School

Anne Marie Bergen
Chair, Cal TAC
District Science Coordinator/Teacher
Oakdale Joint Unified School District

Peg Cagle
Mathematics Teacher
Lawrence Middle School & Gifted Magnet

Janet English
Director of Educational Services
KOCE-TV

Sandie Gilliam
Elementary and Secondary Mathematics
Methods Instructor

Javier González
Mathematics Teacher
Pioneer High School

Diana Herrington
Mathematics Teacher
Clovis High School

Stan Hitomi
Science and Math Coordinator
San Ramon Valley Unified School District
Chair, Board of Directors
Center for the Future of Teaching and Learning
Immediate Past Chair, Cal TAC

Juliana Jones
Mathematics Teacher
Longfellow Middle School

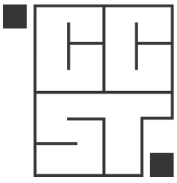
Suzanne Nakashima
Elementary School Teacher
Lincrest Elementary School

Sue Pritchard
Science Teacher
Washington Middle School

Barbara Shannon
Co-Director
Synergy Kinetic Academy

Mark Stefanski
Biology Teacher and
H.D. Thoreau Faculty Chair for Sustainability
Marin Academy

Katrina Williams
Elementary School Teacher
Harvest Elementary School



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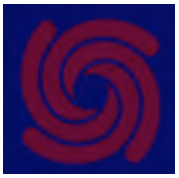

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