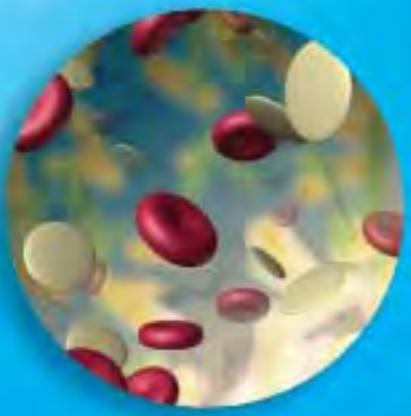
The Preparation of Elementary School Teachers to Teach Science in California

▶ *Challenges and Opportunities Impacting Teaching and Learning Science*





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 CCST is a non-profit organization established in 1988 at the request of the California State Government and sponsored by the major public and private postsecondary institutions of California and affiliate federal laboratories in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and recommending public policies and initiatives that will maintain California's technological leadership and a vigorous economy.

This project was conducted in collaboration with the Center for the Future of Teaching and Learning (CFTL), a public, non-profit organization made up of education professionals, scholars, and public policy experts. CFTL's purpose is to strengthen the capacity of California's teachers for delivering rigorous, well-rounded curricula and ensuring the continuing intellectual, ethical, and social development of all children.

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Letter From CCST

It has been a decade since CCST released the California Report on the Environment for Science and Technology, a report that looked at the big picture and sought to identify priorities for further action and study. Science and mathematics education was one of these priorities. Since that time, we – along with many others – have continued to look ever closer at the factors affecting how our students are taught and the degree to which California is preparing them with the knowledge and the tools necessary to thrive and function in a state whose economy relies heavily on science and technology.

In contrast to the systems approach we have adopted in previous reports, this document focuses on a relatively narrow piece of the puzzle: the preparation of elementary school teachers to teach science. This area has received much ink in education literature, though few definitive studies, because there are few metrics in place to track. We are grateful to our partners in California's institutions of higher education, in particular the California State University Center for Teacher Quality, for making available survey data that gives important insights into how well K-6 teachers and their supervisors assess their proficiency in science. In this report, we present the basics of what is involved in preparing elementary teachers, what is known - and not known – about their ability to teach science, and promising programs which are working to enhance elementary teacher preparation in science.

There is much that is not covered here, and it is important to recognize the context in which this report must be read. Successful science education reform must encompass a range of issues extending far beyond the actual teacher preparation programs. Among them are preschool programs, adequate and appropriate administrative support, and informal and out-of-school science learning. These issues are not addressed here. Nor is professional development, which is an essential component of teacher training and a central part of any strategy to improve science teaching in California's public schools – to say nothing of the content standards themselves.

What the report does do is shed light on a neglected part of the science and math education dialogue. The state's focus on improving secondary STEM education has been diligently maintained in spite of omnipresent and serious budget issues. It is time to turn our attention to the elementary schools, and in so doing, move one step closer to a true systems approach in science education reform.

Susan Hackwood
Executive Director, CCST

Stephen Rockwood
Education Committee Chair, CCST

Executive Summary

Introduction

California is by many measures the nation's leading science and technology (S&T) state. However, as CCST has noted as early as 1999, California's educational system has not been producing the quantity of proficient science and engineering graduates needed to meet these S&T industries' growing requirement for skilled workers.[1] Throughout the past decade, CCST and the Center for the Future of Teaching and Learning (CFTL) have examined the preparation of California's science and mathematics teachers. In their jointly produced 2007 report, they explored the details of the preparation and training of teachers with subject specific credentials in mathematics and science, concluding that the state lacked a coherent system to consistently produce fully prepared teachers in these disciplines and that the state did not have the capacity to meet the demand for fully prepared science and mathematics teachers.[2] However, this analysis focused on the supply and distribution of teachers with appropriate subject-specific credentials at the middle school and high school levels.

In grades K-6, almost all teachers hold a multiple subject credential, which enables them to teach all subject areas, including science in a self-contained classroom. Not enough is known about how elementary school teachers are prepared to teach science in the lower grades, or the skills and knowledge they bring to the classroom.[3] Indicators of elementary school teacher content knowledge are not as extensive as those for single subject credentialed teachers. However, it is possible to identify some correlations between certain preparation pathways and the preparedness of elementary teachers, as reported by themselves and their supervisors.

This report provides a quantitative, descriptive and qualitative review of how elementary school teachers are prepared to teach science. It describes:

- Elementary science education and performance in California.
- How elementary teachers are prepared to teach science.
- The range of content knowledge that elementary teachers are required to learn during the preparation process.
- How prepared elementary teachers are to teach science, as rated by themselves and their supervisors.
- Examples of different teacher preparation approaches in practice at several public and private education institutions in California.

[1] California Council on Science and Technology. (1999). California Report on the Environment for Science and Technology. (Sacramento: CCST)
[2] CCST and CFTL (2007), p.83.
[3] Ibid, p.85.

- Recommendations for measuring and improving the preparedness of both new teachers and currently practicing elementary teachers to teach science.

What We Know About Science Teaching in Elementary School

California's students perform below par for the nation in science: the most recent national assessment of 4th graders showed 50% of California students scored at or below basic proficiency in the subject – only Mississippi had a higher percentage of students below basic proficiency.[4]

There are several reasons for this ranking. One is the diminishing amount of classroom time available for science. Since the enactment of the federal No Child Left Behind Act (NCLB) in 2002, which focuses on mathematics and reading, there has been an average decrease of 32% nationally in terms of minutes spent on other subjects including science.[5] Research suggests that in California, even less time is spent on science at the K-6 level.[6] One 2007 California survey of schools in the Bay Area found 80% of elementary teachers reported spending 60 minutes or less per week on science, including 16% who reported that they spent no time at all on science.[7]

However, pressures to increase time spent complying with NCLB are only part of the issue. There also is evidence that elementary teachers are less well prepared to teach science than other subjects, both according to their own self-evaluations and ratings by their supervisors. According to data gathered during an eight-year span by the CSU Center for Teacher Quality, supervisors rated only 76% of first-year teachers as well or adequately prepared to teach science, as opposed to reading (84%) or math (83%). As for the teachers themselves, an even lower percentage (62%) reported that they were prepared to teach science. What's more, when a different study asked the same questions of experienced teachers, the percentage of respondents reporting themselves as prepared in reading and math was notably higher than that of the first-year teachers – but not so for science.

The Root of the Problem

The available survey data do not specify why elementary teachers are less comfortable teaching science. However, we know that most entry-level science courses are not specifically designed for prospective teachers. As a result, the range of science content courses taken by prospective teachers at the undergraduate level is not necessarily aligned with the science content they are later required to teach. Further, an estimated 60% of multiple subject credential teachers complete their lower division course

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[4] National Assessment of Educational Progress, Average fourth-grade NAEP science scores and %age of students in each achievement level in 2005, by state, http://nationsreportcard.gov/science_2005/s0106.asp. A new assessment was performed in Spring 2009, but results will not be published until 2010.
[5] McMurrer, Jennifer. (2008). Instructional Times in Elementary Schools: A Closer Look at Changes for Specific Subjects (Center on Education Policy) p.4.
[6] Sherri L. Fulp (2002). Status of elementary school science teaching. (North Carolina: Horizon Research, Inc.)
[7] Dorph, R., Goldstein, D., Lee, S., Lepori, K., Schneider, S., Venkatesan, S. (2007). The status of science education in the Bay Area: Research brief. Lawrence Hall of Science, University of California, Berkeley; California.

requirements at a community college, where there is often even less alignment with teacher preparation programs than at four-year institutions.

Both UC and CSU have spent considerable resources in recent years to improve the quantity and quality of secondary school (single-subject credentialed) science teachers. While there are indications that even a focus on single-subject science teachers can have a beneficial effect for multiple-subject teachers in these programs as well, there are few teacher preparation programs with a specific focus on science for elementary school teachers. A working group of educational experts examined 40 teacher preparation programs in 14 institutions; of these, nine were deemed to have promising approaches to preparing teachers to teach science, and only three focused on multiple-subject teachers.

In short, there has been increasing administrative pressure to focus on reading and math at the expense of other subjects such as science at the elementary level, and a significant percentage of multiple-subject teachers aren't comfortable with the subject to begin with. Many of them are primarily exposed to science content through lower-division college courses that are not necessarily aligned with teaching standards. The fact that experienced teachers seem to gain confidence in their reading and math teaching, but not science, suggests that much stronger preparation and in-service support is necessary.

Recommendations

There are programs that warrant further observation, support, and evaluation, in addition to consideration of their promise for replication, scaling up, and sustainability in order to continue to strengthen science teaching significantly in all of California's classrooms. Our recommendations focus on understanding and building upon these models.

1. Share and Disseminate Information on Existing Promising Programs and Infrastructure Proactively and More Effectively

In 2010, the CSU should convene a system-wide symposium on best practices in multiple subject teacher preparation focusing on teaching K-6 science. Based on the data analyzed for this report, it appears that more specific data exist at the campus level regarding the success of multiple-subject preparation programs in this area. This first symposium of its kind would provide a critical, tangible opportunity for these data to be shared and applied throughout the state.

Use the California STEM Innovation Network (CSINet) to promote the outcomes of this symposium and incorporate results into a broader STEM education strategy for the state.

2. Adapt existing policies to protect and enhance K-6 science teaching

By 2011, the California Commission on Teacher Credentialing should align the multi-subject science course requirements with single subject science requirements; UC and CSU should pilot this approach in their respective Cal-Teach/SMI and MSTI.

The California Community College System Chancellor's Office should develop system-wide articulation agreements with the CSU in particular, focusing on lower division requirements for multiple subject teachers.

3. Take a Leadership Role in the Discussion of Science Standards

Student and teacher standards are undergoing revision at the national level. The National Academy of Science has urged attention to the incorporation of an inquiry-based approach and there has been significant interest in California in strengthening the focus on inquiry-based learning in teacher programs. California needs to take a leadership role in this process and work diligently to ensure that teacher preparation programs both anticipate and reflect these revisions.

4. Follow the Recommendations of the "Building a Village" Convocation

The problem of K-6 teacher confidence and preparation in science appears systemic and not subject to a quick fix. The 2009 National Academies convocation "Nurturing and Sustaining Effective Programs in Science Education for Grades K-8: Building a Village in California," which was convened to help inform this report, lays out a blueprint to address the challenge sustainably. It should be implemented.

5. Use New Data to Guide Policy

Make use of new information being gathered by CFTL about the components of effective elementary science teacher preparation programs and how teachers are prepared and continually supported.

The efforts of the CSU Center for Teacher Quality need to be replicated for other systems. Individual preparation institutions should implement surveys similar to the CSU study in consultation with the CSU and the CSINet, with the discussion to begin during the symposium in recommendation 1.

The state of California claims a rich set of institutions and talented individuals who are developing and implementing innovative programs to enhance the quality of K-6 science teaching and learning. Progress is being made in connecting these distributed programs both across campuses and across institutions – yet much more must be done in a systematic and focused manner to improve teacher training and development in order to achieve measurable progress and impact on teacher readiness to teach science.

1. Science and Mathematics Education in California

Key Findings

- *Emphasis on math and reading scores due to the No Child Left Behind (NCLB) Act have led to less time and resources for other subjects, including science.*
- *Not enough is known about how K-6 teachers are prepared to teach science. However, 50% of California 4th graders scored at or below basic proficiency in science in the most recent national assessment.*
- *National proficiency scores are on a par with the levels recorded in the California Standards exam, where 51% of 5th graders performed at or below basic proficiency.*
- *Nationally, the amount of time spent on science in the K-6 classroom has declined by at least a third since 2001. One California study found even lower totals, with only 50% of teachers spending at least an hour a week, and 16% spending no time at all on science.*

Background

California is by many measures the nation's leading science and technology state. As the California Council on Science and Technology (CCST) has noted for years, the state's many high-tech sectors, from agriculture to aerospace and from medicine to telecommunications, benefit from a workforce with strong backgrounds in mathematics and science. However, as CCST has also noted as early as 1999, California's educational system has not been producing the quantity of proficient science and engineering graduates needed to meet these industries' growing requirement for skilled workers.[8]

As we conclude the first decade in the 21st century, this situation has not improved. Data from the Bureau of Labor Statistics suggest that employment growth in science and engineering (S&E) related occupations will outpace overall employment growth by a factor of two through 2014.[9] The quality of the science, technology, engineering, and mathematics (STEM) education U.S. students receive remains a major source of concern for policymakers[10] and business CEOs. Leaders across the U.S. from diverse sectors have recognized the critical importance of recruiting and training more and better-prepared science teachers for the nation's schools to address and impact this continued stagnation. This finding was a central conclusion of *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, the 2005 report of the Committee on Prospering in the Global Economy of the 21st Century

[8] California Council on Science and Technology. (1999). *California Report on the Environment for Science and Technology*. (Sacramento: CCST)
[9] Bureau of Labor Statistics (BLS). (2006) *National Industry-Occupation Employment Projections 2004–2014.* Washington, DC: U.S. Department of Labor.
[10] Stine, Deborah D. and Matthews, Christine M. (2009) *The U.S. Science and Technology Workforce* (Congressional Research Service)

of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine.

The Committee[11] reported these actions as its two highest priorities:

- *Annually recruit 10,000 science and mathematics teachers.*
- *Strengthen the skills of mathematics and science teachers through training and education programs as well as continuing development programs throughout their careers.*

CCST, in its related 2007 report, *Shaping the Future: California's Response to Rising Above the Gathering Storm*, reinforced this message, adding that California needs to vastly improve K-12 science and mathematics education in order to increase its talent pool.[12] Similarly, the Public Policy Institute of California (PPIC) has identified the gap between the demands of California's economy and the supply of college-educated workers as posing a serious threat to the state's economic future. Based on the current trend, California will not have enough highly educated workers by 2025.[13] In order to generate highly educated workers, California must train and educate K-12 teachers who have demonstrated proficiency in a 21st century competency of science.

The May 2004 compact between Governor Schwarzenegger and California's higher education community identified the critical shortage of K-12 science teachers as a major priority. Consequently, California's institutions of higher education, spanning the entire spectrum from 2-year community colleges to 4-year universities, have focused considerable efforts and resources on expanding middle and high school teacher education programs.

Throughout this decade, CCST and the Center for the Future of Teaching and Learning (CFTL) have examined the preparation of California's science and mathematics teachers. In their jointly produced 2007 report, they explored the details of the preparation and training of teachers with subject specific credentials in mathematics and science, concluding that the state lacked a coherent system to consistently produce fully prepared teachers in these disciplines and that the state did not have the capacity to meet the demand for fully prepared science and mathematics teachers.[14] However, this analysis focused on the supply and distribution of teachers with appropriate subject-specific credentials at the middle school and high school levels. Because mathematics and science classes at the high school level must be taught by teachers with specialized credentials, it is possible to quantify the percentage of teachers without the specific credentials in any given subject at that level.

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[11] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. Committee on Prospering in the Global Economy of the 21st Century, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (2005)

[12] California Council on Science and Technology (2007) *Shaping the Future: California's Response to Rising Above the Gathering Storm* (Sacramento: CCST)

[13] Johnson, Hans (June 2009) *Educating California: Choices for the Future*, Public Policy Institute of California (PPIC).

[14] CCST and CFTL (2007), p.83.

The situation is different at the elementary school level. In grades K-6, almost all teachers hold a multiple subject credential, which enables them to teach all subject areas, including science, in a self-contained classroom. As CCST observed in its previous analyses of California's science, technology, engineering and mathematics (STEM) education system, not enough is known about how elementary school teachers are prepared to teach science in the lower grades, or the skills and knowledge they bring to the classroom.[15] What is known is that California's students perform below par for the nation in science: the most recent national assessment of 4th graders showed 50% of California students scored at or below basic proficiency in the subject – only Mississippi had a higher percentage of students below basic proficiency.[16] For a state whose economy relies so heavily on its science and technology sectors, this assessment is nothing short of alarming.

Indicators of elementary school teacher content knowledge are not as extensive as those for single subject credentialed teachers. However, it is possible to establish some correlations between certain preparation pathways and the preparedness of elementary teachers, as reported by themselves and their supervisors.

Goals of This Study

This report provides a quantitative, descriptive and qualitative review of how elementary school teachers are prepared to teach science. It describes:

- Elementary science education and performance in California.
- How elementary teachers are prepared to teach science.
- The range of content knowledge that elementary teachers are required to learn during the preparation process.
- How prepared elementary teachers are to teach science, as rated by themselves and their supervisors.
- Examples of different teacher preparation approaches in practice at several public and private education institutions in California.
- Recommendations for measuring and improving the preparedness of both new teachers and currently practicing elementary teachers to teach science.

The teacher preparation landscape is rapidly changing, and it must be observed that the majority of teachers in California earned their credentials before the teacher preparation standards set forth under Senate Bill 2042 (Alpert) went into effect in 2004. That law requires that subject matter training for prospective teachers be tied to the state's content standards for students.[17]

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[15] Ibid, p.85.

[16] National Assessment of Educational Progress, Average fourth-grade NAEP science scores and %age of students in each achievement level in 2005, by state, http://nationsreportcard.gov/science_2005/s0106.asp. A new assessment was performed in Spring 2009, but results will not be published until 2010.

[17] Guha, R., Shields, P., Tiffany-Morales, J., Bland, J., & Campbell, A. (2008). *California's teaching force 2008: Key issues and trends.* Santa Cruz, CA: The Center for the Future of Teaching and Learning. p.65.

California Guidelines for Effective Science Teaching

According to the California Department of Education, effective science programs:[18]

- Are based on standards and use standards-based instructional materials.
- Develop students' command of the academic language of science used in the content standards.
- Reflect a balanced, comprehensive approach that includes the teaching of investigation and experimentation skills along with direct instruction and reading.
- Use multiple instructional strategies and provide students with multiple opportunities to master the content standards.
- Include continual assessment of students' knowledge and understanding, with appropriate adjustments being made during the academic year.
- Continually engage all students in learning and prepare and motivate students for further instruction in science.
- Use technology to teach students, assess their knowledge, develop information resources, and enhance computer literacy.
- Have adequate instructional resources as well as library-media and administrative support.
- Use standards-based connections with other core subjects to reinforce science teaching and learning.

These guidelines suggest that the primary goals for teaching science at the K-6 level are first and foremost to understand what the standards are and to translate the standards into effective teaching and learning activities. Equally important is for the students to learn the content represented in the standards. However, a teacher's understanding of what the standards entail does not necessarily equate to acquiring content knowledge, nor does it ensure acquiring the ability to effectively teach the content. This is consistent with the approach of the National Council for Accreditation of Teacher Education (NCATE), whose program standards include limited assessment of scientific content knowledge, self-efficacy, and educational preparedness.[19]

Methodology

The study involved data collection and analysis from public and private K-6 teacher preparation programs across the state and consultation with a working group of teachers, science education faculty, and other experts. Given the large number of institutions throughout California actively engaged in elementary school teacher preparation projects, this report reflects a "snapshot" rather than a comprehensive and complete documentation and assessment of California's preparation of teachers to teach science at the elementary school level. Key elements of the report methodology included:

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[18] Curriculum Development and Supplemental Materials Commission (2004). *Science Framework for California Public Schools, Kindergarten Through Grade Twelve.* Sacramento, CA: California Department of Education, p. 11.
[19] National Council for Accreditation of Teacher Education (2004), *Program Standards for Elementary Teacher Preparation*, p.16.

- **Engagement of Knowledgeable Experts**
  - CCST convened a K-6 Science Teaching Working Group (Appendix A) comprised of teachers, science education faculty, and other education experts who are actively engaged in providing "wisdom of practice" and practical knowledge, advice, review, and recommendations. This group recommended data sources and individuals who could help guide research and identified universities with innovative liberal arts programs that address the issue of science content for students interested in pursuing careers as elementary school teachers. The Working Group emphasized the importance of "inquiry-based" learning and encouraged CCST to seek out teacher preparation curricula that included this teaching method.

- **Research and Data Collection**
  - Data from institutions of higher education (public and private; profit and not-for-profit) that have accredited teacher preparation programs for multiple subject credentials, including enrollment and graduation figures and CSU survey data from the new graduates of teacher preparation programs (2001-2007).
  - The California Commission on Teacher Credentials (CTC) Teacher Supply reports (1999-2007).
  - National Science Board indicators, elementary school student performance in science and math (2000-2010).
  - National Science Board indicators, science teacher professional development (2000-2010).
  - State policies that govern the science content that multiple subject-credentialed teachers are expected to know.
  - Representative sampling of science methods curricula and syllabi in accredited teacher preparation program.

- **Evaluation/Validation of Report Summary, Findings, and Recommendations**
  - A multi-step review and comment cycle provided a critical feedback loop both in terms of overall report clarity and accuracy as well as validation of proposed findings and recommendations.
  - New ideas and suggestions were sought by all involved in the project.

These methodology components reflect an integrated and interdependent process to ensure a valid report with actionable findings and recommendations.

Science in the Classroom

The *Science Framework for California Public Schools* states the following:

> The elementary school science program provides the foundational skills and knowledge students will need in middle school and high school. Students are

introduced to facts, concepts, principles, and theories organized under the headings of physical, life, and earth sciences.[20]

The standards, which were put in place in 1998, focus on introducing students to scientific thinking, practice, and ethics through a series of benchmark core concepts for each grade. Beginning in 2004, the California Standardized Testing and Reporting (STAR) program has administered standards-based tests to California 5th graders measuring the achievement of state content standards. This is the first and only point at which the state assesses elementary students for proficiency in science standards.[21] In contrast, STAR examinations in English and Mathematics are administered annually beginning in the 2nd grade.

The performance of California 5th graders on the STAR science exams, although initially poor, is now essentially comparable to (and as low as) other subjects (see Table 1); 49% of 5th graders scored at proficient or better in science, compared to 54% of 5th graders in English-language arts and 57% in mathematics.

Table 1: Percentages of 5th Grade Students Scoring at Proficient or Above on California Standards Tests (2009)

English – Language Arts (5th grade)	54%
English – Language Arts (all grades, 2-11)	50%
Mathematics (5th grade)	57%
Mathematics (all grades, 2-11)	46%
Science (5th grade)	49%
Science (5th, 8th, and 10th grade)	50%

Source: CDE[22]

It is notable that the proficiency level recorded by the STAR exam is comparable to that recorded by the NAEP survey in 2005 (above), and that this score is markedly lower than the national average of 66% at or above basic proficiency.[23]

The primary focus on mathematics and English has stemmed in large part from the federal No Child Left Behind Act (NCLB). NCLB went into effect in 2002 and linked federal funding to assessments in mathematics and reading. According to a study by the Center on Education Policy, in the five years following enactment of NCLB, this resulted, nationally, in an average decrease of 32% in terms of minutes spent on other subjects including science, social studies, arts and music, and physical education.[24]

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[20] Curriculum Development and Supplemental Materials Commission (2009). *Science Framework for California Public Schools, Kindergarten Through Grade Twelve* (California Department of Education) p.24.
[21] NB the National Assessment of Educational Progress exams, which are national, assess students at the 4th grade level and are administered every 4 years.
[22] http://www.cde.ca.gov/nr/ne/yr09/yr09rel119.asp#tab5
[23] NAEP, op.cit.
[24] McMurrer, Jennifer. (2008). *Instructional Times in Elementary Schools: A Closer Look at Changes for Specific Subjects* (Center on Education Policy) p.4.

However, there is evidence that even less time is spent on science at the K-6 level in California. The Center on Education Policy study found that schools reported they spent an average of 152 minutes per week on science in the 2006-7 school year (down from 226 in 2001-2). Other studies have found lower reported totals spent on science – as low as 125 minutes per week even before the enactment of NCLB, according to one study.[25] Yet a 2007 California survey of schools in the Bay Area found substantially lower totals: 80% of K-5th grade multiple-subject teachers reported spending 60 minutes or less per week on science. This number was considerably less than the estimates provided by the district offices, which indicated that only 50% of elementary school classrooms spend 60 minutes or less per week. In this survey, a remarkable 16% of the teachers who responded stated that they spent *no time at all* on science.[26]

As seen in Figure 1, this percentage is even higher in K-2, where more than 20% of respondents stated they spent zero minutes per week on science, compared to 3rd-5th grades, where 10% of teachers reported spending no time. In part, this discrepancy may be due to the fact that, for grades K-3, standards-based science content is now integrated into nonfiction material in the basic reading/language arts reading programs. However, even the state instructional standards state that, for teaching science, "Effective use of limited instructional time is always a major consideration in the design of lessons and courses."[27]

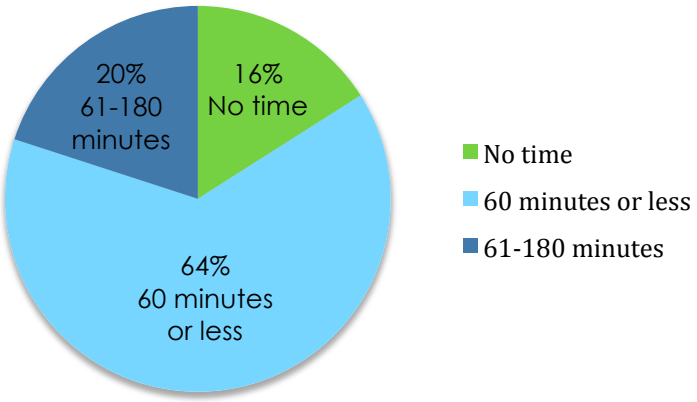

Figure 1: Minutes per Week on Science in Self-contained K-5 Classrooms
Source: Lawrence Hall of Science (2007); see
http://www.lawrencehallofscience.org/rea/bayareastudy/ltd_min_wk_sci.html

The California science standards framework originally was scheduled to be revisited in 2010. However, following substantial cuts in the 2009-10 state budget, operations for the California Curriculum Development and Supplemental Materials Committee have been suspended; the next planned revision of the science standards is now scheduled for 2013-2014 at the earliest.

[25] Sherri L. Fulp (2002). *Status of elementary school science teaching.* (North Carolina: Horizon Research, Inc.)
[26] Dorph, R., Goldstein, D., Lee, S., Lepori, K., Schneider, S., Venkatesan, S. (2007). *The status of science education in the Bay Area: Research brief.* Lawrence Hall of Science, University of California, Berkeley; California.
[27] *Science Framework for California Public Schools, Kindergarten Through Grade Twelve,* p. 11.

In short, results from the available measures of California K-5 student science performance are not encouraging, and evidence at the national and state levels suggests that less and less time is being spent on science in elementary school despite the institution of the California Standards Test at 5th grade in 2004. Due to the lack of time as well as the lack of resources, many teachers reported an inability to include any inquiry-based science in their K-6 curriculum.

2. Preparing K-6 Teachers to Teach Science in California

Key Findings

- *The state awarded 23,320 teaching credentials in 2007-8, down 3.5% from 2006-7 and 25% from 2001-2.*
- *The decline has disproportionately affected the number of multiple-subject credential teachers, which dropped by 39% since 2003-4, compared with a drop of only 17% in single-subject credential teachers.*
- *The primary alternative teacher preparation route (internship credentials) focuses more heavily on single-subject credentials.*

The California Commission on Teacher Credentialing document, *Standards of Program Quality and Effectiveness for the Subject Matter Requirement for the Multiple Subject Teaching Credential (September 2001)*, serves as a handbook for teacher educators and program reviewers**.** This handbook provides a comprehensive set of criteria that guides the academic content standards for students in science in K-8.[28] Specific science requirements are outlined below:

Content Domains for Subject Matter Understanding and Skill in Science

The standards of quality and effectiveness for the subject matter requirement for the multiple subject teaching credentials in California divide science into three primary areas:

1. Physical Sciences
    a. Structure of properties of matter
    b. Principles of motion and energy

2. Life Sciences
    a. Structure of living organisms and their function (physiology and cell biology)
    b. Living and non-living components in environments (ecology)
    c. Life cycle reproduction and evolution (genetics and evolution)

3. Earth and space sciences
    a. Solar system and the universe (astronomy)
    b. Structure and composition of the Earth (geology)
    c. Earth's atmosphere (meteorology)
    d. Earth's water (oceanography)

[28] California Commission on Teacher Credentialing; *Standards of Quality and Effectiveness for the Subject Matter Requirements for the Multiple Subject Teaching Credential; Handbook for Teacher Educators and Program Reviewers*; 6 September 2001; pA17-20.

Subject Matter Skills and Abilities Applicable to the Content Domains in Science[29]

Ideally, candidates for Multiple Subject Teaching Credentials know how to plan and conduct a scientific investigation and apply principles of experimental design. They are also required to distinguish between dependent and independent variables and controlled parameters, and between linear and nonlinear relationships on a graph of data; use scientific vocabulary appropriately; select and use a variety of scientific tools (e.g., microscopes) and know how to record length, mass, and volume measurements using the metric system. They should also be able to interpret results of experiments, communicate the steps in an investigation, record data, and interpret and analyze numerical and non-numerical results using charts, maps, tables, models, graphs, and labeled diagrams. They should make appropriate use of print and electronic resources (including the Internet) when preparing an experiment.

In particular, they need to be able to communicate the steps and results of a scientific investigation in both verbal and written formats.

Teaching Science in a Multiple Subject Assignment

Multiple subject candidates are supposed to demonstrate their ability to teach the state science standards, balancing the focus of instruction between information, concepts and investigations. They should be able to effectively illustrate science concepts and principles, scientific investigation, and experimentation. The manner in which they demonstrate these skills varies by preparation program.

Teacher Preparation Routes

There are numerous pathways towards becoming a teacher in California, but all teachers must be certified by the California Commission on Teacher Credentialing (CTC). Typically, a teacher candidate must complete a baccalaureate degree, pass the California Basic Educational Skills Test or suitable equivalent, complete a CTC-approved teacher preparation program, and demonstrate subject matter competency—which requires that elementary teachers pass the relevant California Subject Examinations for Teachers, CSET.[30] A flow diagram outlining the teacher preparation system is shown in Figure 2. In this figure, the triangles are input points where different prospective teacher populations enter the teacher production system; the rectangles represent requirements that must be completed before advancing to the next stage; and diamonds represent populations of teachers actually in the classrooms.

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[29] Ibid; p A21

[30] Beginning in May 2007, a second option became available for individuals to meet the Basic Skills Requirement, formerly known as the CBEST requirement: individuals interested in earning a Multiple Subject teaching credential could pass the California Subject Examinations for Teachers: Multiple Subjects (CSET:MSE) plus an additional Writing Skills subtest. -

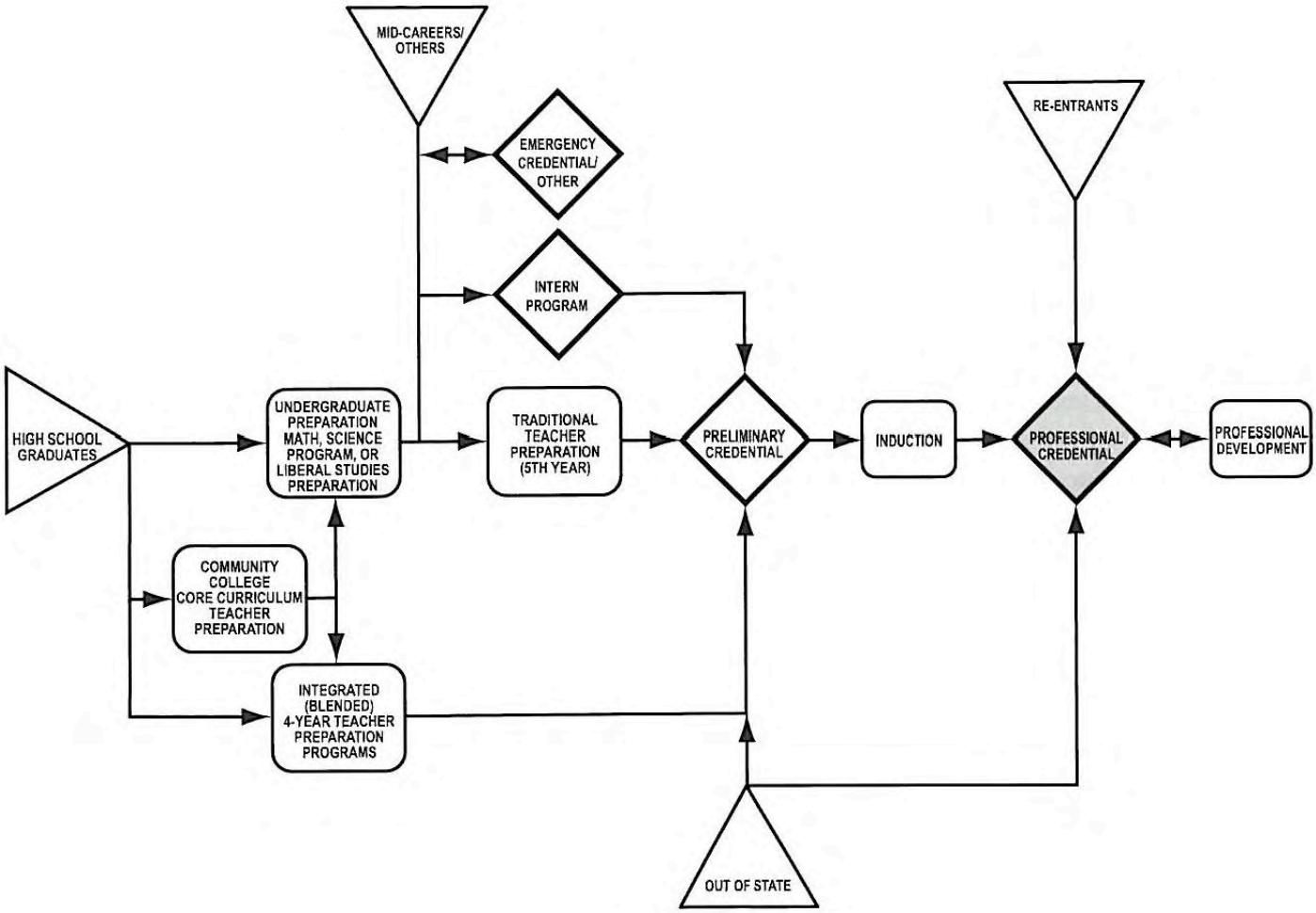

Figure 2: Schematic flow diagram of the teacher production system
Source: CCST & CFTL, 2007[31]

Most teachers follow the traditional preparation route, which entails enrollment in a 5th year teacher-preparation program leading to a preliminary credential following achievement of their baccalaureate. The preliminary credential permits teachers to begin working in the classroom for up to five years, during which time they must complete an approved induction program in order to receive a professional credential.

[31] CCST and CFTL (2007) p. 13. Although the state now uses "provisional intern credietials" instead of "emergency crededitals" this diagram is still correct in terms of entry points and flows of potential teachers. I

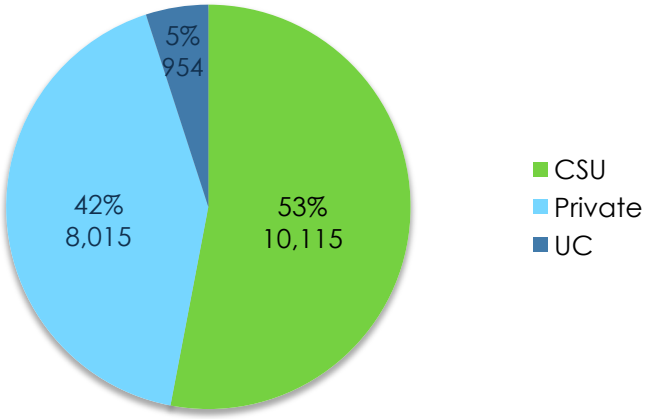

Figure 3: Percentage of awarded credentials from California institutions
Source: Commission on Teacher Credentialing

In 2007-8 23,320 teachers were awarded credentials in California, with 19,084 from a California institute of higher education and the remainder from district programs or out-of-state programs.[32] The California State University System produces approximately 53% of teachers in the state, followed by private and independent schools (42%) and the University of California (5%).[33] Typically, prospective teachers pursuing multiple subject credentials cover most of their mathematics and science content at the undergraduate level.

Although no specific undergraduate major is required to enter a traditional teaching preparation program following the baccalaureate, the CSU and many private institutions offer liberal studies majors designed with the teacher preparation pathway in mind (although these programs are not exclusively for prospective teachers). Traditional liberal studies programs do not offer significant pedagogical content during the four-year baccalaureate studies; rather that material is addressed in the credential program. "Blended" programs include pedagogically focused credential studies in the undergraduate program and are typically completed in less than five years.

Most entry-level science courses are not specifically designed for prospective teachers; hence the science classes often are not oriented towards providing teachers with content expertise in the particular areas they are expected to teach. In other words, the range of science content courses taken by prospective teachers at the undergraduate level is not necessarily aligned with the science content they are later required to teach.

As will be described later, it also should be noted that as many or more than 60% of multiple subject credential teachers are estimated to complete their lower division course requirements at a community college. This indicates that any efforts to strengthen teacher preparation at the undergraduate level in California must include the community colleges as well as the four-year institutions.

[32] Commission on Teacher Credentialing (2009). *Teacher Supply in California: A Report to the Legislature (2007-08)* p. 2.
[33] Ibid., p. 9.

Alternative Programs

Alternative routes are another way to enter the teaching profession, drawing a diverse pool of prospective teachers, including mid-career entrants from other fields. The primary alternative route in California is the internship credential, which authorizes prospective teachers to begin teaching while they participate in programs that prepare them for certification. These internships are compliant with NCLB and are offered for prospective teachers who have demonstrated subject matter competency. In 2007-8, the Commission on Teacher Credentialing issued 1,254 new multiple subject intern credentials,[34] compared with 5,687 internship credentials overall and 9,768 regular multiple subject credentials. Although multiple subject credentials accounted for 49% of credentials issued in 2007-8, they accounted for only 22% of internship credentials, indicating that this alternative route focuses more on single subject and educational specialist credentials.[35]

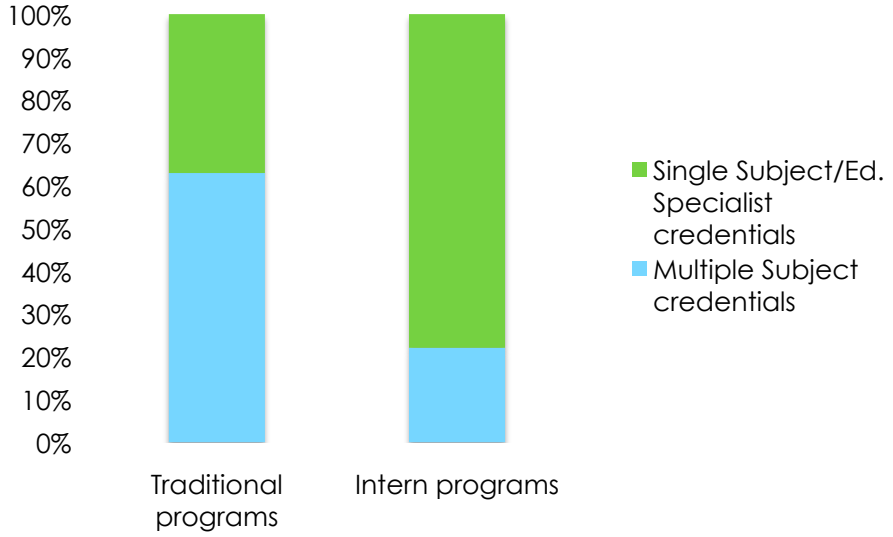

Figure 4: Percentages of multiple subject credentials awarded to teachers prepared in California IHE programs, traditional vs. intern
Source: Commission on Teacher Credentialing

Although the internship credentials are considered to be NCLB compliant, CCST and CFTL consider teachers holding internship credentials to be under-prepared.[36] However, most of these prospective teachers earn preliminary credentials during the period they hold positions as interns.

Recent California legislation has been enacted to increase the supply of teachers by reducing barriers into the profession via alternative routes. Senate Bill1209 (Scott), passed in 2006, included several provisions that simplified the process of earning a

[34] Commission on Teacher Credentialing (2009), op.cit.
[35] The use of emergency permits has been phased out, with none issued in 2007-8; however a new credential, the short-term staff permit, has been instituted with essentially the same goal, namely to allow districts to address urgent staffing needs in the absence of adequate supplies of credentialed staff.
[36] CCST and CFTL (2007), p.44.

teaching credential, which may help encourage more individuals to consider entering the profession. The legislation streamlined testing requirements for prospective teacher candidates and made it easier for teachers who hold credentials from outside the state to earn a credential in California.

3. How Well Prepared Are Elementary Teachers to Teach Science?

Key Findings

- *The California State University Center for Teacher Quality surveyed over 12,500 first-year teachers over an eight-year period regarding how prepared they felt. Over the same period, approximately 8,000 supervisors were also asked to rate the same pool of teachers.*

- *First-year teachers consistently have reported themselves better prepared to teach reading and math than science.*

- *Supervisor assessments of the teachers have been consistently higher, and increased over the eight years of the survey, leading to a difference of approximately 20% by 2006-7.*

- *Experienced teachers reported higher self-assessments of proficiency in reading and math, but nearly identical levels in science as first-year teachers..*

In general, discussions of the preparedness of the teaching workforce in California have focused on the percentages of teachers without credentials or, at the middle and high school levels, teachers without the appropriate single-subject credential for the subject areas to which they are assigned. CCST and CFTL found in their 2007 report, *Critical Path Analysis of California's Science and Mathematics Teacher Preparation System*, that little attention has been paid to the preparation of elementary school teachers to teach science as part of California's recent focus on STEM education.[37] Much of the discussion about science and mathematics education and the need for teachers proficient in these fields has focused on high school, where single subject credentials are required to teach in the various disciplines and the primary metric for success is often seen as a successful transition to a higher education institution.

Assessing the preparedness of fully credentialed multiple-subject teachers to teach science is a different matter. Most studies seeking to evaluate teachers' proficiency in a given subject area have focused on interview studies measuring teachers' perceptions of their own preparedness, without a comparative analysis of students' educational outcomes.[38] However, research on teacher efficacy has indicated that there is a relationship between self-assessments of preparedness and behaviors that affect student learning, including a willingness to try new instructional techniques, persistence in problem-solving, and levels of planning and organization.[39]

Currently, the most comprehensive data available on the subject-matter preparedness of teachers come from the California State University System-wide Evaluation of Teacher Preparation, conducted by the Center for Teacher Quality at the CSU

[37] CCST and CFTL (2007), p.85.
[38] Harrington, Jennifer (2007). "How elementary teachers with multiple subjects credentials are prepared to teach science." (CCST internal report)
[39] Darling-Hammond, Linda, Chung, Ruth, Frelow, Fred and Fisher, Heidi. (2002) "Variation in Teacher Preparation: How Well do Different Pathways Prepare Teachers to Teach?" *Journal of* Teacher Education Vol. 53, No.4.

Chancellor's Office. The survey has been administered annually since 2001 to a random sample of first-year teachers who graduated from teacher credential preparation programs in the CSU,[40] as well as to their supervisors. There is currently no such equivalent source of information available from other credential granting institutions in California.

CSU Annual Survey Parameters

Survey results were examined for the graduates of CSU multiple subject teacher preparation programs from 2001 to 2007. This represented a total of 12,753 participants over eight years. This number is approximately 23% of graduates from CSU multiple subject teaching preparation programs and just over 12% of all multiple subject graduates of California teaching preparation programs over that period of time. The survey population contains K-8 teachers, not just K-6; however, the majority of teachers surveyed were teaching in K-6. Furthermore, the majority of respondents were liberal studies majors as undergraduates.

School site supervisors of the graduates also were surveyed. Supervisors were primarily principals (92%) or assistant principals (8%). An average of just over 1,000 supervisors responded per year, representing approximately 17% of public elementary schools in the state.

The survey asked teachers and their supervisors to report how well prepared they were to "know and understand" the subject matter in each of 24 content areas taught in the elementary grades. Not all subjects were surveyed through all eight cohorts, but assessments of overall preparedness to teach reading, mathematics, and science were included in every survey. The surveys were administered to teachers during the last two months of their first year of teaching; supervisors' assessments were collected at the same time of the school year. Details on the survey are included in Appendix B.

Survey Results, 1999-2007

School supervisors were asked to respond to the question "How well did this teacher know and understand each subject listed below?" for each of the 24 elementary school subjects in six topic areas: 1) reading-language arts, 2) history-social science, 3) mathematics, 4) science, 5) visual and performing arts, 6) physical education, health and human development. In the science topic area, respondents were asked to evaluate the teacher's knowledge in the four science domains covered in elementary education: physics, chemistry, biology and earth science. They were asked to consider their classroom observations and conferences with the named teacher, and to report how well the teacher was prepared to teach the subject according to California grade-level standards at their assigned grade level. Supervisors ranked teacher knowledge and understanding according to the following scale:

3 = teacher was <u>well prepared</u> to know and understand this subject.

[40] We are grateful to the CSU Center for Teacher Quality and Chancellor's Office for permission to use the survey data from this report. See www.calstate.edu/teacherquality for more information about the Annual Report.

2 = teacher was adequately prepared to know and understand this subject.
1 = teacher was somewhat prepared to know and understand this subject.
0 = teacher was not at all prepared to know and understand this subject.

Similarly, teachers were asked "When you taught material related to this subject in your class, how well did you know and understand the material?" for the same set of subject matter areas. Teachers ranked teacher knowledge and understanding according to the following scale:

3 = When I taught materials related to this subject, I knew and understood it well.
2 = When I taught materials related to this subject, I knew and understood it adequately.
1 = When I taught materials related to this subject, I knew and understood it somewhat.
0 = When I taught materials related to this subject, I knew and understood it not at all.

Supervisors consistently reported a higher percentage of teachers well or adequately prepared in all subjects than teachers did (Figure 5). Supervisors reported that teachers were especially well prepared in mathematics and reading-language arts, with the figure across cohorts averaging 84% and 83% respectively. In science, the supervisors reported a somewhat lower percentage were well or adequately prepared, averaging 76%.

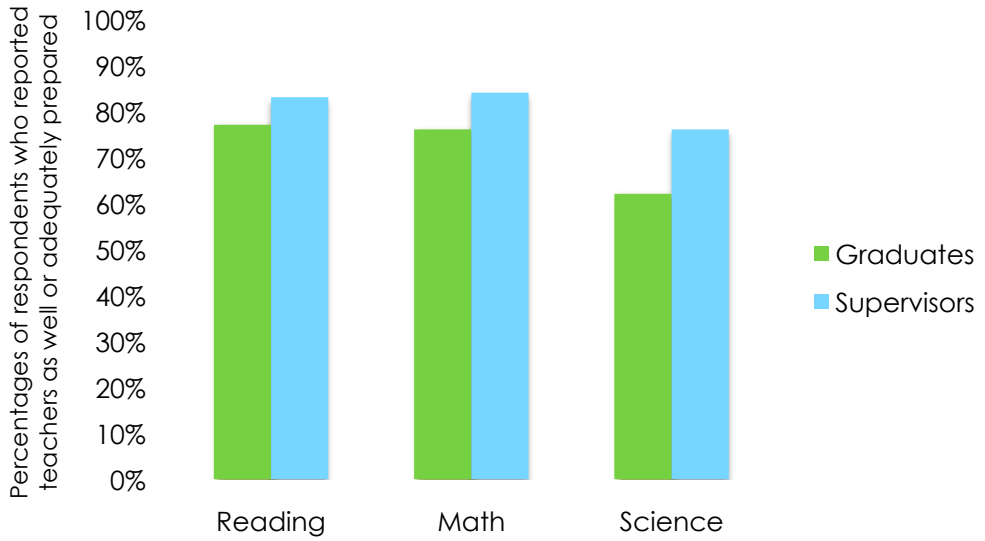

Figure 5. Perception of content preparedness for first-year multiple subject teachers: graduate self-assessments and supervisor assessments, aggregated for 1999 - 2007
Source CSU Center for Teacher Quality

Similarly, teachers felt they had the most knowledge and understanding in the subjects of mathematics and reading-language arts as opposed to science (Figure 5). The difference between supervisor and teacher assessments for science was larger than the differences in reading and mathematics, indicating that the supervisors consider the teachers to be considerably better prepared than the teachers themselves reported over time (Figure 6).

The results in mathematics and reading-language arts are unsurprising given the strong emphasis on those subjects under No Child Left Behind. Because schools were required to make adequate yearly progress in only those subject areas, teacher preparation, induction, and professional development programs also highlighted content knowledge and skills in those areas.

The difference in teacher and supervisor perceptions of preparedness became more pronounced over the course of the survey. While the difference for reading remained unchanged by the eighth year of the study (7%), and rose only slightly for mathematics (from 8% to 11%), for science it was more pronounced from the outset (12%) and rose to a remarkable 20% by the last cohort (Figure 4). The shift reflects a notable increase in the perceptions of preparedness by supervisors.

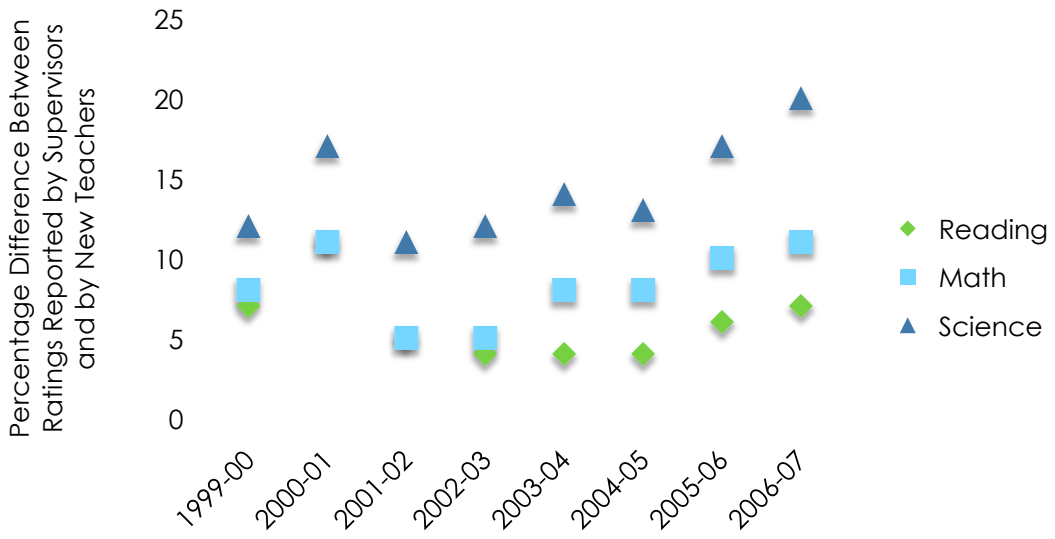

Figure 6. Difference in assessments between supervisors and teachers regarding preparedness for reading, math, and science, 1999-2007
Source: CSU Center for Teacher Quality

This finding is consistent with previous research concerning elementary school teachers.[41] It suggests that, despite available metrics to the contrary, teachers remain much less confident about teaching science than other subjects. The fact that scores have risen on the science standards exam (Figure 7) as well as in supervisor assessments also suggests that there has been, in fact, some improvement in the actual readiness of multiple subject teachers to teach science in grades K-6. However, the teachers themselves may not recognize this improvement. Further study would help clarify the nature of this correlation.

[41] Dorph et al., op.cit.

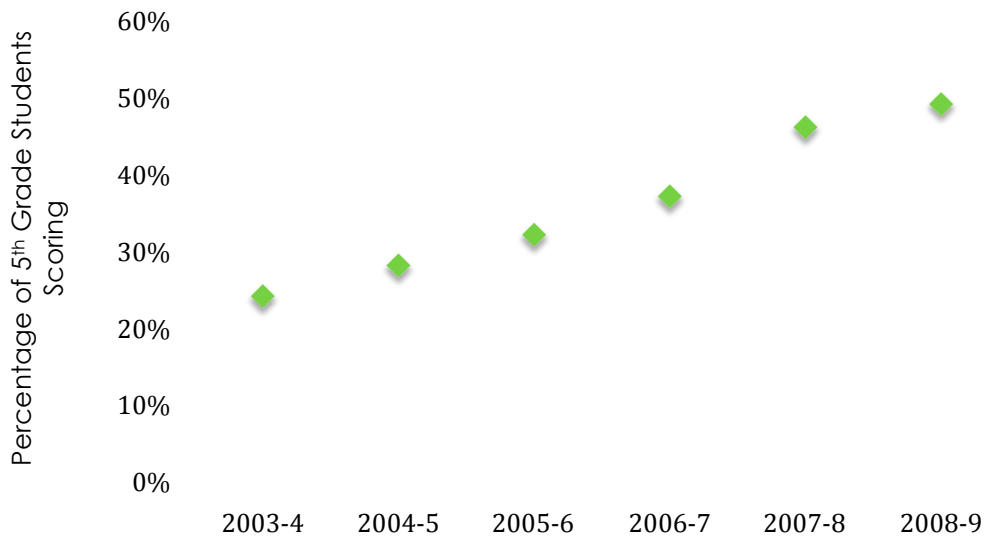

Figure 7: Percentages of 5th grade students scoring at proficient and above in science on California standards tests (2004-2009)
Source: CDE[42]

Moreover, comparison with a sampling of more experienced teachers suggests that teachers' perception of their ability to teach science does not improve with time. A 2007 Lawrence Hall of Science study surveyed 1000 teachers of all experience levels in the Bay Area and found that, while the number of teachers reporting themselves as adequately prepared or better to teach reading and math were higher than the first-year teachers surveyed by CSU, the science numbers were no different (Figure 8).

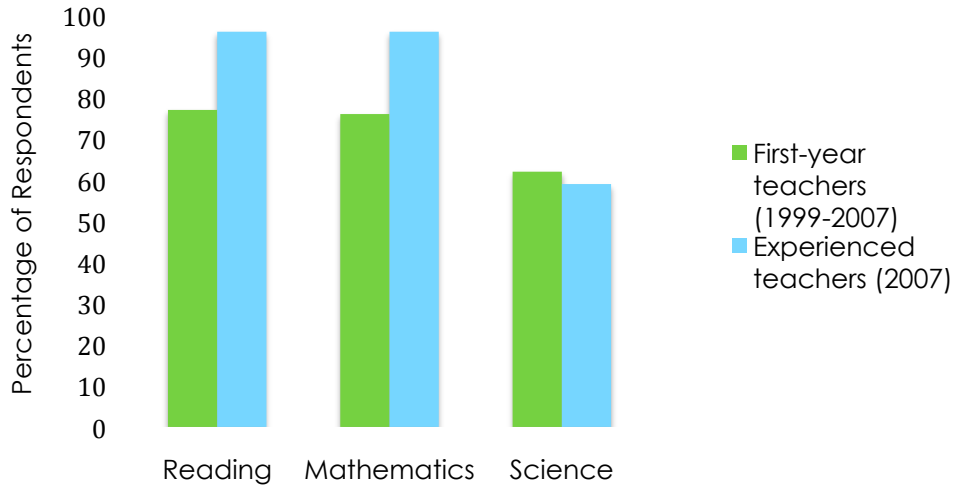

Figure 8: First-year teacher perception of content preparedness versus experienced teachers (data reflects an aggregation 1999-2007)
Source CSU Center for Teacher Quality

[42] http://www.cde.ca.gov/nr/ne/yr09/yr09rel119.asp#tab5

The fact that veteran teachers also reported themselves to be less well prepared in science may reflect the emphasis on mathematics and reading mentioned earlier. The federal emphasis on those subjects resulted in a shift in the focus of the California Subject Matter Projects, as well as a substantial investment in the Mathematics and Reading Professional Development Program.[43] With teachers entering the classroom with less confidence in their science teaching and the lack of opportunities for them to strengthen their content knowledge and skill through professional development, it appears that teachers find themselves at a disadvantage when it comes time to teach science. This is where continuing development programs for teachers designed by master teachers can become effective in overcoming the lack of confidence and training in science teaching.

[43] Initially established in 2001 under Assembly Bill 466, the Mathematics and Reading Professional Development Program was reauthorized in 2007 under Senate Bill 472 to continue until 2012.

4. Selected Teacher Education Programs Designed to Strengthen the Preparation of Science Teaching in California

Key Findings

- *With the guidance of the Working Group, CCST examined 40 projects in 14 institutions designed to improve the preparation of teachers to teach science.*
- *Nine programs were identified as promising, only three of which focus specifically on K-6 teacher preparation (Cerritos College, Chico State, and Chapman University).*
- *However, even programs that focus on the production of single-subject credential teachers have a positive effect on the preparation of multiple-subject teacher candidates in the institution to teach science.*
- *The programs at Chico and Cerritos share some common approaches, including an integrated pedagogical approach, a focus on partnerships with other stakeholder institutions, internship opportunities, and a focus on sustainability over time.*

As a result of the Working Group's deliberations and consultations with other experts from all sectors of California's educational systems, CCST surveyed 14 higher education institutions in order to identify and highlight promising approaches for strengthening K-6 teacher preparation in science. From these 14 institutions, which span the state both geographically and structurally (2-year to 4-year), more than 40 projects were reviewed and nine institutions were specifically identified by Working Group members as having initiatives reflecting promising approaches from each sector (Table 2). All nine of these initiatives are summarized in Appendix C.

Table 2. Promising Teacher Preparation Programs in California with a Focus on Science Education as Identified by the Working Group

Community College	CSU	UC	Private/Independent
Cerritos College	Cal Poly/SLO	UC Irvine	Chapman University
	Chico State	UC Riverside	Stanford University
	Cal State Fullerton	UC Santa Cruz	

A distinction needs to be made between programs aimed at improving secondary science teaching, i.e., the production of single-subject credentialed teachers in science, and those concentrating on elementary science teaching. Much of the focus has been on programs such as the California State University Math Science Teacher Initiative (MSTI), which has specific goals in increasing math and science credentialed teachers. The increase in resources and attention to science teacher preparation offers more opportunities to enhance the preparation of multiple-subject teachers in science, but this, too, is often focused on middle schools. At that level, teachers can hold either a multiple subject or single subject credential (and, as of 2009, the new Foundational Level General Science Credential, which is intended to strengthen science teaching for middle schools). Cal State Fullerton, for example, has a Teacher Recruitment Project

that has been successfully recruiting multiple school subject candidates to pursue a second authorization in middle school science. However, it does not directly address K-6 teachers.

Of the nine promising projects, only three (Cerritos College, Chico State, and Chapman) are specifically targeted to K-6 science teachers. The remaining projects are secondary programs with promise to serve as models for K-6 teacher preparation.

Representative examples of promising initiatives with demonstrated impacts are highlighted below. Each of these initiatives has been recognized for its promise by external programs, such as the "2005 AACC Teaching by Choice Award" for Cerritos Teacher TRAC Program and National Science Foundation grants for MSTI (CSU) and Cal Teach (UC). The representative examples include 2-year community college and 4-year public and private institutions. Several of the programs are in the early stages of implementation and, although they've been built upon demonstrated research and pedagogy, their demonstrated impact and sustainability will be determined in the future. Details on all nine programs in a common case study template are provided in Appendix C.

These case studies only serve as a snapshot of the substantive efforts underway throughout the state; however, common principles, values, and underpinnings for recruiting, preparing, and retaining science teachers are found both in long-standing efforts as well as newly initiated ones. These include:

- Supporting approaches that increase the prestige, distinction, and compensation of teaching careers in the sciences.
- Utilizing strategies that fully prepare new science teachers and provide them with opportunities for continuous professional growth and development.
- Preparing candidates for inquiry-based teaching and learning.
- Collaborating with school districts in science teacher preparation and education reform.

Note that community colleges in particular play an important and often unheralded role in preparing elementary school teachers. **In the CSU evaluation of teacher preparation, 65% of teachers earning multiple subject credentials had completed their lower-division coursework at community colleges, with 37% of these receiving CSU credit toward their subject-matter preparation.** Most subject-matter preparation programs rely heavily on students using general education courses to fulfill their subject matter competency, science coursework included, and these are the requirements that students typically fulfill at community college.

Preparing Teachers to Teach Science: The Broader Effort (Secondary Education)

For the California State University, the Mathematics and Science Teacher Initiative (MSTI) represents CSU's system-wide commitment to double its production of teachers in these fields from approximately 750 (in 2003) to 1500 (in 2010). Since the program began in 2004, CSU has increased its production by more than 75%. The CSU has identified four fundamental best practices that reflect its campuses' experiences in the

MSTI program and the research on teacher recruitment, preparation, and retention in the science and mathematics teaching fields. It has focused on those underlying approaches that have been shown to be associated with effectiveness in recruiting, preparing and retaining well-prepared science teachers. These four best practices reflect a systemic approach for preparing and retaining a high quality science teacher workforce in California.

Best Practices

1. **Utilizing broadly based, comprehensive, multi-faceted recruitment approaches to attract outstanding candidates into teaching careers.**

2. **Creating multiple pathways that enable flexible and seamless transitions into and among a range of rigorous teacher credentialing programs.**

3. **Establishing articulated community college transfer programs that entail both articulated academic programs and supportive experiences that enable community college students to work together with CSU students before transfer.**

4. **Enabling future science teachers to be both teachers and scientists through partnerships with federal laboratories in which they engage directly in research with laboratory scientists.**

The Cal State Fullerton Mathematics and Science Teacher Initiative (MSTI) integrates these four best practices in a systemic manner and its efforts along with those of other CSU campuses have been recognized nationally.[44] All of the best practices except the Science Teacher As Researcher (STAR) were designed to apply to both elementary and secondary teacher candidates. Although STAR began as a program for secondary teacher candidates, a number of elementary candidates have participated successfully in summer research programs with federal labs, and elementary candidate participation will continue.

While this report is focused on preparation of elementary teachers, understanding the campus approach to recruiting and preparing secondary teachers provides a context for understanding its success with multiple subject candidates. Several CSU campuses (e.g., Cal Poly San Luis Obispo, Cal State Fullerton, San Francisco State University, Chico State) have established interdisciplinary Science and Mathematics Education Centers or Departments that provide a mechanism to bring faculty from education and the science departments together to collaborate on programs that improve K-12 science teacher education across disciplinary boundaries.

Cal State Fullerton recruits science teachers in nine different credential areas. The science credential is considered technology–rich with a laptop-lending program and

[44] CSU Bakersfield, Chico, Dominguez Hills, Los Angeles, Monterey Bay, and Cal Poly San Luis Obispo were recognized as having model approaches for teacher preparation by the U.S. Department of Education and awarded Teacher Quality Partnership grants. CSU Fresno and San Francisco State University, as well as CSU Fullerton, have been recognized for their leadership of promising strategies aimed at doubling preparation of new science and math teachers by APLU.

partnerships with local companies, such as Vernier Technologies, the National Geographic JASON Project and Intel Education. Cal State Fullerton emphasizes the use of technology to improve teaching and learning in science through improved student research, collaboration, communication and productivity. For the past several years, the Teacher Recruitment Project has been successfully recruiting multiple-subject candidates to pursue a second authorization in middle school science. The Future Teachers Program brings more than 1,000 high school students who are interested in teaching as a career to campus every year.[45]

Cal State Fullerton and the University of California Santa Barbara both participate in the Association of Public and Land Grant Universities (APLU) Leadership Collaborative, a group of 27 institutions drawn from universities making a commitment to the national Science and Mathematics Teacher Imperative (SMTI). Cal State Fullerton is recognized nationally for its collaboration between the College of Education and the College of Natural Sciences and Mathematics to recruit and support science, technology, engineering, and mathematics teachers. Likewise, Cal Poly San Luis Obispo, CSU Fresno, and San Francisco State University are also among the 116 APLU universities that have made a formal commitment to improve the preparation of science and mathematics teachers in middle and high schools nationwide.[46]

CSU is making considerable progress in meeting its goal of doubling the number of mathematics and science teachers by 2010 as indicated in Table 3 (based on credential figures provided by the Commission on Teacher Credentialing for CSU Campus Science Teacher Production (2002/03 – 2007/08). The system has increased its production by 76.6%.

Table 3. CSU Mathematics and Science Teacher Secondary Credential Production by Subject: 2002-03 to 2007-08

	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Mathematics	349	475	524	572	783	786
Science	419	581	487	485	505	570
Math and Science Total	768	1,056	1,011	1,057	1,288	1,356

Source: CSU Mathematics and Science Teacher Initiative 2008-9 Final Report

The University of California, launched California Teach (Cal Teach)—the system-wide counterpart to the CSU's MSTI— in 2005 to recruit, support, and prepare secondary science and mathematics teachers. The initiative began in response to state and national concerns regarding the critical shortage of qualified science and mathematics teachers. Cal Teach combines quality undergraduate courses and classroom experience to prepare students to enter a teacher credential program.

The nine UC campuses (Berkeley, Davis, Irvine, Los Angeles, Merced, Riverside, San Diego, Santa Barbara, and Santa Cruz) all have Cal Teach programs. Working under

[45] Additional information can be found at: http://nsm.fullerton.edu/scied/CESME/Index.html
[46] Additional information can be found at: http://www.teacher-imperative.org

an overarching Cal Teach umbrella, each campus program has its own unique structure and governance model. For example, UC Santa Barbara (UCSB) has created a Minor in Science and Mathematics Education. The experiences and resources of Cal Teach are offered to UCSB undergraduates, including transfer students from regional community colleges. The courses include experiences with K-8 students and teachers in various informal learning situations (museums, sea centers, botanical gardens). Students are placed in elementary classrooms (grades 4-6) in local schools with teachers who are taking part in a state funded inquiry science professional development project, Science Matters! In these classrooms, students work with specially prepared teachers by assisting in implementing science experiments and demonstrations in elementary classrooms.

Preparing Teachers to Teach Science: the K-6 Effort

While the Cal Teach and MSTI programs have specific goals in terms of subject credentials produced, efforts to improve the preparation of elementary teachers to teach science have been more challenging to implement.

In a 2007 CCST literature review[47] on elementary teachers with multiple subjects credentials, five factors were identified that impact elementary teachers' preparation to teach science

Factors that Impact Ability to Teach Science

1. **Pedagogical content knowledge and content knowledge in science are interactive and inseparable in the teaching process.**

2. **Self-efficacy and pedagogy are both significant in terms of teachers' perception of their own ability, confidence and willingness to engage students in scientific topics.**

3. **Both pre-service and in-service preparations are necessary.**

4. **Outcomes-based assessment reform puts the onus on teachers and students. However, it does not provide support or incentives to schools to provide the time and resources needed to develop new curricula to meet reform demands.**

5. **Science coalitions and reform support movements are working to account for the demands of state and federal reforms and the pressures on students and teachers to meet certain criteria.**

These support movements and organizations are providing much-needed outreach and support not only to meet reform initiative outcome measures, but also to give students and teachers a clear and applicable understanding of science and technology. This research suggests that considerable emphasis and attention has been

[47] Harrington, op.cit.

placed on science assessments and reform efforts to improve science education over the past decade.

Many campuses have some science programs or classes geared towards prospective teachers, but often these are of extremely limited scope and duration. A set of classes at San Jose State designed for prospective teachers, for example, was canceled last year due to low student demand and faculty workload shifts to higher demand courses.[48] However, there are some exceptions to the rule.

CSU Chico

The principal program that has focused for the longest time and to the greatest extent on improving K-6 science education in California is the pre-service education program in science at California State University Chico. This program includes four core elements:

1. The undergraduate Core in natural sciences for Liberal Studies major
2. The undergraduate Area of Concentration for Liberal Studies majors
3. The B.A. in Natural Sciences with a concentration in Science and Environmental Literacy, and
4. The Professional Education course in the School of Education Credential Program.

The Core courses in Natural Sciences are required of all Liberal Studies majors and pre-requisite to the Multiple Subjects Credential Program in the School of Education. The five courses are: Concepts in Physical Science, 3 units; Concepts in Life Science, 3 units; Concepts in Earth/Space Science, 3 units; Concepts in Environmental Science, 3 units; and Internship in Science Teaching, 1 unit. These courses are aligned to the standards of the Science Framework for California Public Schools.

The first four courses are designed to introduce fundamental scientific concepts, the difficulties young children encounter in learning the concepts, and "best practices" for teaching and assessing student learning within relevant knowledge domains. The courses are structured into one fifty-minute lecture or discussion and two two-hour activities per week. The activities are designed to support and encourage conceptual understanding and to provide opportunities for students to engage in hands-on experiences with physical and biological objects and events appropriate for elementary school age children. Opportunities to observe interns teaching scientific concepts or to work directly with children are integrated into each course.

The Hands-On Lab is a vital component of the program. This unique facility is administered by the Department of Science Education, which offers undergraduate students an internship opportunity to give teaching a try. Each week, classes of elementary school children in grades 4, 5, and 6 (and as of 2008, K-3) come to the lab to learn about topics ranging from plate tectonics to electricity to photosynthesis. In the course of a 90-minute period, children rotate through six stations where interns focus on

[48] The CSU San Jose State "Chem 35/Phys 35" course, which focused on standards aligned for undergraduate elementary teachers, was not offered in Spring 2008 for this reason.

concepts in the California Science Standards. The "teachers" or interns are undergraduate students enrolled in NSCI 489. This demonstration laboratory offers students a one-of-a-kind opportunity to work with children in an instructional capacity at an early point in their career and to receive feedback from an experienced mentor.

The program is particularly notable for its size. Each semester some 80 classes (or 2000 children) visit the lab and teachers vie for an opening in the schedule. The lab has served tens of thousands of students over the years, and is now a central feature of Chico State's approach to science teacher education.

The following is a more detailed description of the three institutions specifically targeting K-6 science teachers.

Cerritos College Teacher Training Academy (Teacher TRAC) Program

In 1999, Cerritos College established a community college-university teacher education partnership program with CSU Long Beach committed to the recruitment, development, and preparation of quality K-12 teachers.[49] The Teacher Training Academy program (Teacher TRAC) was designed to combine strong leadership, institutional support, community relationships, early service learning/field work experience, faculty expertise and commitment, student-centered pedagogy, and technologically rich learning environments.

More than 60% of the 470 Teacher TRAC and Pre-TRAC students are the first in their family to attend college, and more than 50% have received financial aid benefits. The majority of Cerritos' graduates begin in developmental courses (91%). After transferring to a 4-year university, the Teacher TRAC students consistently attempt and earn more units and achieve a higher grade-point average than students who started their post-secondary studies at the university. Of the 270 Teacher TRAC students who transferred prior to May 2005, only three changed majors or left the program.

The Teacher TRAC program established Cerritos College as the first community college in California to have a group of students complete an integrated, standards-based, K-8 pre-service teacher preparation program, transfer to a partner university program, and graduate with their baccalaureates and teaching credentials. The Teacher TRAC program has been integral in transforming many of its graduates from underrepresented, non-traditional students into highly qualified teachers who have returned to teach in the very districts where they received their education.

The Teacher TRAC program has a faculty leadership team comprised of a director, a service learning/fieldwork coordinator, four counselors, a faculty development coordinator, three mentors, and a full time program assistant. In its second year of operation, the TRAC leadership team was honored with the "Outstanding International Regional Leadership Award" by the Chair Academy. The program also received the"2005 AACC Teaching By Choice Award" and the "2006 Board of Governors Exemplary Program Award." The hallmarks of this program are its:

[49] Cerritos College Teacher Training Academy (Teacher TRAC) Program description, Susan Parsons.

- Strong curriculum pathway coupled with its integrated service learning/fieldwork experiences
- Extensive counseling and student services
- More than 60 vested program faculty
- Dedicated resources
- Professional development experiences
- On-going program evaluation

While the Teacher TRAC program has articulation agreements with several universities, CSU, Long Beach is its largest transfer institution. This exemplary collaboration has so successfully integrated the two programs that Cerritos College is able to offer a comprehensive, fully articulated curriculum that virtually mirrors the first two years at CSULB. The curriculum is also aligned with the California Content and Professional Teaching Standards as well as the California Technology Standards.

A keystone of the Teacher TRAC program is its service learning/fieldwork component that provides students with the opportunity to formally participate in real-world teaching interactions early in their pre-service teacher education program. In addition to preliminary field observation experiences, each student may spend 40 hours or more working with and being mentored by one of the program's master teachers as they assist students in need of more individualized instructional attention.

Over the past ten years, the Teacher TRAC Service Learning/Fieldwork Coordinator has developed and trained a network of over 250 Master Teachers from five surrounding elementary school districts to provide mentoring for the Teacher TRAC students. A strong alliance and partnership was developed in 2000 with one of the participating district's AmeriCorps program. This collaboration allows the Teacher TRAC students to complete their AmeriCorps service hours at the same site as their education course service learning hours. In 2001, Cerritos College also received a grant that allowed the Teacher TRAC program to expand its program and service learning/fieldwork experiences through a new Teaching Scholar Partnership Program (TSP). This program formalized a pathway and training for future K-8 teachers to concentrate on mathematics or science. The TSP program was institutionalized at the end of the grant, and has been used as a model for the implementation of a special education and a secondary mathematics-science teacher pathway.

Chapman University

In 2008, Chapman University's Science Teaching and Research (STAR) Institute was awarded a four-year grant by the California Postsecondary Education Commission for a new professional development project titled "Science-Centered Literacy for K-2 Students: Project SMART'" The project will help improve teaching in K-2 in the core content areas of math, science and English. As part of the project, the STAR Institute will hold summer academies where teachers not only will receive training, but also will be put into action immediately with summer school students in the Anaheim City Elementary School District. Approximately 90 teachers will be served over the life of the project. These teachers will form Professional Learning Community teams to take the

material back to their school sites, implement it in their classrooms, and share it with colleagues.

Key Program Elements

The CSU Chico and Cerritos programs share some common approaches:

- **Integrated Pedagogical Approach:** The programs are solidly grounded with demonstrated and acknowledged pedagogical foundations in the investigative nature of science, bringing inquiry-based approaches to teaching and learning. This is largely a function of organization and teamwork. At CSU Chico, for example, regular communication among faculty in the program has helped build a common approach and maintain it in close alignment with state standards.
- **Partnerships**: Bringing together resources from diverse institutions is the key, both for the programs themselves and for other stakeholders, such as school districts, informal science organizations, federal laboratories, funding agencies and foundations.
- **Internship Opportunities***:* These programs get prospective teachers into an environment where they have the opportunity to work with students and apply the pedagogy they are learning.
- **Funding Sources:** Sustainability and scalability of high quality, effective programs are directly attributed to adequacy and dependability of resources (dollars, content, people, and facilities).

There are many promising programs addressing the need to strengthen K-6 science teachers' preparation, induction, and professional development. Several are working toward building track records, relying on evaluations and assessments to quantify and demonstrate impact and best practices. In addition, a number of innovative programs have been initiated recently. Although the data are not yet available to substantiate outcomes, the beginnings are promising. These programs warrant further observation, support, evaluation, and consideration of their promise for replication, scaling up, and sustainability. They are essential to continuing to strengthen science teaching significantly in all of California's classrooms.

5. Findings and Recommendations

Key Findings

- *There has been improvement in K-6 science education in the past several years, but both self-reported teacher ratings and student proficiency scores suggest that even greater improvements are required to prepare students for the 21st century workplace.*

- *Preparation of K-6 teachers to teach science varies by program and institution, and teachers benefit where there is an institutional focus on science education, whether at the secondary or elementary level.*

- *Science education at the K-6 level is increasingly recognized as essential to building a stronger science education pipeline overall.*

- *There are existing programs that can be effectively leveraged to improve preparation of K-6 teachers to teach science, e.g. interactive web-based materials, immersive science by connecting to community stakeholders (parents, teachers, community centers, etc.), informal learning experiences (museums, science centers, etc.).*

- *Community colleges play a significant role in preparing elementary school teachers: 65% of teachers earning multiple subject credentials had completed their lower-division coursework at community colleges with 37% of these receiving CSU credit toward their subject matter preparation.*

Science has long been identified as the area in which most elementary school teachers find themselves least prepared[50] and California's K-6 teachers appear to fare no better in this regard than teachers elsewhere in the U.S. Many factors surely affect the relatively poor overall science proficiency levels of California K-6 students on national assessments such as the NAEP[51] (at the 4th grade testing level). Among them are the challenge of increasing time spent on reading and mathematics at the expense of other subjects such as science due to the accountability provisions of the No Child Left Behind Act.[52] Still, the preparation that prospective teachers receive is a factor in their preparedness, confidence, and persistence. There are facts that are known with respect to teacher preparation, including:

- Standards for what teachers need to know upon completion of their program.
- Teachers do not "feel" well prepared to teach science; however, their supervisors disagree.
- Student performance in science is going up.

[50] E.g. studies as far back as Weiss, I.R. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education: Center for educational research and evaluation.* (Washington, D.C.: U.S. Government Printing Office.
[51] National Assessment of Educational Progress, op.cit.
[52] McMurrer, Jennifer (2008), op.cit.

But, what is not known with quantifiable certainty is whether teachers are being adequately prepared.

There have been improvements in the perceived content preparation of K-6 teachers to teach science, according to both supervisor ratings and teacher self-ratings (although the former improved much more significantly than the latter over time). Proficiency scores on California standards-based exams have gone up in recent years,[53] suggesting improvements in the ability of elementary teachers to teach science. However, even though student performance is going up, the state's lackluster performance relative to the rest of the country points to the need for greater progress.

The framework for elementary science teaching in California currently focuses on understanding of, adherence to, and communication of the standards – reflecting what teachers are expected to know before entering the classroom. However, the science requirement in institutions of higher education for individuals pursuing multiple-subject teacher certification vary and, as such, the alignment to standards varies. **Further, the range of credits required in science for liberal studies majors in California community colleges and universities ranges from as much as 14 to as few as 6 credits**. Introductory level courses in science are not typically oriented towards teachers. They emphasize content not necessarily aligned with California science content standards and fail to provide a background in science education.

The findings in this study are echoed in a report from the "Nurturing and Sustaining Effective Programs in Science Education for Grades K-8: Building A Village in California" convocation organized by the National Academy of Sciences and the National Academy of Engineering with CCST.[54] The convocation, held on April 29-30, 2009 at the Arnold and Mabel Beckman Center in Irvine, California, brought together stakeholders from across the state to discuss the creation of effective and sustainable programs for elementary and middle school science education. Not only were K-12 teachers and administrators present, but also representatives from business and industry, higher education, state and federal government, educational researchers, and philanthropic organizations were also among the participants.

The convocation report highlights the crucial role that effective K-8 science education plays in the workforce pipeline for jobs in science, technology, engineering, and mathematics. Despite this fact, there has been too little focus on K-8 science education. Currently available data on graduates of teacher preparation programs in California is limited to those from the CSU System, which prepares just over half of the teachers who earn their degrees from California institutions. Hence, a comparison of the preparedness of teachers to teach science among graduates of CSU, UC, and various independent institutions is not possible. Some studies have suggested that there is no statistically significant difference overall in the preparedness of teachers who earn their certification through alternative routes and those who follow traditional

[53] See Figure 5 above.
[54] National Academy of Sciences and National Academy of Engineering (2009), Nurturing and Sustaining Effective Programs in Science Education for Grades K-8: Building A Village in California: Summary of a Convocation.

preparation pathways.[55] However, these have focused on math and reading and there are no direct studies on science teaching outcomes.

- The CSU System-wide Evaluation of Teacher Preparation case studies confirm that supervisor assessments of CSU teacher graduates were consistently more positive than teacher self-assessments, and more so in science than for reading or mathematics. The findings conform to other research identifying the relative lack of confidence of elementary teachers in the teaching of science.

- Promising science teacher preparation programs exist, with more being pioneered each year that unite content, methods, and inter-institution connectivity between community colleges and four-year campuses. Examples of these programs can be found among CSU, and UC campuses and independent institutions and their community college partners. Some programs also include other partners, which may help sustain them for the long term. These programs represent models worthy of consideration for expansion.

This study did not address the learning goals of specific science content and methods courses that are offered to pre-service elementary teachers in the undergraduate preparation or credential programs. While some programs clearly provide deliberate instruction or experiences that involve inquiry-based approaches, it is not clear how widespread this practice is, nor is it clear yet what impact using this kind of approach has on the preparation and effectiveness of elementary teachers.

The snapshot provided within this report gives us a glimpse into the preparation of elementary teachers in science and their perceived effectiveness. The stakes are so high in regard to student learning and the future of California's technical workforce, **the following recommendations largely call for a sustained, thorough examination of the status of elementary science teacher preparation and science teaching and learning in the state. In addition, they advise continued leveraging of the existing programs and infrastructure that show promise**.

Despite California's seemingly insurmountable science education challenges – not enough time spent on science, underprepared teachers, and eroded support systems – there is hope for a new reform effort based on the movement toward national standards, new research regarding educational practices, and the interest of scientific, business and philanthropic organizations. In fact, one of the key outcomes from the convocation was agreement that it will take the establishment of a multi-stakeholder coalition focused on reform in order to advance California's science education system.

[55] Constantine, J., Player D., Silva, T., Hallgren, K., Grider, M., and Deke, J. (2009). An Evaluation of Teachers Trained Through Different Routes to Certification, Final Report (NCEE 2009-4043). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. This study established teacher preparedness by examining student outcomes in four states, including California. The study only focused on reading and math, however.

Recommendations

California's institutions of higher education recognize the critical importance of K-12 science teacher preparation. Although the emphasis today is predominantly in secondary education, there is an increasing focus in K-6 science teaching and a recognition of the ability to leverage secondary (primarily middle school) single subject certification to impact K-6 teaching. Given the findings presented throughout this report, additional work and emphasis is needed and warranted in K-6 science teaching in order to improve the learning and teaching of future teachers and ultimately the learning and competency of their students.

Recommendations for measuring and improving the preparedness of both new teachers and existing elementary teachers to teach science are provided below. The recommendations are prioritized and grouped under the following three categories: Leverage Existing Promising Programs and Infrastructure, Sustain and Expand On-going Data Collection and Commission New Research. These categories are fundamental principles that provide a systemic approach to improving California's overall teaching of K-6 science. Specific, actionable recommendations with accountability partners and suggested timetables follow:

Share and Disseminate Information on Existing Promising Programs and Infrastructure Proactively and More Effectively

In 2010, the CSU should convene a system-wide symposium on best practices in multiple subject teacher preparation focusing on teaching K-6 science. Based on the data analyzed for this report, it appears that more specific data exist at the campus level regarding the success of multiple-subject preparation programs in this area. This first symposium of its kind would provide a critical, tangible opportunity for these data to be shared and applied throughout the state.

California's higher education institutions, informal science centers, federal research laboratories, and corporate partners who support professional development programs for teachers should participate in this symposium. The goal would be to identify opportunities for elementary teachers to develop their science content knowledge and pedagogical skill, including much greater use of new technology to build technical competence. The CSU Science Teacher and Researcher (STAR) program, managed by Cal Poly San Luis Obispo, could serve as a model for institutions beginning this process.

Use the California STEM Innovation Network (CSINet) to promote the outcomes of this symposium and incorporate results into a broader STEM education strategy for the state.

Adapt existing policies to protect and enhance K-6 science teaching

By 2011, the California Commission on Teacher Credentialing should align the multi-subject science course requirements with single subject science requirements; UC and CSU should pilot this approach in their respective Cal-Teach/SMI and MSTI programs.

The California Community College System Chancellor's Office should develop system-wide articulation agreements with the CSU, focusing in particular on lower division requirements for multiple subject teachers.

Higher education institutions with blended programs should revise their curriculum so that science content courses taken by prospective teachers at the undergraduate level align with science content, skills, and attitudes that they are required to teach, as well as teacher performance assessments.

Community colleges, in collaboration with 4-year institutions, should increase emphasis on Assumption Program of Loans for Education (APLE) participants taking science courses to fulfill subject matter competency within two years.

Take a Leadership Role in the Discussion of Science Standards

Student and teacher standards are undergoing revision at the national level. The National Academy of Science has urged schools to incorporate an inquiry-based approach to instruction in their curricula. There also has been significant interest in California in strengthening the focus on inquiry-based learning in teacher programs. California needs to take a leadership role in these revisions and work diligently to ensure that teacher preparation programs both anticipate and reflect the changes. There are significant opportunities for teacher preparation programs to adopt inquiry-based approaches.

Follow the Recommendations of the "Building a Village" Convocation

The issue of K-6 teacher confidence and preparation in science appears systemic and not subject to a quick fix. The 2009 National Academies convocation "Nurturing and Sustaining Effective Programs in Science Education for Grades K-8: Building a Village in California," which was convened to help inform this report, lays out a blueprint to address the challenge sustainably. It includes:

- The creation of 12 regional science resource centers (at a cost of approximately $2.5 million each) to assist with professional development and curriculum implementation
- Allocation of $2,500 per teacher for staff development in science
- The above to be developed and sustained by statewide coalition of stakeholders dedicated to creating an outstanding science education system, with each sector playing a distinct role

The CSINet should serve as the coalition of stakeholders and work to coordinate efforts of constituent organizations effectively.

Use New Data to Guide Policy

Make use of new information being gathered by CFTL about the components of effective elementary science teacher preparation programs and how teachers are

prepared and continually supported. These data should be used to guide the CSINet and teacher preparation policy as a whole.

The efforts of the CSU Center for Teacher Quality need to be replicated for other systems. Individual preparation institutions should implement surveys similar to the CSU study in consultation with the CSU and the CSINet, with the discussion to begin during the symposium in recommendation (1).

As the National Academies' "Nurturing and Sustaining Effective Programs in K-8 Science Education" report states, the human and scientific resources, and thus the potential, of California are rich. California is home to arguably the largest university system in the world, with 200,000 undergraduates in the University of California, 400,000 in the California State University system, and 2.5 million students in California's community colleges. California is a global innovation, research, and technology leader, and has significant numbers of nationally and internationally recognized scientists and engineers working at its universities, research organizations and corporations. While everyone has a role to play, the state's colleges and universities have a key role as the central producer of elementary school teachers. The increasing momentum around the establishment of common national science standards should be viewed as an opportunity for teacher education and professional developments to get ahead of the game and drive the reform agenda. Finally, the new general science credential recently established in California offers another opportunity for teacher education programs to step up to the plate and get into the game.

The state of California embraces a rich set of institutions and talented individuals who are developing and implementing innovative programs to enhance the quality of K-6 science teaching and learning. Progress is being made in connecting these programs both across campuses and across institutions – yet more must be done in order to achieve measurable progress and impact on student performance. The APLU cites this environment as "islands of change" reflecting different "models" for how to prepare teachers.

California's institutions of higher education, working in partnership with various stakeholders, are charting a course to improve the preparation of elementary teachers working in the state's schools. The programs are in place, the data is being captured, and these efforts need to be scaled up and sustained.

Appendix A. Working Group

Name	Affiliation(s)
Peter Arvedson	Cal TAC member, Science Teacher La Puente High School
Anne Marie Bergen	Cal TAC Chair, District Science Coordinator/Teacher, Oakdale Joint USD
Kathy DiRanna	Statewide Director, West Ed K-12 Alliance
Kim Edwards	Education Programs Consultant, Milken Family Foundation
Javier González	Cal TAC member, Mathematics Teacher, Pioneer High School
Maria Alicia Lopez-Freeman	Executive Director of the California Science Project
Bev Marcum	College of Natural Science Professor CSU Chico
Suzanne Nakashima	Cal TAC member, Elementary School Teacher, Lincrest Elementary School
Sue Pritchard	Cal TAC member, Science Teacher Washington Middle School
Barbara Shannon	Cal TAC Vice Chair, Co-Director Synergy Kinetic Academy
Mark Stefanski	Cal TAC member, Biology Teacher and H.D. Thoreau Faculty Chair for Sustainability Marin Academy
Ed Walton	Chemistry Professor, CalPoly Pomona
Katrina Williams	Cal TAC Member, Elementary School Teacher, Harvest Elementary School
Judi Wilson	Director, Science & Special Projects San Joaquin County Office of Education

Appendix B. CSU System-wide Evaluations of Teacher Preparation Details

(a) The population of each cohort consisted of teachers prepared on the 22 campuses of the California State University and in the system-wide program of multiple-subject preparation called CalStateTEACH.

(b) Graduates who accepted teaching positions in elementary schools were invited to assess their CSU preparation during the last two months of their first teaching year.

(c) Graduates were asked to consider their overall experiences as first-year teachers and to report how well they had been prepared to teach each subject according to California's curriculum standards in that subject and at their grade levels.

(d) CSU asked that the administrator who had already evaluated the teacher's performance for district re-employment also assess each graduate's preparation.

(e) Supervisors' assessments occurred concurrently with graduates' assessments, and were most commonly completed by the principals and assistant principals of the elementary schools where the first-year teachers were working.

(f) Each supervisor was asked to consider their classroom observations and conferences with the named teacher, and to report how well the teacher was prepared to teach a subject according to California grade-level standards in the subject.

(g) The evaluative response options for both groups of participants were: well prepared, adequately prepared, somewhat prepared and not-at-all prepared to teach the subject according to California's grade-level curriculum standards.

(h) Participants were encouraged to select "X" if there was too little evidence in their actual experience to render a reliable judgment. X replies are not counted in the tables above. X was selected more often in science than it was in reading or math.

(i) Of the participants who gave the four evaluative responses, figure 5 shows the percentages (rounded to integers) of graduate respondents and supervisor respondents who reported the teachers to be either well prepared or adequately-prepared.

(j) Not shown are the participants who reported teachers to be either somewhat prepared or not-at-all prepared. In all cases, these percentages were the reciprocals of the values shown above.

Appendix C. Promising Teacher Preparation Programs

CCST surveyed 14 higher education institutions in order to identify and highlight promising approaches for strengthening K-6 teacher preparation in science. From these 14 institutions, which span the state both geographically and structurally (2-year to 4-year), more than 40 projects were reviewed; nine institutions were specifically identified by the Working Group members as having initiatives reflecting promising approaches from each sector. These Working Group members did not differentiate between K-6 and K-12 programs, resulting in three (Cerritos, Chico State, and Chapman), which are K-6 centric. The remaining six (Cal Poly San Luis Obispo, Cal State Fullerton, UCI, UCR, UCSC, and Stanford) are secondary programs, which can nonetheless impact K-6 programs.

For these nine institutions, progressing from a 2-year public community college to 4-year public and private institutions, a common case study template has been prepared to serve as a tool for further comparison and assessment. Contact information for each program is provided.

Colleges and Universities

- Cerritos College
- California Polytechnic State University, San Luis Obispo
- California State University, Chico
- California State University, Fullerton
- University of California, Irvine
- University of California, Riverside
- University of California, Santa Cruz
- Chapman University
- Stanford University

Questions Asked

- Business/Education Challenge – What was driving need for change?
- Key Considerations and Approach – How did you go about addressing the problem/challenge?
- Solution – What did the 'solution' look like?
- Critical Success Factors – What were key lessons learned in making it work?
- Results – What was the outcome? What benefits gained? What measurable impact achieved?

Cerritos College Teacher Training Academy (Teacher TRAC)

Business/Education Challenge – What was driving need for change? (knowledge management)
• Projected teacher shortage: 500,000 new teachers needed nationally in the next decade (DOL 2007) to replace projected number of retirees and accommodate significant shift in US demographics • Design innovative pre-service teacher education programs that will successfully prepare the next generation of teachers to address the stated need

Key Considerations and Approach – How did you go about addressing the problem/challenge?
• Pre-service teacher education programs need to be designed to affect a pedagogical transformation if they are to create more socially-conscious teaching practices • Colleges and universities are incorporating service learning/field experience into their program curriculum to provide pre-service teacher education candidates with first-hand experience and knowledge of real world classroom and student dynamics early in their educational journey.

Solution – What did the 'solution' look like?

- Established Teacher Training Academy (Teacher TRAC)
- Established a faculty leadership team comprised of a director, a service learning/fieldwork coordinator, four counselors, a faculty development coordinator, 3 mentors, and a full time program assistant.
- Articulation agreements with several universities;
- California State University Long Beach (CSULB) is aligned with Cerritos whereby Cerritos offers a comprehensive, fully articulated curriculum that mirrors almost exactly the 1st two years at CSULB.
- Curriculum is aligned with the California Content and Professional Teaching Standards and the California Technology Standards.
- Service learning/fieldwork (a key component) provides students with the opportunity to formally participate in real-world teaching interactions early in their pre-service teacher education program.
- Students have opportunity to spend 40 hours or more of service learning, working with and being mentored by one of the program's master teachers as they work with and assist students in need of more individualized instructional attention --allowing students to become reflective practitioners. Through reflection and peer/instructor feedback, students increase their understanding of educational practices and issues.

Critical Success Factors – What were key lessons learned in making it work?

- Teacher TRAC was predicated upon a number of important factors including: strong leadership, institutional support, community relationships, early service learning/field work experience, faculty expertise and commitment, student-centered pedagogy, and a technologically rich learning environments.

- An in-depth, long-term program evaluation process which has tracked students from the high school teaching academies and pathways through the program's transfer to CSULB and into their teaching careers.

- Focus groups of recent graduates, who are presently teaching, help in substantiating the program's original ideology (students empowered with content knowledge and real-world service learning experiences early in teacher preparation education.)

- Teacher TRAC graduates cite the power and impact of early service learning experiences as critical factors in sustaining and confirming their commitment to become future educators; school administrators and teaching colleagues consistently found Teacher TRAC graduates to be exceptionally competent, polished, and poised.

- Teacher TRAC provides students with various professional development opportunities, e.g. attending both local and national conferences (California National Science Teacher Association), attending programs with guest speakers and panel presentations by Teacher TRAC graduates.

- Students developed a future teachers club.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

- After transferring to the university, the Teacher TRAC students consistently attempt and earn more units and achieve a higher grade-point average than students who began their post-secondary education at the university.

- Of the 270 Teacher TRAC students who transferred prior to May 2005, only three have changed majors or left the university.

- Teacher TRAC program established Cerritos College as the first community college in California to have a group of students complete an integrated, standards-based, K-8 pre-service teacher preparation program, transfer to a partner university program, and graduate with a B.A., student teaching and teaching credential.

- Over the past 10 years, developed and trained a network of more than 250 Master Teachers from five surrounding elementary school districts to the college who provide mentoring for Teacher TRAC students.

- Alliance and partnership developed in 2000 with the participating district's AmeriCorps program, allowing students to complete their AmeriCorps service hours at the same site as their education course service learning hours.

- Creation of Teaching Scholarship Program (TSP) which formalized a pathway and training for future K-6 teachers to concentrate on mathematics or science; students selected as teaching scholars and participated in service learning/fieldwork opportunities under the direction of mentors from both Cerritos and a district elementary school.

Case Study Contact

Name: Sue Parsons
Position: Director, Teacher TRAC and Learning Communities
Organization: Cerritos College
Telephone: 562-860-2451 ext 2671
Email: parsons@cerritos.edu

Cal Poly Math Science Teacher Initiative (MSTI), Cal Poly, San Luis Obispo

Business/Education Challenge – What was driving need for change? (knowledge management)
• Recruit more math and science majors into teaching careers • Economic competitiveness

Key Considerations and Approach – How did you go about addressing the problem/challenge?
• Cal Poly's science and education faculty worked together in blending science content with pedagogy courses and in recruiting students into teaching as early as the freshman year. The Chemistry Blended Program that enables candidates to earn a BA and credential in slightly more than 4 years is in effect. Biology, Physics and Geosciences Blended Programs are currently under development. The Geosciences Blended Program will capitalize upon the new Geosciences credential that is expected to be approved soon. • To streamline the process of obtaining a credential, Cal Poly has created comprehensive program templates for math majors and minors that address program entry, progress, and completion. Advising, co-curricular opportunities, information about professional roles, financial aid resources, and other materials are made available for entering students as well as for current students. Cal Poly San Luis Obispo is also developing science and mathematics credential programs that will be offered in an online environment. • Supervised tutoring and other field based experiences in local K-12 schools play a major role in Cal Poly's "Learn by Doing" instructional practices. These opportunities are both paid and unpaid, and are available for selected qualified candidates in collaboration with new and existing local school districts. • Cal Poly began a science "Learn by Doing" lab in which undergraduates teach students from local schools lessons based on scientific inquiry. Further development and expansion of this program is planned. This lab is based on CSU Chico's successful "Hands on Lab." • An additional significant opportunity across the CSU for aspiring science teachers is the Science Teacher and Researcher (STAR) program, which provides a summer research experience in federal research labs, such as Lawrence Berkeley and Lawrence Livermore National Laboratories, NASA, and Stanford Linear Accelerator. STAR interns participate in weekly

science education workshops that are intended help students connect the "doing" of science with the "teaching" of science. Cal Poly coordinates this program for the CSU.

Solution – What did the 'solution' look like?

Physical Science Series:

- Course series is taught in studio classroom setting with a room configuration including tables and computers for students to work in collaborative groups. Adapted course to use curriculum specifically for elementary teachers developed by Fred Goldberg at San Diego State University/Physics and Everyday Thinking (PET) and Physical Science and Everyday Thinking (PSET). This curriculum involves guided inquiry and addresses student misconceptions. Liberal studies students watch and critique video of elementary students discussing topics covered in the class.
- The content aligns closely with state standards.

Central Coast Science Project (CCSP)

- K-16 professional development (PD) opportunity in science is based in the Chemistry and Biochemistry Department and has been serving the community for more than 15 years.
- Includes faculty leaders in all science areas and literacy as well as teacher leaders from the San Luis Obispo area and northern Santa Barbara. Partnerships include: LEA: Santa Maria-Bonita, Santa Maria Joint High School Joint Unified and Guadalupe Districts.
- Project divided:
    - Intensive programs
    - Undergraduate program
    - Inquiry-based activities for teachers for PD and classroom use
    - Service to other science teacher in the area

Learn By Doing Lab (LBDB)

- Students majoring in math, science, engineering and liberal studies become science teachers for visiting elementary and middle school groups
- Benefits:
    - Cal Poly students have opportunity to explore science teaching
    - Visiting students do hands-on, inquiry-based science in a college setting

Critical Success Factors – What were key lessons learned in making it work?

Physical Science Series (PSS)

- PET/PSET curriculum is more complete and better aligned with science standards compared to previous curriculum

Central Coast Science Project (CCSP)

- Faculty and teacher interaction – active professional learning communities
- Focus on California standards and the scientific method
- Support from university in use of facilities, release time, tenure and promotion

Learn By Doing Lab (LBDL)

- Strong administrative support from the Center for Excellence in Math and Science Education (CESaME) – staff registers visiting schools, oversees logistics and administers pre/post surveys to both Cal Poly students and visitors.
- Enrolling Liberal Studies (LS) students with STEM students provides an effective synergy. LS students bring knowledge of classroom strategies and child development, while STEM students have deeper understanding of the concepts.

Overarching:

- Noyce award used to provide financial aid to candidates during their path to credentialing.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

Learn By Doing Lab

- This program is growing:
  - Spring 2008, the LBDL was initiated with a stand-alone physical science lab.
  - Winter 2009, life science and engineering labs were added and the physical science lab moved to a dedicated, renovated space on campus.
  - Spring 2009, earth science lab added
- Student enrolment increased to 41 students participating in Spring 2009 and number of visitors increased to ~1600 in Spring 2009.

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The "Hands on Lab" (Internship in Science Teaching) Chico State

Business/Education Challenge – What was driving need for change? (knowledge management)
• Attracting students into the Elementary School Teachers of Science field

Key Considerations and Approach – How did you go about addressing the problem/challenge?
• The Core courses in Natural Sciences are required of all Liberal Studies majors and pre-requisite to the Multiple Subjects Credential program in the School of Education. The 5 courses are: NSCI 141 (Concepts in Physical Science, 3 units); NSCI 142 (Concepts in Life Science, 3 units); NSCI 342 (Concepts in Earth/Space Science, 3 units); NSCI 343 (Concepts in Environmental Science, 3 units); and NSCI 489 (Internship in Science Teaching, 1 unit). These courses are sequenced and aligned to the standards of the *Science Framework for California Public Schools,* which is strongly aligned to the *National Science Education Standards.* • The first four courses are designed to introduce fundamental scientific concepts, the difficulties young children encounter in learning the concepts, and "best practices" for teaching and assessing student learning within relevant knowledge domains. The courses are structured into one fifty-minute lecture or discussion and two two-hour activities per week. The activities are designed to support and encourage conceptual understanding and to provide opportunities for students to engage in hands on experiences with physical and biological objects as well as events that are appropriate for elementary school age children. Opportunities to observe interns teaching scientific concepts or to work directly with children are integrated into each course.

Solution – What did the 'solution' look like?

- Unique facility administered by the Department of Science Education, California State University, Chico, which offers undergraduate students an opportunity experience teaching.

- Each week, classes of elementary school children in grades 4, 5, 6 (recently K-3) come to the Lab to learn about topics ranging from plate tectonics to electricity to photosynthesis. During a 90-minute period, children rotate through 6 stations where interns focus on concepts in the California Standards.

- The "teachers" (interns) are undergraduate students enrolled in NSCI 489 (Internship in Science Teaching, 1 unit). This demonstration laboratory offers students a one-of-a kind opportunity to work with children in an instructional capacity at an early point in their career and to receive feedback from an experienced mentor.

- Each semester some 80 classes (2000 children) visit the lab and teachers vie for an opening in the "Hands On Lab schedule.

- The Lab has served tens of thousands of students over the years, and is now a central feature of CSU, Chico's distinctive approach to science teacher education.

- Undergraduate students who major in Liberal Studies are required to select an Area of Concentration. Those who select the Natural Sciences AoC go on to take an additional 12-13 units in natural sciences, including NSCI 321 (Scientific Inquiry) and one course each in physical, life and Earth/space science.

- Students pursuing a Single Subject Credential in Foundational Level Science go on to take an additional 19-20 units in natural sciences (for a total of 45 units). The Conceptual Abstract for this degree program has been approved and the Department is awaiting final campus approval. The degree is a "stand alone" program but it will be "linked" so that Liberal Studies majors may double major and qualify to teach middle school science and even foundational level science in non-departmentalized high schools, which are common in many areas of the North State region.

Case Study Contact

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Undergraduate Science Preparation for Future Elementary/Middle School Teachers, California State University Fullerton (K-12)

Business/Education Challenge – What was driving need for change? (knowledge management)
• Double the production of math and science teachers and enhance the quality of the science teachers' proficiency in subject content

Key Considerations and Approach – How did you go about addressing the problem/challenge?
Multiple programs and resources exist to support the preparation of elementary/middle school science teachers at the undergraduate, credential, and graduate levels. Representative samples include: • Center for Careers in Teaching (CCT) • Teacher Recruitment Project (TRP) • CATALYST Center for Advancement of Research in Teaching & Learning Math & Science • California Math Science Partnership (CMSP) • PRISE Summer Internships • Undergraduate Reform Initiative (URI) • Contextual Coursework for Elementary Pre-Service Teachers (ConCEPT) The Science Education Programs Office, housed in the College of Natural Sciences and Mathematics, is involved in all university activities associated with the undergraduate, credential, and graduate preparation of science teachers. The Office mission is to support the preparation of teachers who are competent in subject matter content necessary to effectively teach science at the elementary and secondary levels.

Solution – What did the 'solution' look like?
• CCT collaborates with the Science Education Programs Office to provide academic advising to enrolled and transfer students and facilitates the coordination of several programs that focus on the preparation of elementary and middle school science teachers. • TRP works with multiple subject candidates and program completers to facilitate the adding of a FLGS credential. • CATALYST will pursue the advancement of research and its application to

practice and policy in 5 broad areas: teaching and learning in math and science; use of cyber-learning to improve math and science teaching and learning; recruitment and preparation of math and science teachers; enriching the professional development and experience of teachers; and program evaluation of math and science education.

- CMSP "Collaborating for Excellence in Middle School Science," grant partners Fullerton with 25 middle schools, five districts, & the Orange County Dept. Of Education. The grant provides resources for middle school science teacher candidates, including new understandings about the use of science notebooks, Vernier science probeware, K'NEX toys, Chapman University, and the Ocean Institute to improve middle school teaching.

- PRISE places future science teachers with an informal science education agency partner. Candidates work with the agency mentor to plan and complete a project, such as developing a display or interacting with site visitors. Partner agencies include the Discovery Science Center, Santa Ana Zoo, Ocean Institute, Newport Back Bay Science Center, Tucker Wildlife Sanctuary, and Fullerton Arboretum.

- URI sought to reform the teaching and learning of science for general education (GE) and pre-service teacher education courses as well as in foundation and service courses taken by science majors.

- ConCEPT was a collaborative effort with five local community colleges to develop inquiry-oriented lab-based courses in the sciences for future elementary teachers that would be better matched than traditional lecture courses to the special needs of this unique population. The primary pedagogical goals were to help future teachers understand science and to model instructional methods that they might adapt for the elementary classroom; to make a dramatic break from traditional science courses, which are theoretical, often abstract, and based on isolated disciples; to create a new paradigm of thinking that focuses on the connections between all the sciences; to teach science in the context of real-world situations or phenomena, showing how different science disciplines are used together to understand and solve problems; to help students focus on the nature of scientific inquiry; and to develop a series of cross-disciplinary courses for pre-service elementary teachers to be offered at community colleges and the CSU

Critical Success Factors – What were key lessons learned in making it work?

- *Best practices in recruitment are broadly-based, comprehensive, and multi-faceted*
- Key attributes of best practices in creating multiple credential pathways: building flexible and seamless transitions into and between programs.
- *Best practices in financial support and incentives focus on making available and helping students access a range of types of financial support that meet their individual needs*
- *Best practices in partnerships with Federal Laboratories enable future science teachers to be both a teacher and a scientist*. The partnerships have the potential to substantially enhance the quality of science teacher preparation. Partnerships with federal science agencies provide the opportunity for science and math credential candidates to participate in leading edge scientific research as well as for campuses to integrate the research into the credential program.

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Cal Teach Science and Math Program University of California Irvine (UCI)

Business/Education Challenge – What was driving need for change? (knowledge management)
• UC Irvine launched its Cal Teach Science and Math Program in 2006 in response to the critical shortage of qualified middle school and high school math and science teachers throughout the state. The need is expected to increase with an anticipated wave of teacher retirements.

Key Considerations and Approach – How did you go about addressing the problem/challenge?

• The Cal Teach program is a collaborative initiative sponsored by the School of Biological Sciences, School of Physical Sciences, and Department of Education. Program strategies are to: a) offer undergraduates opportunities to explore math and science teaching as a career option; and b) offer degree program options that make it possible for undergraduates to earn a bachelor's degree in math, science, or other technical field and a California teaching credential—all in four years.
 	
• The UCI Cal Teach Science and Math Program is not designed specifically to enhance science teaching for pre-service elementary teachers or to provide science professional development for elementary teachers. However, one of the Cal Teach introductory courses that is offered in both of the pathway options described below addresses topics in the teaching and learning of elementary math and science.
 	
• The course "Cal Teach 1 – Introduction to Science and Math Teaching" is designed to introduce aspiring teachers to the elementary math and science content standards and to build their knowledge about what elementary level students are expected to know and understand, and about some of the inquiry-based pedagogies that support the learning of math and science in elementary classrooms. The course provides:
 	
  o A foundation on which Cal Teach program undergraduates will later build additional understanding in other courses about teaching and learning math and science in middle and high school classrooms.
  o Field experiences for the undergraduates in regional elementary classrooms, under the supervision of a host teacher. Field activities include:
  ▪ UCI student engagement with individual and small groups of elementary-age learners
  ▪ Preparing and teaching at least one lesson on a math or science topic.

Solution – What did the 'solution' look like?

- UCI provides two teacher preparation pathways for aspiring teachers of middle school and high school math and science:

1. The Cal Teach 4+1 Pathway
    - Undergraduates in math, science, engineering, or computer science degree programs enroll in a series of courses that develop their math and science pedagogical content knowledge and provide K-12 field experiences in regional elementary, middle, and high school classrooms. These courses are designed to allow aspiring math and science teachers an opportunity to explore the teaching profession while they: a) get some experience with the teaching and learning of math and science content in K-12 schools (including making connections between their university-level content knowledge and California K-12 science and math content standards); and b) start to build some of the pedagogy competencies from the California Teacher Performance Expectations. Undergraduates who participate in the Cal Teach 4+1 Pathway are prepared to enter a post-baccalaureate single subject teacher preparation program after they graduate with a bachelor's degree.

2. The Cal Teach 4-year Degree plus Credential Pathway
    - UCI launched several new Cal Teach degree programs in 2008 for undergraduates in math, science, engineering, or computer science that lead to a bachelor's degree in one of these disciplines and a math or science single subject teaching credential, all in four undergraduate years. The first cohort of this new program is expected to graduate in spring of 2012. The teacher preparation curricula include two of the introductory fieldwork-based courses that are part of the 4+1 pathway. It also includes other required education and pedagogical coursework, plus student teaching in a secondary school setting, which is needed to earn a California single subject credential in math or science.

Science Content Standards:

- UCI student are introduced to the California Content Standards for math and science early in the Cal Teach 1 introductory course. In subsequent class meetings, whenever the teaching of particular elementary science topics are modeled and then practiced by UCI students, they also learn how the lesson is aligned with particular standards.
- When UCI students plan and enact a lesson in an elementary classroom where they are completing fieldwork, they must identify

the particular grade-level content standard(s) their lesson addresses.

- The course instructors and host teachers provide feedback to the UCI student during the lesson planning process and after the lesson has been taught to engage the students in reflection on what the standard really means and how they can assess whether the elementary students have learned what was intended.

Critical Success Factors – What were key lessons learned in making it work?

- UCI students report that the field experience in elementary classrooms has been worthwhile and positive, including the teaching of at least one lesson. For many, it solidifies their desire to continue on with additional courses that focus on middle and high school science and math teaching.

- The instructors report that the format of the course is working well. In every class session the instructors introduce a topic (and associated standards), model the teaching of a particular lesson that addresses that topic, with attention to student-centered and inquiry-based pedagogies and the support of hands-on science or math materials. In the final part of class, the UCI students take over by doing the lesson activities that were modeled and by reflecting on what they are learning from it.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

- While systematic or complete data about what the host teachers are learning from the visiting UCI students is not available, anecdotally, they report being very positive about having a UCI student majoring in math or science in their classroom to provide additional learner support along with some new science and math lesson ideas. Many comment that they wish they could persuade UCI students to pursue a multiple subject rather than single subject credential because of the need for elementary teachers with math or science backgrounds.

- Although the introductory course is advertised for aspiring secondary teachers of math and science, a small number of undergraduate aspiring elementary teachers have enrolled since the course was introduced in 2006.

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Cal Teach – SMI, University of California Riverside (UCR)

Business/Education Challenge – What was driving need for change? (knowledge management)
• Preparing well-trained STEM teachers

Key Considerations and Approach – How did you go about addressing the problem/challenge?

• Creating partnerships between UCR's Graduate School of Education, the ALPHA Center, academic departments in the College of Natural and Agricultural Sciences, the College of Engineering, and the University Education Extension Program, creating multiple pathways for students to:
  o Achieve admissions eligibility with a teaching credential program of choice
  o Establish professional networks
  o Deepen their subject knowledge through field experiences, including partnering SMI with the California Mathematics and Science Teacher Initiative (CMST) to create a four-year continuum
  o Gain public school classroom experiences very early in their undergraduate careers
  o Access the Aurora Project for community college transfer students.
• Well-established connections with local K-12 communities have enabled UCR to craft professional development opportunities that replenish and expand the pool of successful STEM teachers.
• With the recent conferral of a NSF Noyce award, UCR will build on its partnership with a nearby low-performing school district (Moreno Valley Unified) to create a continuum of teacher preparation and development that will result in 43 new secondary mathematics and science teachers. The Noyce program will impact 56 classrooms in six middle and five high schools supporting 14 district mentor teachers per year and 2,000 secondary level students.

Solution – What did the 'solution' look like?

- Through campus collaborations, the following programs have been created and implemented:
  - Teacher Mentor Certification Program (University Extension)
  - Professional development programs that improve teacher instruction, increase student achievement, and improve teacher retention. These programs are research-based workshops and conferences developed through the Inland Area Science Project and the Riverside-San Bernardino County Teacher Association. They include longitudinal evaluation components to determine the effectiveness of pedagogical changes.
  - STEM degree emphases in teacher education
  - Professional development training opportunities that provide network building between pre-service and credential teachers, such as the Mathematics Academy for Teaching Excellence (MATE), Science Quest, Copernicus Project, and *Scientific Teaching* Summer Institute.
  - *Scientific Teaching* Summer Institute Program: This intensive, interactive program is based on a new teaching philosophy modelled in *Scientific Teaching* (Handelsman, 2007). Participants examine principles and practices of "scientific teaching" that provide them with a new set of pedagogical tools to help engage students.

- Students are encouraged as early as their freshman year to explore secondary teaching as a career through multiple types of exposure, including education related courses. The design of a personalized program plan is achieved through one-on-one advising at the SMI Resource Center in partnership with academic advising within each STEM degree program. This dual advising strategy develops meaningful career objectives founded on individual skills and knowledge.

Critical Success Factors – What were key lessons learned in making it work?

- Cal Teach-SMI provides financial support to promote pre-service teacher participation in professional development opportunities (e.g. *California Mathematics Council Annual Conference, Paper Folding With Standards* offered by the Riverside-San Bernardino County Math Teacher's Association, the *Understanding the Culture of Poverty Conference* arranged by the City of Ontario, and *Inquiry Science Instruction Design* available through UCR University Extension.)

- SMI has entered into agreements with University Extension to provide seats in various Mathematics and Science Inland Area Workshops, and other extension courses at reduced costs.

- Financial assistance to complete pre-credential state requirements (e.g. CSET and CBEST exams) is also available. Pass rate for the CBEST and CSET exams increased following the provision of financial assistance for exam registration payments. Among junior and senior level students, nearly 70% have either completed or are on track to complete the CBEST and CSET examination requirements prior to graduation.

- Degree Programs with Education Emphases: in collaboration with faculty members in STEM department, Bachelor degree options with emphases in science and mathematics education were developed. Each of these degree options provides a framework by preparing participants for entrance into a teaching credential program with a possibility of intern teaching. Because these degree options include core lower- and upper-division major courses, students gain comprehensive subject content knowledge which facilitates effective pedagogy.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

- Since Spring 2006, over 300 students have completed CaT 1, CaT 2, CaT 3, and CaT 4 courses

- SMI student profile based on Fall 2008: by ethnicity, campus comparison in brackets
  - Asian = 35% [36.4%]
  - Chicano/Latino/Spanish = 32% [25.3%]
  - Black/African American = 5% [7.1%]
  - White/Caucasian = 25% [19.3%]
  - Other/Declined = 3% [8.3%]

- Other statistics:
  - Objective in mathematics teaching = 55%
  - Objective in science teaching = 45%
  - Originated as transfer students = 23% (15% minorities)

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Aspiring teachers to learn novel approach to science instruction, University of California Santa Cruz

Business/Education Challenge – What was driving need for change? (knowledge management)
The needs of English language learners are a high priority because they now make up about 20 percent of all K-12 students in the United States--and nearly 50 percent of students in California. A major problem is that most teachers are not being prepared to teach subject matter to English language learners. The goal is to change the way we prepare novice teachers. Educational experts hope to reverse two troubling trends: a "pattern of underachievement" among English language learners, marked by test scores that are about 20 percent lower than the scores of native English speakers, and the declining number of students choosing careers in science.

Key Considerations and Approach – How did you go about addressing the problem/challenge?
• Nearly 1,000 aspiring teachers in San Francisco and San Diego will learn cutting-edge techniques for teaching science to young children whose first language isn't English as part of a collaboration led by UC Santa Cruz. • California State University campuses prepare about 10 percent of the nation's teachers. This project will reach nearly 1,000 aspiring teachers in San Diego and San Francisco 2008-2011. Half will be introduced to Stoddart's model of integrated teaching, and half will learn the traditional approaches to teaching science and language arts. Stoddart's team will monitor and compare the impacts of teachers in each group during their stints as student teachers and into their first year of classroom teaching. • Jerome Shaw, an assistant professor of education at UCSC, will assess the science achievement of K-6 students taught by both cohorts of aspiring teachers in school districts with high proportions of English language learners. The study of student achievement will involve up to 25,000 public school students over the next five years. (2008-2013).

Solution – What did the 'solution' look like?

- The research focused on proving the efficacy of these techniques in teacher preparation and on the impact of this pedagogy on K-6 students.

- Developed, tested, and refined new strategies to help students who do not speak English as their first language learn science. With a $3.1 million grant from the National Science Foundation, Stoddart is sharing her model with faculty at San Diego State University and San Francisco State University, who will integrate instructional practices into their programs. Aspiring teachers will use those techniques during their student teaching assignments as well as in their jobs after graduation. Ultimately, kindergarten through sixth grade students will benefit from the integrated approach to science and language instruction.

- Approach engages students in the phenomena they're studying, which generates a "synergistic" effect, bringing science alive and providing a very powerful context for learning language, because it gives the words meaning. There's a reciprocal relationship between language and science. The learning in each domain enhances the learning in the other.

Critical Success Factors – What were key lessons learned in making it work?

- Teachers learn to teach science in ways that engage students. Hands-on science activities are related to the local environment, whether it's the ocean, weather patterns, or local plants and animals. They are related to parts of their everyday lives.

- Language lessons relate to hands-on activities and objects. Vocabulary is never taught by just listing words on the blackboard. When a teacher uses a word, it's related to a physical object or activity or to a picture or graphic representation. You can learn as many new words in a science lesson as you learn in a foreign language lesson. Science is very language rich.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

- The research focused on proving the efficacy of these techniques in teacher preparation and on the impact of this pedagogy on K-6 students
- A portfolio of strategies has been developed during more than two decades of research. Methods have been adopted by the teacher-education program in UCSC's Education Department and implemented in some local schools and now it's time for wider implementation.
- UC has conducted the research and developed a successful model program that is positioned to expand beyond UC and scale up to have an impact statewide

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Project SMART – Integrating science, math, reading and technology at the primary grades, Chapman University (K-2 Professional Development)

Business/Education Challenge – What was driving need for change? (knowledge management)

- Increase the proficiency and confidence of K-2 teachers to teach science

Key Considerations and Approach – How did you go about addressing the problem/challenge?

- 4-year grant collaboration between Chapman University and the Anaheim City School District funded by the California Postsecondary Education Commission.
- Focus on raising practicing K-2 teachers' science content knowledge through intensive professional development in science content and pedagogy
- Conducted in selected district kindergarten, first, and second grade classrooms through June 2011.
- Serve an estimated total of 90 practicing K-2 teachers, 90 aspiring elementary school teachers enrolled in the university's teacher preparation program, and 2250 K-2 students during the course of the program.

Solution – What did the 'solution' look like?

- 90 K-2 teachers enrolled in two "cohort" groups. Forty-five teachers (15 at each grade level) engage in professional development activities beginning in spring 2008; the remaining 45 teachers join in the project one year later in spring 2009.
- All teachers attend a two-day introduction training session the first spring that they are enrolled in the project, and a five-day SMART Summer Institute the first summer.
- Teachers engage in additional professional learning community (PLC) group meetings throughout the school year, and a follow-up two-day Summer Institute their second year of enrollment.

- Stipends provided to teachers for their participation on non-school days, and substitutes provided for any activities/meetings occurring during the school year.

- Chapman science and mathematics faculty work on an ongoing basis with practicing Anaheim City School District teachers and future elementary teachers enrolled in Chapman's teacher education program on their understanding of science, math, and technology. At the same time, Chapman education faculty work with participants on strategies for delivering science-based integrated instruction in the primary grades.

- Teachers implement the activities presented and strategies learned in their own K-2 classrooms with their students and meet regularly with their peers to examine their progress and share their experiences.

- Throughout the project, participating students will be observed and evaluated on their progress in all content areas and their results compared to students who are not enrolled in the program.

Critical Success Factors – What were key lessons learned in making it work?

- Project is centered on what researchers have proven to be the most critical factor influencing student achievement: the classroom teacher.

- Leadership team contends that the promotion of knowledge requires more than reliance on scripted material, such as is seen and promoted in many classrooms today.

- Innovative practices need to be responsive to teachers' work and needs, rather than disconnected from the reality of today's classrooms and students.

- All of the techniques being used in this project are designed to be efficient, effective, and adaptable, making them "teacher-friendly" while aiming for the highest quality of instruction.

Case Study Contact

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STEP Elementary Co-terminal Teaching Program, Stanford University

Business/Education Challenge – What was driving need for change? (knowledge management)
• The goal is to prepare program graduates to meet both the practical and intellectual challenges of the teaching profession, to serve the needs of the diverse population of today's students, and to revitalize the profession and the field by preparing educational leaders for tomorrow's schools.

Key Considerations and Approach – How did you go about addressing the problem/challenge?
• Desired outcomes for graduates include: an understanding of teaching as intellectual work and as a caring profession; a depth of content knowledge and a repertoire of powerful pedagogical practices; and a view of teaching and of the role of education in society informed by appreciation of the socio-cultural contexts of education. • The content and design of the program are organized to foster an understanding of and commitment to research, reflection and inquiry in the classroom; collaboration across individuals, institutions and communities; a blending of theory and practice; and the effective use of technology as a teaching and learning tool.

Solution – What did the 'solution' look like?
• The Co-terminal program is a 5-year curricular pathway into careers in teaching. • Graduates of the Co-terminal program will receive a bachelor's degree in one of Stanford's undergraduate departments, a master's degree in education, and a State of California preliminary multiple-subject teaching credential. • Admission to the program is highly selective and made on the basis of academic achievement and demonstrated commitment to teaching as a career and the ideals of social justice and public service.

Critical Success Factors – What were key lessons learned in making it work?

- Small size (approximately 20 candidates), access to top faculty and experienced cooperating teachers, and coherent design offer highly focused instruction interwoven with hands-on teaching experience, sustained mentoring and personalized advising.
- Integration of the many areas of knowledge that underlie effective teaching and provides multiple opportunities for observing, planning, and practicing diverse pedagogical approaches in specific clinical contexts.
- Candidates participate in three field placements in local, public elementary schools, covering a range of grade levels.
- Teacher candidates are supported by exceptional cooperating teachers and university supervisors.
- Increasingly, classroom placements are with Partnership Schools that are actively engaged in projects of school reform and that have partnered with Stanford to combine professional training with cutting-edge school-based research.
- The teaching practicum consists of an average of sixteen hours a week at the school site and a weekly seminar at Stanford.
- Teaching responsibilities gradually increase during the year with the candidates' growth and development.

Results – What was the outcome? What benefits gained? What measurable impact achieved?

- STEP's relationships with Teachers for a New Era and the Woodrow Wilson Foundation have highlighted the connections between programs in the education school and those in the humanities and sciences.
- These collaborations have also informed STEP's attention to the continuum of teacher development, beginning in the undergraduate years and extending into the early years of independent practice.

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Appendix D. California Council on Science and Technology

2009 - 2010 BOARD MEMBERS

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*** New Council Members**

Appendix E. California Teacher Advisory Committee

2009 - 2010 California Teacher Advisory Council Members

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

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Co-Director,
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La Puente High School

Peg Cagle *
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Kermit McKenzie Jr. High

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Mathematics Teacher
Pioneer High School

Diana Herrington
Mathematics Teacher
Clovis High School

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Appendix F. Reviewers

The California Council on Science and Technology adheres to the highest standards to provide independent, objective, and respected work. All work that bears CCST's name is reviewed by council members and senior fellows; education projects such as this one also are reviewed by the California Teacher Advisory Council (Cal TAC). In addition, the council seeks peer review from external technical experts. The request for rigorous peer review results in a protocol that ensures the specific issue being addressed is done so in a targeted way with results that are clear and sound.

In all, this report reflects the input and expertise of nearly 30 people in addition to the principal investigators. Reviewers include experts from academia, national laboratories, and non-profit organizations.

We wish to extend our sincere appreciation to the external reviewers who have agreed to be listed below and to those who requested not to be identified. In particular, we wish to acknowledge the input provided on numerous occasions throughout the composition of the report by the California State University Chancellor's Office and the Center for the Future of Teaching and Learning. Their expertise and diligence in reviewing this report has been invaluable, both in rigorously honing the accuracy and focus of the work and in ensuring that the perspectives of their respective areas of expertise and institutions were taken into account. Without the insightful feedback that these reviewers generously provided, this report could not have been completed.

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