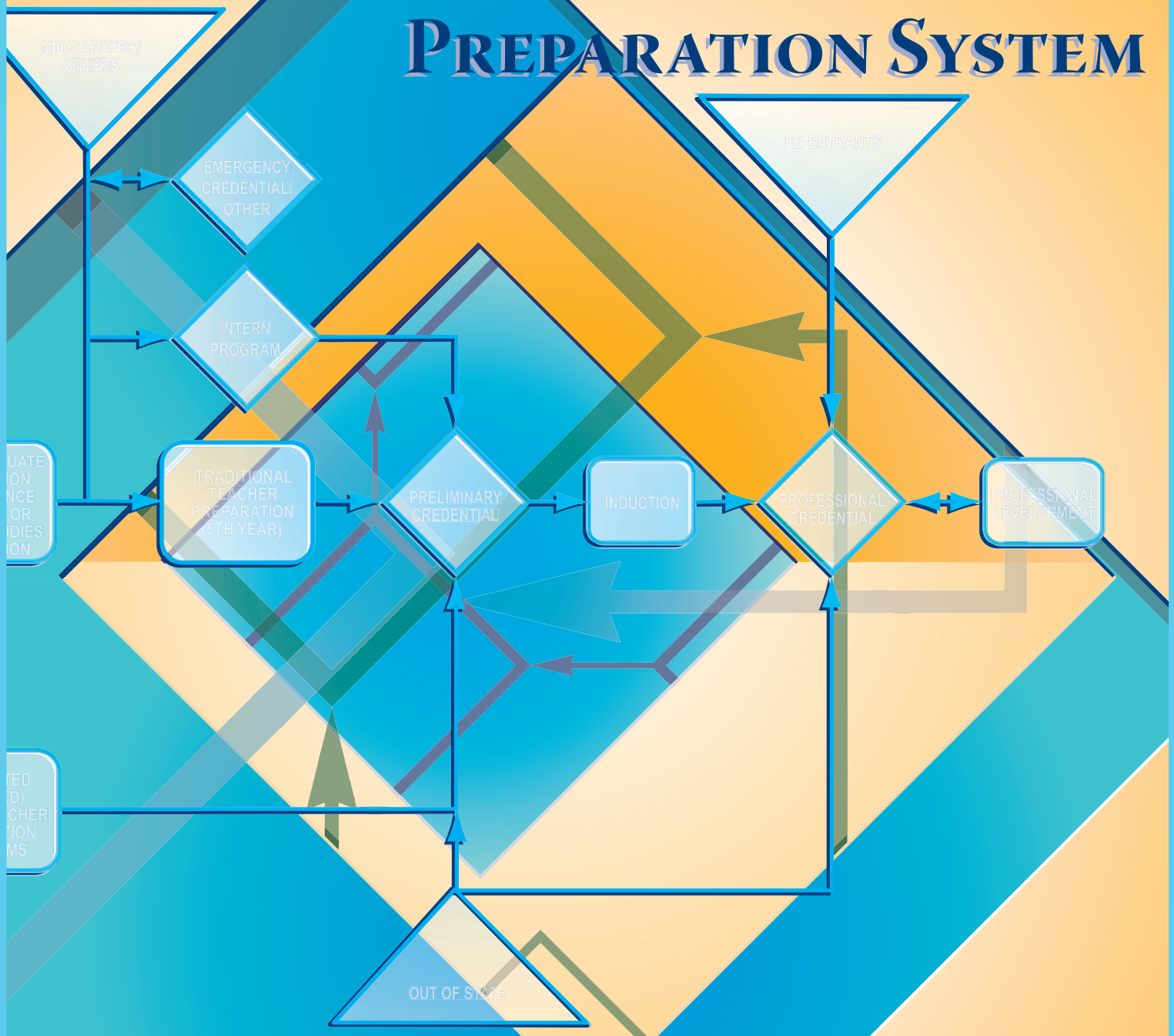
Critical Path Analysis of California's Science and Mathematics Teacher Preparation System



March 2007

California Council on Science and Technology
The Center for the Future of Teaching and Learning

Critical Path Analysis of California's Science and Mathematics Teacher Preparation System

A report prepared by the

California Council on Science and Technology

and

The Center for the Future of Teaching and Learning

March 2007

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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 curriculum and ensuring the continuing intellectual, ethical, and social development of all children.

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LETTER FROM CCST AND CFTL

For nearly a decade, our two organizations have been paying close attention to the health of the educational system in California. The California Council on Science and Technology (CCST) has produced a number of reports on California's science and technology educational system, beginning with *California Report on the Environment for Science and Technology* in 1999. The gap between the demand for and supply of skilled science and technology workers identified in our reports continues to be an ongoing serious issue. During this same period, the Center for the Future of Teaching and Learning (CFTL) has documented annually the status of the teaching profession, with a particular focus on the number of fully prepared teachers and the disproportionate assignment of underprepared teachers to schools with large numbers of poor, minority and English learning students throughout the state. For several years CFTL has been calling the attention of the state's policymakers to the substantial number of science and mathematics teachers who are underprepared, teaching out of field, or new to the profession.

This current collaboration between our organizations builds on the intersection of our respective interests and expertise — fully prepared and effective science and mathematics teachers in middle and high schools. It also provides a unique perspective as it examines the whole system of science and mathematics teacher development — recruitment, preparation, induction, professional development, and retention.

Our conclusions are troubling: despite efforts in California to boost the quantity and quality of fully prepared and effective teachers, a shortage of these teachers in science and mathematics persists, especially in low-performing schools. While this finding won't be news to many readers, the report also identifies the scope and scale of the problem — underprepared science and mathematics teachers, the maldistribution of these teachers in low-performing schools, and not enough professional development to build content knowledge and skills to deliver this content powerfully and well.

The problems are serious and must be addressed quickly. As noted in the landmark 2005 National Academies' report *Rising Above the Gathering Storm,* the costs of failing to invest in our science and technology infrastructure — including education — are potentially catastrophic for the nation as a whole. Governor Schwarzenegger and members of the Legislature also recognize the implications of weak science and mathematics teaching and its effect on the economy. With committed leadership by elected officials, significant strategic investments can be made with a view to building for the future.

What seems to get lost in most discussions about STEM education is that, although preparing for a career in mathematics and science can be challenging, it can also be very exciting. These fields require high levels of creativity and inventiveness by individuals working alone or in teams in the laboratory or in the classroom. Unfortunately all too often talented science, technology engineering and mathematics undergraduates who make up the likely pool of prospective teachers do not seem to perceive teaching as offering the same sense of adventure, personal rewards, excitement and satisfaction as

other employment. This contrasts with the perception of the many highly accomplished mathematics and science teachers we work with on a regular basis who, despite limited resources and numerous other challenges, find teaching to be an extremely rewarding career. We believe that the perception of STEM undergraduates must change and the constraints on good teaching must be addressed immediately in order to attract much-needed new teachers, as well as retain the experienced and effective members of the existing workforce. Policymakers need to ensure that teaching is as attractive as other STEM careers for those who have both the competence in the content area and knowledge of pedagogy to teach children.

To that end, this report carries a serious message, but also offers hope. As a first important step, new chaptered legislation will ensure that the state can collect the data it needs to track its teacher workforce as a whole. Such data collection will help California better understand and respond to the shortages in fields such as science or mathematics. Other key actions must be taken in the near term to ensure that adequate numbers of science and mathematics teachers are fully prepared to meet the impending demand due to attrition and retirement. What is needed is a large and sustained commitment by the state's education leadership, the institutions of higher education, and schools and districts throughout the state to produce enough well-prepared teachers with single-subject credentials in science and mathematics, to support them in their early years of teaching so that they succeed and stay in the profession, and ensure that professional development continues throughout their careers.

Fortunately, there is consensus that these problems can be successfully addressed, and momentum is building in our high-tech industries, institutions of higher education, and among policymakers to make the needed changes and investments. We trust that this document will be a useful tool in making science and mathematics education for all students in California a stable and long-lasting priority.

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EXECUTIVE SUMMARY

The link between education, particularly science and mathematics education, and America's overall economic well-being has been observed and documented for decades by scholars and policymakers. Despite the need for homegrown production of qualified workers, their number has been declining for some time. That decrease does not bode well for our economy, as competition for skilled jobs increases not only in other parts of the country, but also in other nations around the world.

Science and Mathematics Teachers Matter

- Teachers are a crucial component in the system of science, technology, engineering and mathematics (STEM) education.
- K-12 student experience with science and mathematics plays a significant role in influencing whether they pursue STEM degrees.
- All students in California's large and increasingly diverse population need access to fully prepared science and mathematics teachers.
- STEM careers pay better than average. A healthy economy generates the revenue in California that enables the state to support an educational system that creates a workforce to supply STEM-intensive industries.

California's economy depends heavily on the science and technology sectors. Policies that affect the number and quality of science and mathematics teachers are one critical mechanism to ensure that California remains a national and world leader in science, technology, engineering and mathematics (STEM) fields and in economic competitiveness.

Teachers have a key proactive role to play in ensuring that high-quality science and mathematics instruction in elementary and secondary levels will serve as building blocks for success in the workplace and in higher education. It simply makes sense for the state to develop and support policies that prioritize high-quality science and mathematics education for all students. Such a priority is particularly urgent as the state considers strategies to avoid a predicted decline in educational attainment.

California lacks an adequate supply of fully prepared and effective science and mathematics teachers at the middle and high school levels. In this report, we define "fully prepared" as teachers who are credentialed and are teaching courses in which they are certified. Since the implementation of the state's class-size reduction initiative in 1996, California has experienced shortages of fully prepared teachers at all levels and subject areas. Although the problem has abated somewhat in recent years, studies show that shortages remain in secondary schools, including in the science and mathematics fields.

California's shortage of fully prepared and effective teachers begs a few fundamental questions: How many K-12 science and mathematics teachers are there at the various levels and how many are needed? Where is the greatest shortage of fully prepared science and mathematics teachers? What are the most promising routes to the classroom for science and mathematics teachers? And, where are the breaches in the system? To the extent possible, this study addresses these questions for policymakers in California and for institutions that prepare teachers.

This project is a confluence of many years of independent research efforts by the California Council on Science and Technology (CCST) and the Center for the Future of Teaching and Learning (CFTL). CCST has been examining STEM education as a means of understanding science and technology (S&T) workforce production and, by extension, the health of California's vital S&T economic sector. CFTL, in turn, has been documenting the status of California's teaching profession through a series of annual reports beginning in 1999. These two streams of independent analysis caused CCST and CFTL to conclude that science and mathematics teacher preparation, recruitment, induction and support merited a systematic examination that had not been done before in California.

Our overall conclusion after many months of study and analysis is that California's system of science and mathematics teacher development from the recruitment of candidates to the professional development of experienced veterans is not meeting the current or future needs of the state. Addressing the need to ensure that all students have the kind of high-quality science and mathematics instruction required of citizens in the 21st century calls for prompt and concrete action by the state's education policymakers.

Critical Path Analysis

A critical path analysis (CPA) is a tool often used in industry to plan complicated projects and analyze complex business processes. A key feature of a CPA is its ability to find bottlenecks and points in the system where, if major problems exist, the system fails to function. For this report, we adapted some techniques of a formal CPA to examine each major component of California's science and mathematics teacher production system — from recruitment of teachers, through their preparation and certification, and on to professional development once they are working in the classroom.

Understanding Science and Mathematics Teacher-preparation in California

California's public education system is comprised of over 307,000 teachers who serve more than 6 million students. The teacher workforce includes 17,500 teachers who teach science and 22,500 who teach mathematics in middle and high schools. Yet there is a demonstrable, chronic shortage of science and

mathematics teachers as many are not fully prepared to teach science and mathematics subject matter.

The Science and Mathematics Teacher Workforce

- California currently has approximately 17,500 teachers who teach science and 22,500 who teach mathematics in middle and high schools. Not all of these teachers are fully prepared.
- At the middle school level, 10% of science and mathematics teachers were underprepared (those who are teaching but lack a teaching credential); and nearly 30% of novice (1st and 2nd year teachers) science and mathematics teachers were underprepared. Nine percent of science teachers and 12% of mathematics teachers teach out of field.
- At the high school level, 9% and 12% of science and mathematics teachers, respectively, were underprepared; even larger percentages (35% and 40% of novice science and mathematics teachers, respectively) are underprepared.
- The percentage of underprepared science and mathematics teachers is much higher in low-performing and high-minority schools.
- The demand for new science and mathematics teachers in the next ten years is expected to be over 33,000. The current rate of teacher production in California cannot meet this impending demand.

If current trends continue without policymakers taking corrective measures, California will continue with persistent conditions of underprepared science and mathematics teachers, especially in low-performing and high-minority schools, and of out-of-field teachers widely distributed around the state.

The state has an immediate need to recruit high-quality science and mathematics teachers through the various teacher-preparation routes, and then to retain them once they are in the classroom. Education leaders throughout California have come to recognize this need, and the system has been changing to accommodate increases in demand. For example, both the California Department of Education and the California Postsecondary Education Commission — different agencies with missions to serve different parts of the educational system — have funded new programs to recruit and retain more science and mathematics teachers. The California Commission on Teacher Credentialing has authorized alternatives to the traditional teacher-preparation process, such as the integrated program (allowing prospective teachers to earn their teaching credential and college degree simultaneously) and the internship program (allowing prospective teachers to learn "on the job," teaching while they finish their credentialing program).

These have had some effect; available data estimates show that novice science and mathematics teachers are choosing alternative routes nearly half the time. But these programs can vary widely in quality, and there are few objective assessments of their relative merits.

Getting and Keeping Good Teachers

- Although many teacher recruitment efforts have operated in California, several have been discontinued before they were able to demonstrate significant results. Existing programs vary greatly in size and level of funding and little is known about their effectiveness.
- Teacher turnover costs money and impedes districts' ability to maintain a fully prepared and effective teacher workforce.
- Many professional development programs are designed primarily to meet district goals of complying with state requirements.

Both recruitment and professional development programs have suffered wide fluctuations in funding over the years. California has invested in a variety of recruitment programs, but tends to invest on a tactical basis, rather than a strategic one: few programs survive more than two to three years, and the lack of systematic data on the teacher workforce has impeded the state's ability to demonstrate convincingly the effectiveness of any of the programs. Likewise, professional development is handled largely through block grants to districts, whose programs vary significantly in quality and scope. In addition, funding for the largest science-related program — the California Science Project (CSP) — has dropped by 75% since 2002-03. Faced with a shortage of fully prepared teachers to begin with, this seems inconsistent with a goal of maintaining and augmenting a well-prepared and effective teaching workforce.

In short, there is no central system managing the state's science and mathematics education workforce, but a collage of systems, working towards common goals in parallel. Consequently, it is very difficult for any agency or policymaker to understand the true situation, much less coordinate effective action to meet the state's need for fully prepared science and mathematics teachers.

Key Findings

Our analysis shows that California is facing a critical challenge to produce enough fully prepared and effective science and mathematics teachers to meet the demand — both in the short term and the long term. There is a demonstrable chronic shortage of fully prepared teachers in these areas at the middle and high school levels. We found that:

- **In general, California lacks a coherent system to consistently produce fully prepared teachers, especially science and mathematics teachers.** The current array of teacher-preparation programs (traditional, integrated, and alternative), the placement of out-of-state hires, induction programs, especially those for teaching interns; and professional development for veteran teachers is insufficient to meet the need for effective science and mathematics teaching in all of California's classrooms.
- **The state lacks the data necessary to monitor the supply and demand of teachers.** The recently approved California Longitudinal Teacher Integrated Data Educational System (CALTIDES) is a step in the right direction, but must be fully supported and sustained over time.
- **The state has passed promising legislation to bolster the teacher workforce, but the success of these bold policies is dependent on thoughtful and thorough implementation at the local level.** The omnibus teacher workforce bill (Senate Bill 1209; Chapter 517, Statutes of 2006) and the Quality Education Investment Act of 2006 (Senate Bill 1133; Chapter 751, Statutes of 2006), among other measures, have the potential to bring teachers to high-need schools and encourage them to accept jobs in shortage areas such as science and mathematics.
- **California's teacher-preparation programs do not currently have the capacity to meet the demand for fully prepared science and mathematics teachers.** The various teacher-preparation programs in institutions of higher education (and to some extent, school districts) are not meeting the demand for fully prepared science and mathematics teachers. By fully prepared, we mean teachers who have at least a preliminary credential and are teaching in their field of certification. Instead, there are large numbers of underprepared teachers who are assigned disproportionately to high schools with large numbers of poor, minority and English-learning students.
- **There is a large percentage of teachers who may be fully prepared, but are assigned to teach science and mathematics out of their area of expertise.** Out-of-field teaching is not limited to urban areas, but is common in districts throughout the state.
- **Although traditional teacher-preparation programs are still the primary routes for entering science and mathematics teachers, there is a strong trend toward alternative routes such as internships.** The demand for new science and mathematics teachers in the late 1990s and early 2000s led to a large number of waiver and emergency hires whose training did not include earning a preliminary credential before entering the classroom. Those authorizations have all but been eliminated as a result of the highly qualified teacher provision of the federal No Child Left Behind Act, but university and district internships have emerged as an important alternative pathway, especially for science and mathematics

teachers. Internships allow novice teachers to work in the classroom full time while simultaneously earning a preliminary credential.

- **Until recently, new teacher-support programs have not been adequate to accommodate novice science and mathematics teachers who are entering the profession as interns.** However, new legislation enacted this year provides money for induction support for interns, but successful implementation of this Mentor Teacher Program will require some changes in infrastructure at the local level, including the recruitment and training of qualified mentor teachers in high-need areas.
- **Professional development opportunities for middle and high school science and mathematics teachers fall short of meeting the increasing need for deeper subject matter content knowledge and pedagogical skill.** There is a need for more high-quality, content-based professional development for science and mathematics teachers, especially those at the middle and high school levels. Federal and state policies are largely focusing resources and attention on elementary school teachers, especially in mathematics and reading. Programs originally designed for middle and high school teachers, especially the California Science and Mathematics Projects, have been re-cast to accommodate state priorities for elementary school teachers. As a result, high-quality experiences for middle and high school science and mathematics teachers are being cut back.
- **California will experience a shortage of new, fully prepared science and mathematics teachers in the next decade due to attrition and retirement of the existing teacher workforce.** A conservative estimate is that there will be a shortage of 33,200 single-subject middle and high school science and mathematics teachers over ten years. Significant issues emerge as to whether or not current teacher-preparation programs can meet the demand for fully prepared teachers. If internship programs expand to meet the need, the problem of underprepared novice teacher may be exacerbated. It is too soon to tell if current efforts within teacher-preparation institutions to increase the numbers of science and mathematics teachers will meet the demand. Increasing the numbers of interns working toward a preliminary credential while teaching a full load may help to address, but not solve, the shortage problems.
- **California policymakers need to carefully assess the preparation of elementary science and mathematics teachers**. Elementary school teachers play a key role in science and mathematics education, yet not enough is known about how well they are prepared to teach science and mathematics in the lower grades, or the skills and knowledge they bring to the classroom.

Recommendations

In light of these findings, we strongly encourage education leaders and policymakers to take the following actions:

State-wide Education Leadership and Policy Organizations

1. As part of a broader effort to bolster supply of science and mathematics teachers, support the development of programs designed to encourage experienced retirees to enter teaching. Specifically, establish public-private partnerships with industry and business in the areas of science and mathematics to actively recruit retiring professionals to the classroom and place them in internship programs with highly accomplished veteran mentor teachers.
2. Reinstate the Mathematics and Science Summer Institutes offered through the California Subject Matter Projects as a means of increasing support for high-quality, content-based professional development for veteran teachers. Also provide a one-time planning grant for California Subject Matter Project personnel to design and implement just-in-time professional development opportunities to ensure that out-of-field science and mathematics teachers receive the support they need to deliver the required curriculum content effectively so that all students succeed.
3. Build on progress made during the last legislative session to establish a coherent system to recruit, prepare, assign, and retain K-12 science and mathematics teachers, by fully funding the new California Longitudinal Teacher Integrated Data System (CALTIDES) to gather and analyze data and report annually on:
   - The supply and demand of science and mathematics teachers in elementary and secondary schools.
   - The production of single-subject science and mathematics credentials, by field and institution.
   - The numbers of single-subject science and mathematics credentials awarded by institution and type of teacher-preparation program (e.g., traditional, integrated or internship) or to out-of-state prepared teachers.
4. Implement the Memorandum of Understanding (MOU) between the California Community Colleges and the California State University to create a streamlined and strengthened pathway for aspiring teachers by extending these efforts to address articulation agreements between the two systems to support a pipeline for aspiring teachers of science and mathematics. Coordinate MOU activities with the University of California's program to develop new pathways into the teaching profession by identifying community college students interested in both STEM fields and teaching.
5. As part of the monitoring implementation of SB 1209 and SB 1133, review during budget hearings the extent to which fully prepared science and

mathematics teachers are distributed evenly throughout participating school districts.

Institutions of Higher Education (IHE)

6. As part of the annual self-study put forward by institutions with teacher-preparation programs, examine current teacher-preparation programs to determine how they can be expanded to produce more single-subject science and mathematics teachers. Examine the content and pedagogy elements of these programs for multiple-subject credentials to ensure that all elementary school teachers are prepared to teach science and mathematics. Use the results of the self-study as the base upon which improvements to the science and mathematics preparation programs are made.

7. Expand exemplary California Academic Partnership Programs as a means of encouraging IHE campuses to work collaboratively with school districts to ensure that teachers delivered to the classroom are well prepared and supported as new teachers, in both content and pedagogy.

School Districts

8. Ensure a coordinated, cohesive induction into the profession by using the new Mentor Teacher Support Program established in SB 1209 to offer support for all science and mathematics intern teachers and coordinate this program with the district's existing Beginning Teacher Support and Assessment (BTSA) program. Fund the California Subject Matter Projects and other professional development organizations to provide training for mentor teachers to ensure they have the subject matter content knowledge, pedagogical skill and ability to work successfully with adults.

9. Utilize the new professional development block grant funding, the new latitude for developing locally-based professional development programs provided in SB 1209, and resources available to identified schools in SB 1133 to design and implement coordinated, cohesive, coherent professional development programs throughout the districts.

10. Make use of the new provisions in SB 1209 that enable districts and their bargaining units to develop incentive-pay systems to encourage teachers to take assignments in shortage areas and attract them to high-need schools.

Industry, Federal Laboratories, and Informal Science Learning Centers

11. Expand support for professional development of science and mathematics teachers. In particular, provide authentic research and work experiences, especially during the summer months, and build on successful work experience models that integrate the learning of new content with teaching strategies.

CHAPTER 1 - INTRODUCTION

California lacks an adequate supply of fully prepared science and mathematics teachers at the middle and high school levels. In this report, we define "fully prepared" as teachers who are credentialed and are teaching courses in which they are certified and hired. Since the implementation of the state's class-size reduction initiative in 1996, California has experienced shortages of fully credentialed teachers at all levels and subject areas. Although the problem has abated in recent years, studies show that shortages remain in secondary schools, especially in science and mathematics.

California's shortage of fully prepared teachers begs a few fundamental questions: How many K-12 science and mathematics teachers are there at the various levels, and how many are needed? Where is the greatest shortage of prepared science and mathematics teachers? What are the most promising routes to the classroom for science and mathematics teachers? And where are there breaches in the system? To the extent possible, this study addresses these questions for California's policymakers and for institutions that prepare teachers.

1.1 Goals of This Study

To perform this study, the California Council on Science and Technology (CCST), in collaboration with the Center for the Future of Teaching and Learning (CFTL), conducted a critical path analysis (CPA) of science and mathematics teacher production in California. The goals of this study, to the extent that data were available, were to provide descriptive and quantitative information for California policymakers in the following areas:

The Supply and Demand for Science and Mathematics Teachers

- The current supply of science and mathematics teachers.
- The number of science and mathematics teachers produced, hired, and certified.
- The number of science and mathematics teachers needed, and where they are needed.

The System of Science and Mathematics Teacher Production and Licensure

- The academic programs and other pathways for teacher preparation.
- The number of teacher candidates produced per year who are prepared to enter the classroom as science and mathematics teachers.
- The paths toward licensure.

Teacher Recruitment and Retention

- Programs in institutions of higher education that recruit students to become science and mathematics teachers.
- Programs that recruit mid-career candidates to become science and mathematics teachers.
- Efforts to retain teachers in the teaching profession.

Induction

- The training and support of new, or novice, teachers.

Professional Development

- Programs that strengthen teachers' skills and knowledge.

In order to complete this analysis, CCST engaged several principal investigators to focus on different areas of the teacher development system. CCST and CFTL drew upon on the following papers to provide core elements of this report:

- Herbert Brunkhorst, Professor, Department Chair, Science, Mathematics & Technology Education (CSU San Bernardino): *Science Teacher-preparation in California*
- Pamela Clute, Assistant Vice Provost, Academic Outreach and Educational Partnerships (UC Riverside): *Mathematics and Science Teacher Recruitment*
- Judy Kasabian, Professor of Mathematics (El Camino College): *Descriptive Analysis of Mathematics Teacher-preparation at California Public Colleges and Universities*
- Yvonne Lux, Project Director, The Educational Research and Leadership Institute (California Lutheran University): *A Descriptive Analysis of Professional Development and Induction for Teachers of Mathematics in California*
- Eugenia Mora-Flores, Associate Professor, Rossier School of Education (USC): *Descriptive Analysis of Science and Mathematics Teacher-preparation through Credentialing in the State's Private Colleges and Universities*
- Patrick Shields, Director, Center for Education Policy (SRI International): *The Supply, Demand and Distribution of Mathematics and Science Teachers in California*
- Dan Walker, Director, Mathematics and Science Teacher-preparation (SJSU): *Science Teacher Induction and Professional Development*

1.2 What is a Critical Path Analysis (CPA)?

A critical path analysis is a tool often used in industry to plan complicated projects and analyze complex business processes. It shows diagrammatically the interrelations in sequence of all the activities in a project in such a way as to highlight those that are critical for the performance of the overall work.[1] A key feature of a CPA is its ability to find bottlenecks and points in the system where, if major problems exist, the system fails to function. (See Appendix A for more information about the critical path method.)

For this report, we adapted some techniques of a formal critical path analysis to perform a first-of-its-kind examination of each major component of the current system to produce science and mathematics teachers in California — from recruitment of teachers, through their preparation and certification, and on to professional development once they are working in the classroom. *Throughout this analysis, the central focus was on factors that affect teachers.*

[1] 12manage Management Information Portal, http://www.12manage.com/description_critical_path_analysis.html (accessed 1-10-07); § 6.2 Planning. p. 125-126.

1.3 Background

This project is a confluence of many years of independent research efforts by CCST and CFTL. Since the late 1990s, CCST has been considering science and technology education as a means of understanding science and technology (S&T) workforce production and, by extension, the health of California's vital S&T economic sector. In its 2002 report, *Critical Path Analysis of California's Science and Technology Education System*, CCST examined the entire education system as a single process, from kindergarten through postsecondary. [2] That report analyzed science, technology, engineering and mathematics (STEM) degree production in detail in order to determine which points in the education system were impeding success. Although the report identified difficulties at every level of the education system, there were particularly alarming rates of student attrition from science and mathematics courses between the 9th and 12th grades. In short, many students were not completing high school with the science and mathematics skills needed to graduate or advance to a four-year college or university, and many of those who matriculated were not well-prepared to pursue STEM degrees. Also, one of the most disturbing factors identified as contributing to poor student performance in science and mathematics was the lack of fully prepared teachers, particularly in schools with high concentrations of poor, minority, and English-language-learning students.

CFTL, in turn, has been documenting the status of the teaching profession in California through a series of annual reports beginning in 1999. CFTL's reports conclude that many questions about the teacher workforce cannot be answered using current data systems; that high demand to hire new teachers, coupled with inadequate production rates, resulted in large numbers of teachers who were not fully prepared, especially in high-need urban schools; and that a high number of science and mathematics teachers are not fully prepared to teach the subjects to which they are assigned. [3, 4]

These two streams of independent analysis caused CCST and CFTL to conclude that science and mathematics teacher production merited a systematic examination that had not been done before in California.

1.4 Mapping the System

Other professions, such as medicine and law, have well-established pathways and standard courses of study and examinations that allow entry into the profession. In contrast, the teaching profession has developed many routes to

[2] California Council on Science and Technology, Critical Path Analysis of California's Science and Technology Education System (Sacramento: California Council on Science and Technology, 2002).

[3] The Center for the Future of Teaching and Learning, Strengthening California's Teacher Information System (Santa Cruz: The Center for the Future of Teaching and Learning, 2002).

[4] Roneeta Guha, Ashley Campbell, Daniel Humphrey, Patrick Shields, Juliet Tiffany-Morales, and Marjorie Weschler, California's Teaching Force 2006: Key issues and trends (Santa Cruz, CA: The Center For the Future of Teaching and Learning, 2006).

preparation and entry; when traditional routes to entry were insufficient for any number of reasons (such as a dramatic increase in demand for teachers due to an increase in student enrollments or changes in state policies), other routes emerged to make teaching a more attractive career option. This plasticity of teacher production has resulted in a complex and multifaceted process, but not necessarily a coherent system that is able to supply enough fully prepared teachers to meet the demand.

To help frame our discussion of the system, we developed a schematic flow diagram (Figure 1.1) to map pathways now available into the professional credentialed teacher workforce (the shaded diamond). It should be noted that while this figure is constructed roughly chronologically — i.e., a potential teacher would move through the system from left to right — it is not strictly speaking a linear process, and as discussed in Chapters 3 and 4, many teachers begin teaching before they are fully prepared. Versions of this diagram are used throughout the report to emphasize various pieces of the system being analyzed.

In Figure 1.1, the triangles are input points where different prospective teacher populations enter the teacher production system. The rectangles represent requirements that prospective teachers must complete before advancing to the next stage. Each diamond represents a population of teachers that is actually in the classroom. In this CPA, we examined available data for each component of this diagram (the boxes and diamonds). A discussion about methodology and data challenges is located in Appendix B. The basic credential terms referred to in this report are summarized in Table 1.1.

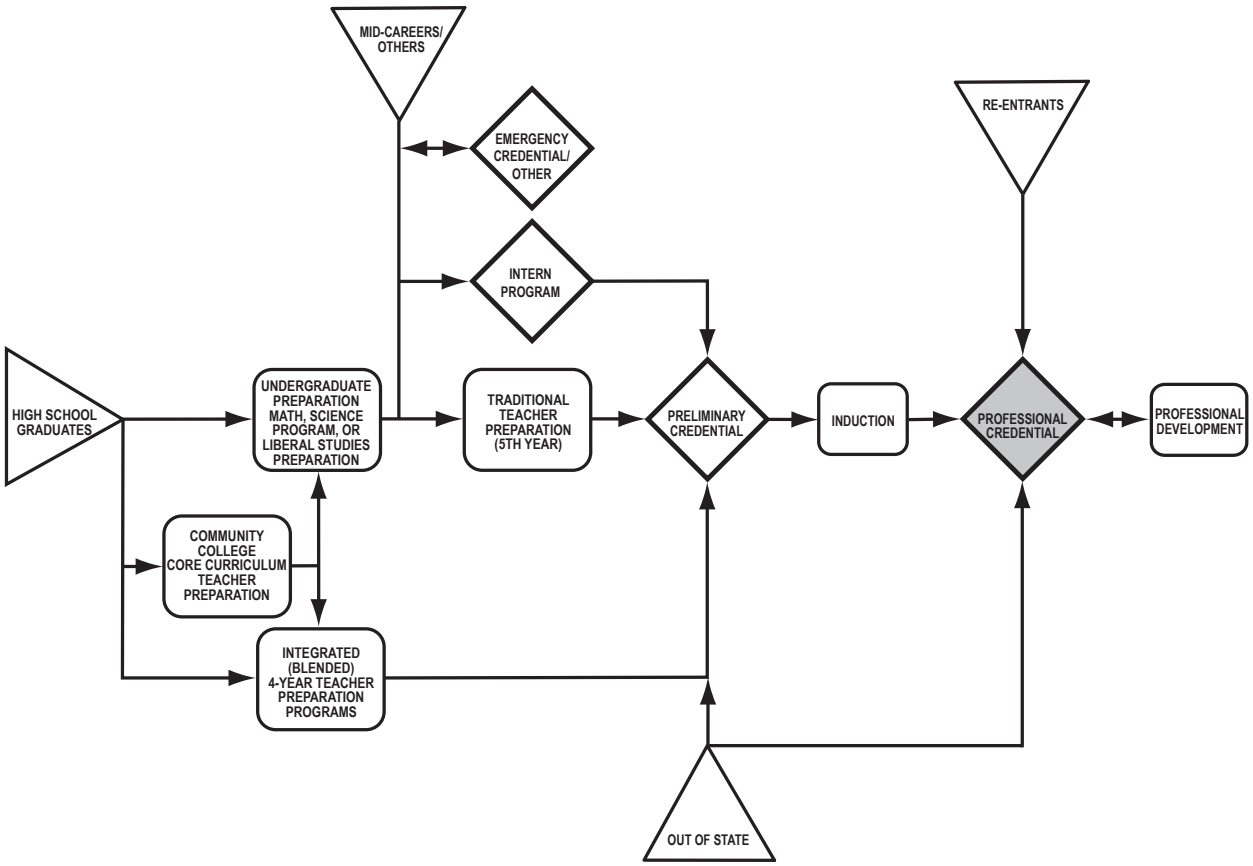

Figure 1.1: Schematic Flow Diagram of the Teacher Production System

Table 1.1. Summary of Key Teaching Credentials and Permits Awarded in California

Professional clear credential	Five-year credential awarded upon completion of an approved induction program.
Preliminary credential	Five-year credential issued to those who complete a baccalaureate, a teacher-preparation program, and other requirements. Additional academic requirements must be completed to qualify for the professional clear credential within five years.
Intern credential	Two-year credential awarded to participants in either a university-based or district-based teacher education program. Holder must have a baccalaureate and demonstrate subject-matter competency. Participants simultaneously teach and complete the teacher education program.
Emergency permit	A one-year permit issued at the request of an employing school district, county office of education, charter school, or state agency to fill a temporary staffing vacancy or need. These permits were phased out in 2006.
Provisional internship permit	Created in response to phasing out of emergency permits. Holder must have a baccalaureate. Renewable annually for up to two years.
Waiver	An authorization provided to teachers who have not demonstrated subject-matter competency. The holder must demonstrate progress towards a credential. Waivers are valid for one year, renewable on a case-by-case basis.

Chapter 2 discusses why science and mathematics teachers are important players in the complex system of STEM education in California. Chapter 3 reports on what is known about the state's current science and mathematics teacher workforce. Chapter 4 describes in some detail the variety of routes to becoming a teacher in California, and which pathways appear to be most attractive to new science and mathematics teachers. Chapter 5 examines recruitment, in part to see how the state has responded to past changes in teacher shortages and also to learn if a coherent system is in place to respond to the current needs. It also discusses teacher retention — a critical issue for California in light of an imminent wave of teacher retirement coupled with losses of teachers through attrition. Chapter 6 addresses induction, which is the support provided to novice teachers as they work towards earning their clear credential. Chapter 7 examines professional development opportunities available to science and mathematics teachers. Chapter 8 discusses the major findings of our analysis, along with recommendations for state policymakers, institutions of higher education, and others interested in supporting K-12 teachers of science and mathematics.

This report is addressed to policymakers and stakeholders, including state government agencies, institutions of higher education, federal laboratories, the private sector, and schools and school districts. All of these groups can use this information to adjust and improve the recruitment, preparation and professional development system for California's science and mathematics teachers. In particular, this report:

- Informs the Governor, Legislature, Secretary of Education, Superintendent of Public Instruction, California Commission on Teacher Credentialing, and institutions of higher education about the production and retention of science and mathematics teachers so as to aid in planning actions and initiatives appropriate to state and federal mandates.
- Offers recommendations to policymakers and key stakeholders to increase the quantity, and improve the quality of science and mathematics teachers.
- Provides useful information for all who are concerned about the supply and demand of science and mathematics teachers, including students, parents, teachers, education support organizations, philanthropic organizations and individuals, and employers.

CHAPTER 2 - WHY SCIENCE AND MATHEMATICS TEACHERS MATTER

Key Points:

- Teachers are a crucial component in the system of science, technology, engineering and mathematics (STEM) education.
- K-12 student experience with science and mathematics plays a significant role in influencing whether students pursue a STEM degree.
- All students in California's large and increasingly diverse population need access to fully prepared teachers who can teach science and mathematics effectively.
- STEM careers pay better than average. A healthy economy generates the revenue in California that enables the state to support an educational system that creates a workforce to supply STEM-intensive industries.

Citizens who are competent and proficient in science and mathematics are especially important in an economy that increasingly depends on science, engineering and technology to spur new ideas for innovation and economic competitiveness. Those ideas mean jobs and prosperity in California.

> *Four important and enduring reasons underscore the need for our children to achieve competency in science and mathematics: (1) the rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread science and mathematics related knowledge and abilities; (2) our citizens need both science and mathematics for their everyday decision-making; (3) science and mathematics are inextricably linked to the nation's security interests; and (4) the deeper, intrinsic value of mathematics and scientific knowledge shape and define our common life, history, and culture. Science and mathematics are primary sources of lifelong learning and the progress of our civilization.*
>
> ***Before It's Too Late:***
> *A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*[5]

Data show that teacher quality is one of the most important determinants of student achievement in science and mathematics. With fully prepared teachers, students can more readily develop the habits that enable creativity and exploration, and develop positive attitudes about science, technology, engineering and mathematics. Without them, students are less prepared to engage fully in rigorous coursework at the university level, or to envision a role for themselves in science, technology, engineering and mathematics-related (STEM) careers, which are so important in our state. [6]

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[5] The National Commission on Mathematics and Science Teaching for the 21st Century, Before It's Too Late: A Report to the Nation (U.S. Department of Education: 2000), 7.

[6] The U.S. Government Accountability Office (GAO) recently reported that a student's experience with science and mathematics from grades K-12 plays a large role in influencing whether the student pursued a STEM degree. Other studies indicate a direct correlation between teacher-preparation and student achievement in science and mathematics. In

2.1 Trends in the STEM Workforce

The importance of the link between education, particularly science and mathematics education, and the United States' overall economic well-being has been observed and documented for decades by scholars and policymakers. [7, 8, 9, 10, 11] Yet several studies show that the homegrown production of qualified workers has been declining for some time. [12] That decrease does not bode well for our economy, as competition for skilled jobs increases not only in other parts of the country, but also in other nations around the world. [13] These analyses also argue that education is key to the health and vitality of the country. Yet even after scores of reports, and hundreds of federal and state programs aimed at increasing the numbers of STEM students, the nation's situation today remains serious. So serious, in fact, that the National Academies issued a report in 2005 with a stern warning for policymakers and educators alike:

> *"Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case... We fear the abruptness with which a lead in science and technology can be lost — and the difficulty of regaining a lead once lost, if indeed it can be regained at all."* [14]

In California, STEM fields are central to our economic strength. The range of science and engineering related industries in this state is second to none, helping to make our economy the sixth largest in the world. [15] Many industries are well established, such as aerospace and space, healthcare, information technology,

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particular, one study of over 5,100 students and 2,200 mathematics teachers found that teachers with a master's degree in mathematics had a clearly positive effect on student scores in the National Educational Longitudinal Study mathematics test. Also, a 1997 survey of several hundred college students who left STEM fields found that approximately 40% reported insufficient high school preparation as a contributing factor. We conclude from these and other data that science and mathematics teachers are a crucial component in the overall STEM education system.

[7] National Commission on Excellence in Education, A Nation at Risk: The Imperative for Educational Reform A Report to the Nation and the Secretary of Education (Washington, D.C.: United States Department of Education, 1983).

[8] U.S. Commission on National Security/21st Century, Roadmap for National Security: Imperative for Change (Washington, D.C.: 2001).

[9] Council on Competitiveness, Innovate America: Thriving in a World of Challenge and Change (2004).

[10] National Academies Committee on Science, Engineering, and Public Policy, Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future (Washington D.C.: National Academies Press, 2006).

[11] George W. Bush. America's Competitiveness Initiative (February 2006).

[12] National Science Board, Science and Engineering Indicators — 2006 (Arlington, VA: National Science Foundation, 2006).

[13] Government Accountability Office (GAO), Higher Education: Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends (Report to the Chairman, Committee on Rules, House of Representatives: October 2005). The GAO found that employment in these fields increased 35% more than the overall rise in employment during the same period. However, during the same period, the percentage of STEM baccalaureate degrees awarded as a proportion of degrees overall declined from 32% to 27%. By the early 2000s, employers relied increasingly on foreign-born technical workers holding H-1B visas; over 75% of these are issued to people in high-tech fields. However, in the 2004 fiscal year, the total number of H-1B visas granted nationwide annually was reduced from 195,000 to 65,000, where it remains today. As some indication of the demand for these visas, in FY 2005 the ceiling for petitions was reached on the first day.

[14] National Academies Committee on Science, Engineering, and Public Policy.

[15] Legislative Analyst's Office, Cal Facts 2004: California's Economy and Budget in Perspective, http://www.lao.ca.gov/2004/cal_facts/2004_calfacts_econ.htm (accessed 1/10/2007).

advanced manufacturing, environmental engineering, and agriculture, yet each relies heavily on creativity and innovation to stay at the forefront. Other industries are new, and depend on new products and applications that emerge from research at the frontiers of science, medicine, and engineering — such as nanotechnology, biotechnology, and new technologies for homeland defense, and alternative, renewable sources of energy. All of these industries require highly qualified scientific and technical workers ranging from entry-level workers, to paraprofessionals and certified technicians, to senior researchers and managers.

The STEM workforce situation is particularly worrisome for California. Despite the predicted needs by industry for employees with baccalaureate degrees,[16] and despite being the home to more top research universities and high tech industries than any other state, California is underproducing baccalaureate STEM degrees. It is in the lowest quartile of states producing bachelor's degrees per 1,000 in the 18-24 year old population, and in the third quartile of bachelor's degrees in STEM disciplines conferred overall relative to the same group.[17]

California is underproducing baccalaureate STEM degrees. It is in the lowest quartile of states producing bachelor's degrees per 1,000 in the 18-24 year old population.

Some researchers predict that this failure to achieve in higher education will have direct economic consequences down the road. Specifically, a recent analysis ranks California last in the projected change in personal income per capita from 2000-2020 — with a projected decline of over 11% in constant dollars (over six times the projected national decline over the same period of 1.8% - see Figure 2.1).[18] That analysis is based in part on the assumption that nearly all states will experience an increase in the percentage of their populations in the 18-64 age range with less than a high school diploma. Such a projected decline in personal income in California caused by lack of educational attainment would have significant consequences for California, because in the last four decades the importance of personal income tax has increased — rising from 18% of General Fund revenues in 1962-63 to 48% in 2002-03.[19] Quite simply, California can't afford — and can't afford to ignore — such a potentially large drop in revenue.

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[16] California Business Roundtable. Keeping California's Edge: The Growing Demand for Highly Educated Workers (California State University Sacramento Applied Research Center: April 2006). This report predicts that by 2022, California companies will need about 2.3 million workers with baccalaureate degrees.

[17] National Science Board, Table 8-13.

[18] Patrick J. Kelly, As America Becomes More Diverse: The Impact of State Higher Education Inequality (National Center for Higher Education Management Systems: November 2005), 28. Data are from the U.S. Census Bureau.

[19] Legislative Analyst's Office, "2002 Cal Facts: State Budget," http://www.lao.ca.gov/2002/cal_facts/budget.html (accessed 1/10/07).

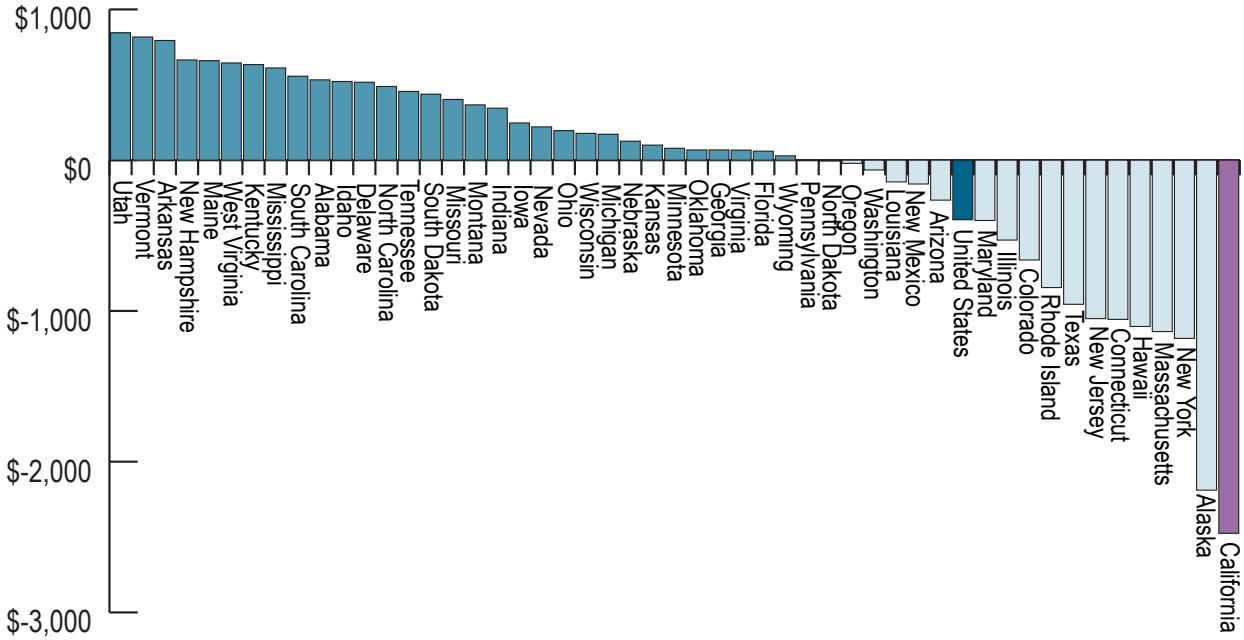

Figure 2.1: Projected Change in Personal Income per Capita by State, 2000-2020

Source: National Center for Higher Education Management Systems (2005)

If California is to avert this predicted decline in revenue, it will need to enable a higher percentage of its students to succeed in school, and thus prepare them to pursue higher education and high-paying jobs in sectors such as STEM. STEM careers pay better on average than non-STEM careers [20] and, at present, comprise a larger percentage of California jobs compared to the rest of the United States. [21]

2.2 Conclusions

Teachers have a key proactive role to play in averting this impending education and economic crisis. High-quality science and mathematics instruction in elementary and secondary schools are the building blocks for success in STEM fields in higher education. Policies that affect the number and quality of science and mathematics teachers are one critical mechanism to ensure that California remains a national and world leader in STEM fields and in economic competitiveness. It simply makes sense for the state to develop and support policies that prioritize high-quality science and mathematics education for all students, particularly as the state considers strategies to avoid a predicted decline in educational attainment.

[20] National Science Board, Chapter 3.

[21] California Council on Science and Technology, 33.

CHAPTER 3 - THE SCIENCE AND MATHEMATICS TEACHER WORKFORCE IN CALIFORNIA

Key Points:

- California has approximately 17,500 teachers who teach science and 22,500 teachers who teach mathematics in middle and high schools. Not all of these teachers are fully prepared.
- At the middle school level, 10% of science and mathematics teachers were underprepared; and 30% of novice science and mathematics teachers were underprepared.
- At the high school level, 9% and 12% of science and mathematics teachers, respectively, are underprepared; even larger percentages of novice science and mathematics teachers (36% and 40%, respectively) are underprepared.
- The percentage of underprepared science and mathematics teachers is much higher in low-performing, high-minority schools.
- An additional problem is the percentage of out-of-field teachers — those who are assigned to teach classes for which they are not fully credentialed. This problem is distributed equally across schools of the state.
- California may need over 33,000 new science and mathematics teachers in the next decade due to attrition and retirement. The current rate of teacher production in California cannot meet this impending demand.

This chapter describes the supply and demand of California's science and mathematics teacher workforce. It focuses primarily on single-subject science and mathematics credentials, which are required of teachers in high school, and preferred in middle school. It also includes the percentages of underprepared and novice middle and high school teachers and their distribution in schools, and out-of-field teachers. The discussion of supply is followed by an analysis of what is known about the demand for teachers at these levels.

3.1 The Science and Mathematics Teacher Workforce

California has the largest teacher workforce in the country, with over 307,000 public elementary and secondary school teachers educating over 6 million students. As shown in Table 3.1, in 2004-05, there were about 22,500 secondary mathematics teachers, comprised of over 10,500 middle school and 12,000 high school teachers. [22] There were over 17,500 secondary science teachers, comprised of over 8,500 middle school and 9,000 high school teachers.

California has the largest teacher workforce in the country, with over 307,000 public elementary and secondary school teachers educating over 6 million students.

[22] SRI International, The Supply, Demand and Distribution of Science and Mathematics Teachers in California (2006). These

Table 3.1: Science and Mathematics Teachers in California, 2004-05

	Mathematics	Science
Middle School	10,500	8,500
High School	12,000	9,000
Total	22,500	17,500

Source: SRI (2006)

3.2 Underprepared Teachers

For years, there has been a persistent shortage of credentialed science and mathematics teachers in California.[23] We define an "underprepared teacher" as one who lacks a preliminary credential (e.g. emergency permit holders, interns, etc.). In addition, novice teachers may have a preliminary teaching credential, but are in their first few years of teaching and are still working toward their professional clear credential (either multiple- or single-subject).[24]

At the peak of the shortage in 2000-01, one-fifth of secondary science and mathematics teachers were underprepared. This problem was particularly acute at the middle school level.

As recent data from the Center for the Future of Teaching and Learning points out,[25] over the last five years, the percentage of underprepared science and mathematics teachers has dropped considerably, yet the percentage of underprepared teachers in these two fields continues to be higher than for the state teacher workforce as a whole (Figure 3.1). At the middle school level, the percentage of underprepared science and mathematics teachers declined by half between 2000-01 and 2005-06, from 22% to 8% in science and from 20% to 9% in mathematics. There has been less progress at the high school level, though, particularly in mathematics, where the percentage of underprepared teachers declined over the last five years from just 18% to 12%. The percentage of underprepared high school science

figures were calculated using data from the California Basic Educational Data System (CBEDS) Professional Assignment Information Form (PAIF) and the Public Schools Database. Only individuals identified as teachers on the PAIF were included in these and subsequent analyses. Teachers were identified as mathematics teachers if they were assigned to teach at least one mathematics course; similarly, teachers were identified as science teachers if they were assigned to teach at least one science course. Because teachers may teach both science and mathematics, the science and mathematics numbers cannot be added. Schools used in these analyses were those identified only as middle schools, junior high schools, and high schools in the Public Schools Database; nontraditional schools were not included in the analyses.

[23] Ibid. While student enrollment was increasing dramatically from mid 1987 — 2005, California's Class Size Reduction Act (CSR) in 1996 created an immediate need for an additional 23,500 teachers, mostly at the elementary level — or a doubling of the demand at that time. Since that demand could not be met with the existing teacher-preparation programs, districts were forced to employ a wide range of solutions to staff their classrooms. The result was hiring as teachers (with full class loads) those who had not completed their teacher-preparation requirements and therefore were without even preliminary credentials. Large numbers of new underprepared teachers had not demonstrated either subject-matter competency or pedagogical skills to teach.

[24] Ibid. Although novice teachers are credentialed to teach their classes, they tend to be less effective than their more veteran peers.

[25] Guha et al.

teachers declined from 17% to 9% during the same period. In contrast, statewide, the overall percentage of underprepared teachers dropped more markedly, from a high of 14% in 2000-01 to 6% in 2005-06.

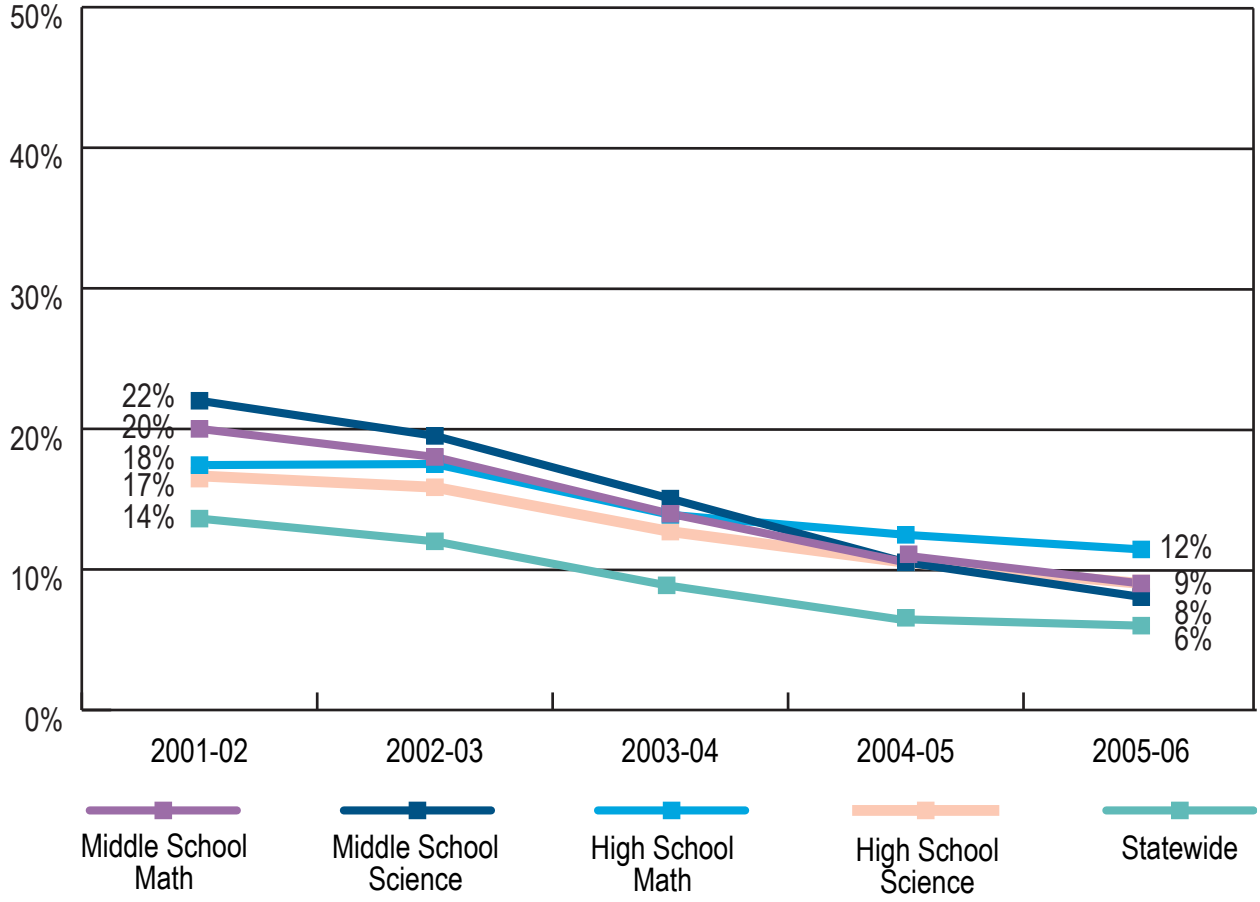

Figure 3.1: Underprepared Science and Mathematics Teachers, 2001-02 to 2005-06

Source: CFTL (2006)

The trends for novice science and mathematics teachers mirror those of underprepared teachers. The percentage of novice science and mathematics teachers has declined slightly over the last five years, but the proportion of novices among science and mathematics teachers remains higher than for the statewide teacher workforce as a whole. In 2005-06, 16% of science and mathematics teachers were in their first- or second-year of teaching, down from approximately 20% in 2000-01. Statewide, however, only approximately 12% of teachers were in their first- or second-year of teaching in 2005-06, down from 15% in 2000-01.

More problematic, however, is that a large percentage of novice science and mathematics teachers are underprepared (Figure 3.2). Faced with a shortage of credentialed teachers, district and school administrators are hiring new science and mathematics teachers

In 2005-06, nearly one-third (29%) of novice middle school science and mathematics teachers were underprepared; even greater percentages of novice high school science and mathematics teachers were underprepared — 35% and 40%, respectively.

who have not yet completed their preparation. In 2005-06, nearly one-third (29%) of novice middle school science and mathematics teachers were underprepared; even greater percentages of novice high school science and mathematics teachers were underprepared — 35% and 40%, respectively. In contrast, less than one-quarter of all novice teachers in all subjects statewide were underprepared. Although the percentage of all underprepared novice teachers has decreased since 2000-01 and seems to be leveling off, the discrepancy between science and mathematics and all teachers persists.

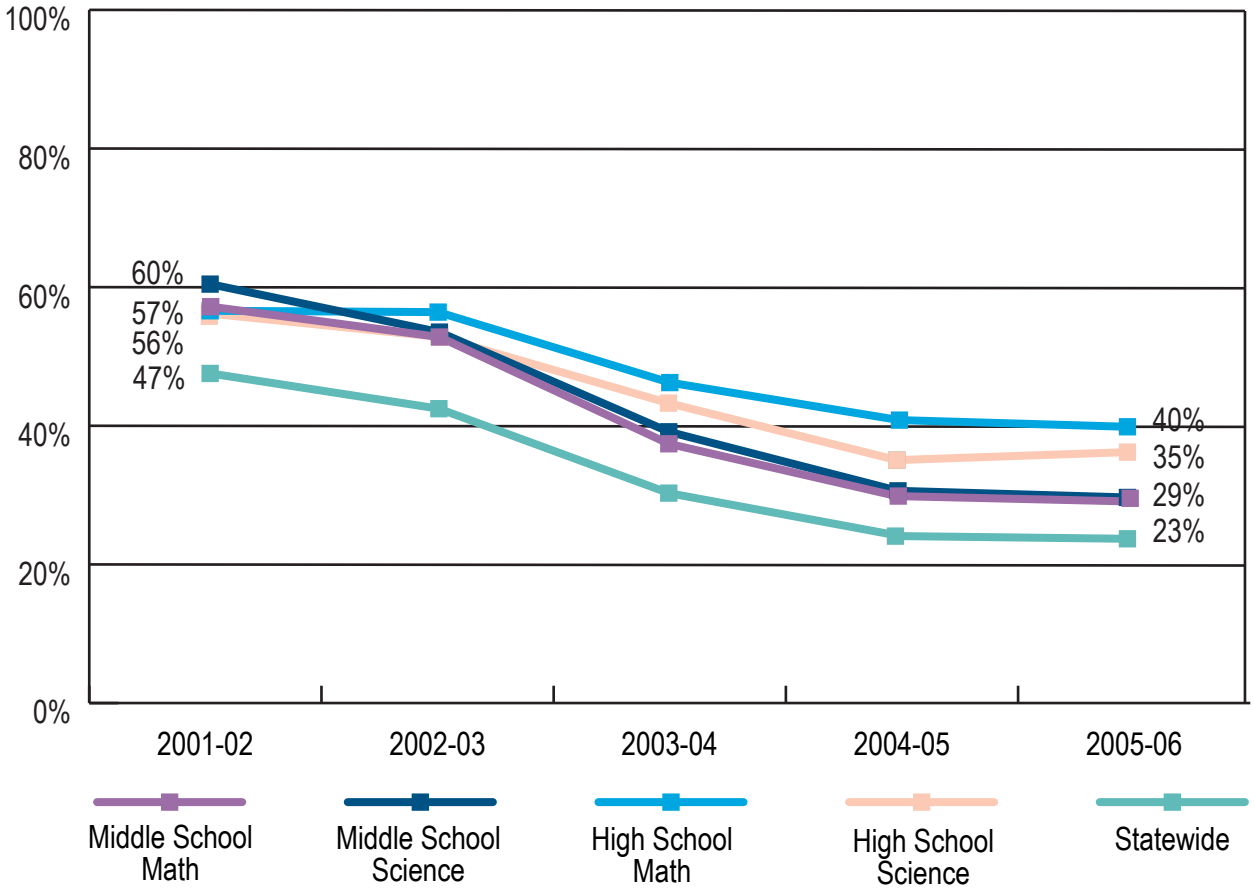

Figure 3.2: Underprepared First- and Second-year Science and Mathematics Teachers, 2001-02 to 2005-06

Source: CFTL (2006)

Despite improvements made in science and mathematics teacher qualifications in the past few years, the state is far from ensuring that every student has a fully prepared

teacher in these critical subject areas. More importantly, the underprepared teachers are distributed unevenly throughout the state, discussed next.

3.3 The Distribution of Science and Mathematics Teachers

In general, California's lowest-performing schools — those where fully prepared and effective teachers are clearly needed — persistently have the least-prepared teaching staffs. Similarly, schools that serve the highest proportion of poor and minority students, and English-language learners struggle more with attracting and retaining fully prepared teachers. Although the state and local districts have made progress to address the maldistribution, inequities persist. [26]

Like the teacher workforce as a whole, the distribution of underprepared science and mathematics teachers has improved over the last five years; yet, there remains a gap between schools with high and low percentages of minority students, and between high- and low- performing schools (Figures 3.3, 3.4, 3.5 and 3.6). In 2005-06, approximately one out of every six science and mathematics teachers in high-minority middle and high schools were underprepared, compared to only about one out of every twenty teachers in low-minority schools. [27] The same ratios hold when looking at the performance levels of schools: one out of six science and mathematics teachers in low-performing middle and high schools were underprepared, compared to only about one out of twenty in high-achieving schools.

As the data presented in Figures 3.3-3.6 illustrate, underprepared science and mathematics teachers are distributed unevenly across California schools. Though the gaps have lessened over the past several years, there still exists more than a three-fold difference between high- and low- performing schools in the percentage of underprepared science and mathematics teachers, and the percentage of underprepared teachers is four times higher in schools with predominantly minority students.

Looking just at credentials, however, masks the extent to which California's students are in classrooms with underprepared science and mathematics teachers. In some cases, teachers may hold credentials, but not specifically for science or mathematics. We discuss the phenomenon of out-of-field teachers next.

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[26] Camille E. Esch, Christopher M. Chang-Ross, Roneeta Guha, Daniel C. Humphrey, Patrick M. Shields, Juliet D. Tiffany-Morales, Marjorie E. Wechsler, and Katrina R. Woodworth, The Status of the Teaching Profession 2005 (Santa Cruz, CA: The Center for the Future of Teaching and Learning).

[27] SRI International. "Approximately one-fourth of middle and high schools are represented in each minority quartile. As the student population in the state becomes more diverse, the minority quartiles have shifted. In 2004-05, one-fourth of schools had student populations that were between 0 and 38% minority; in contrast, in 2000-01, schools in the low-minority quartile had student populations that were between 0 and 31% minority.

Minority Quartiles	2000-01	2001-02	2002-03	2003-04	2004-05
1(low)	0-31% minority	0-32% minority	0-33% minority	0-35% minority	0-38% minority
2	32-58% minority	33-60% minority	34-60% minority	36-63% minority	39-66% minority
3	59-83% minority	61-85% minority	61-85% minority	64-86% minority	67-88% minority
4(high)	84-100% minority	86-100% minority	86-100% minority	87-100% minority	89-100% minority

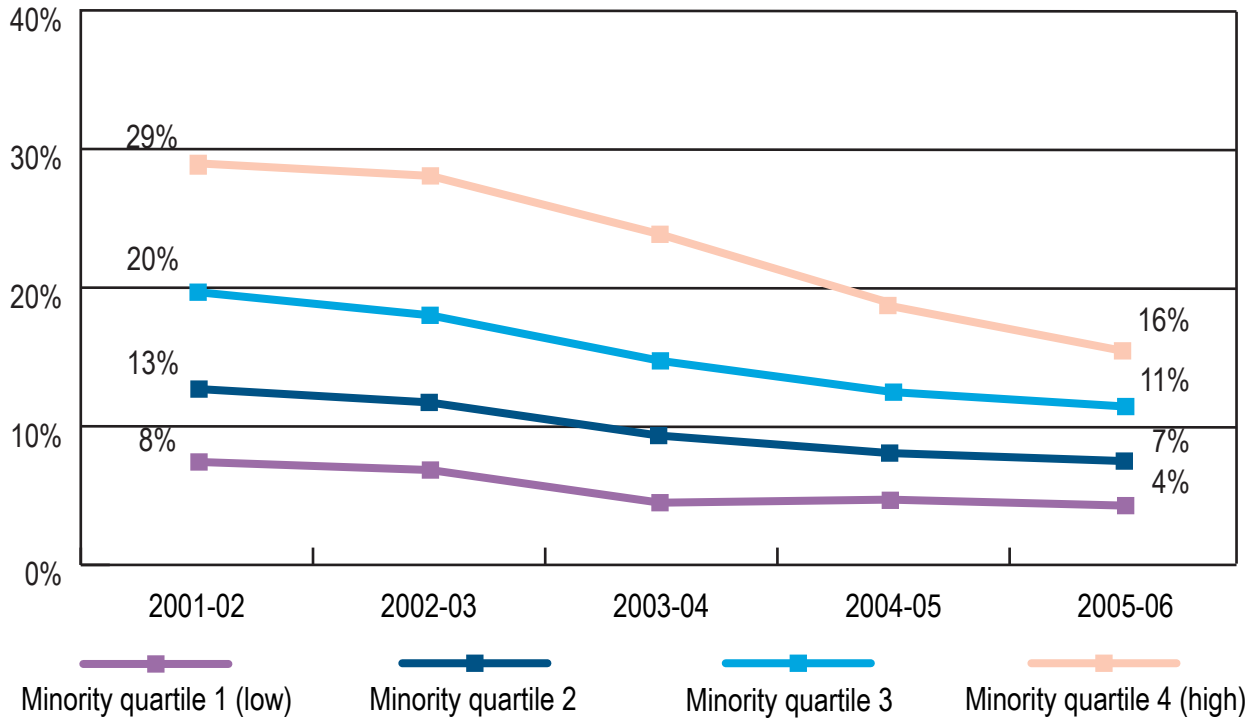

Figure 3.3: Underprepared Mathematics Teachers by Percentage of Minority Students, 2001-02 to 2005-06

Source: CFTL (2006)

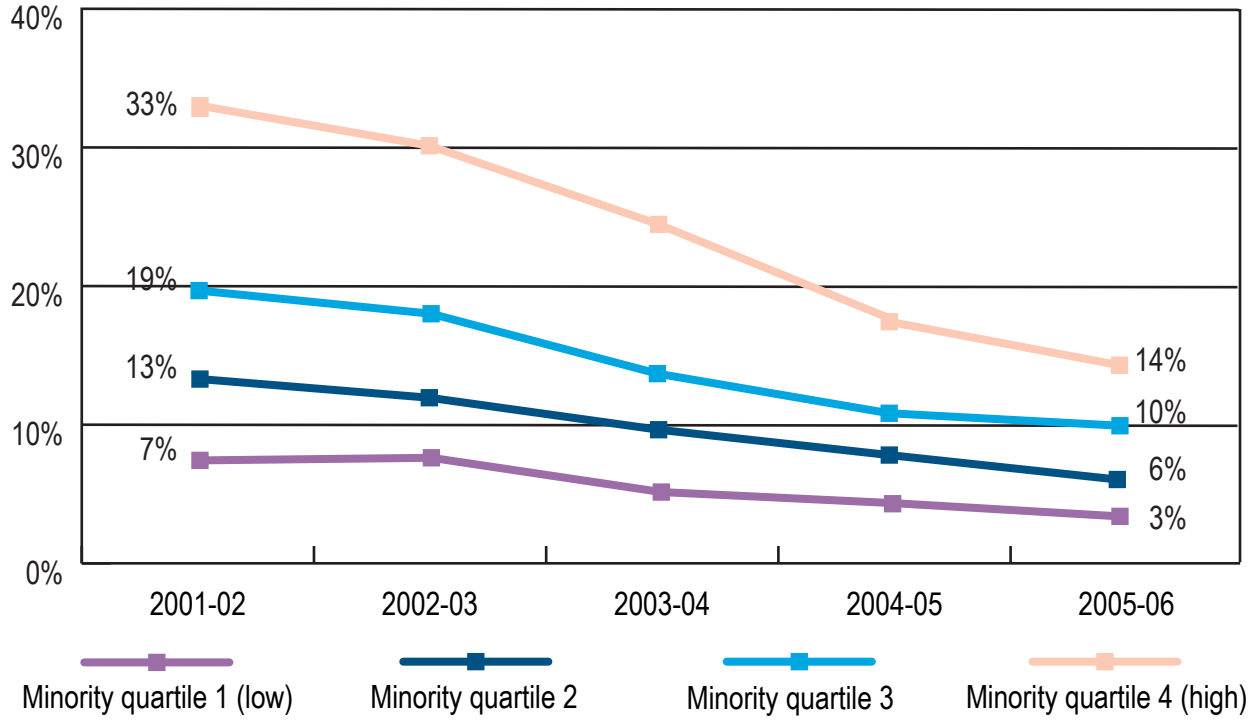

Figure 3.4: Underprepared Science Teachers by Percentage of Minority Students, 2001-02 to 2005-06

Source: CFTL (2006)

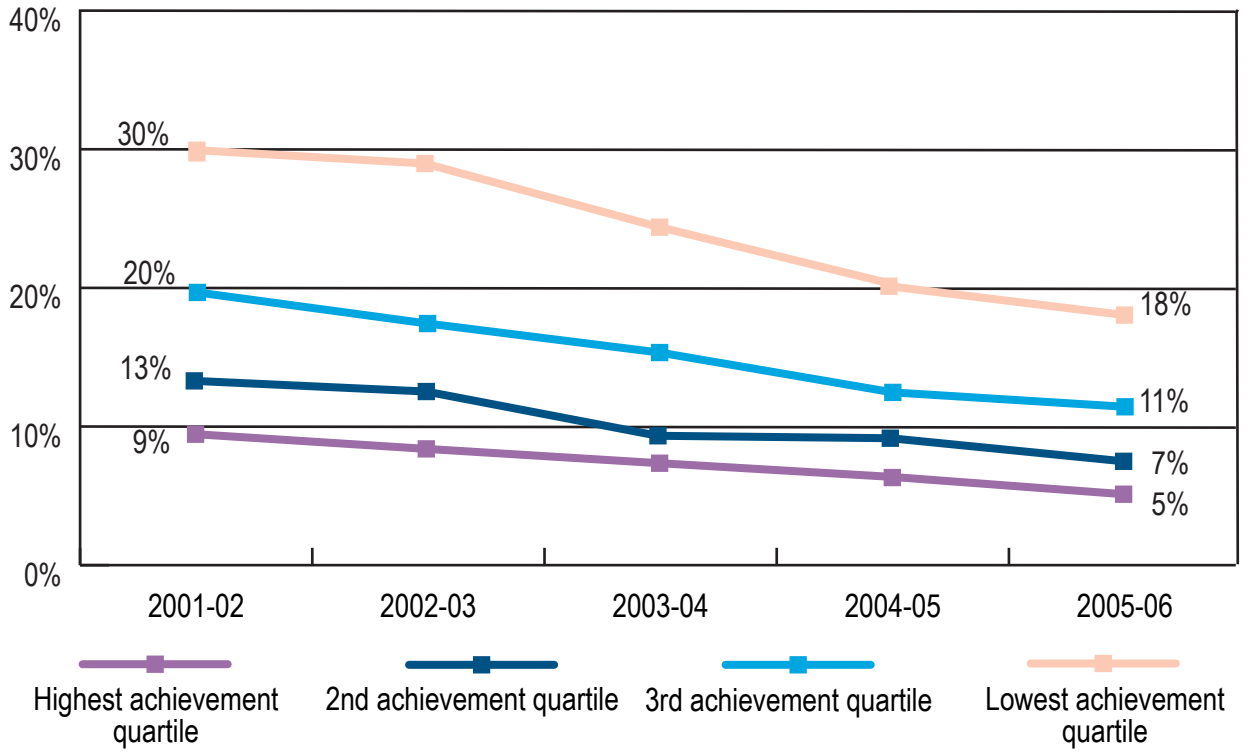

Figure 3.5: Underprepared Mathematics Teachers by Academic Performance Index (API), 2001-02 to 2005-06

Source: CFTL (2006)

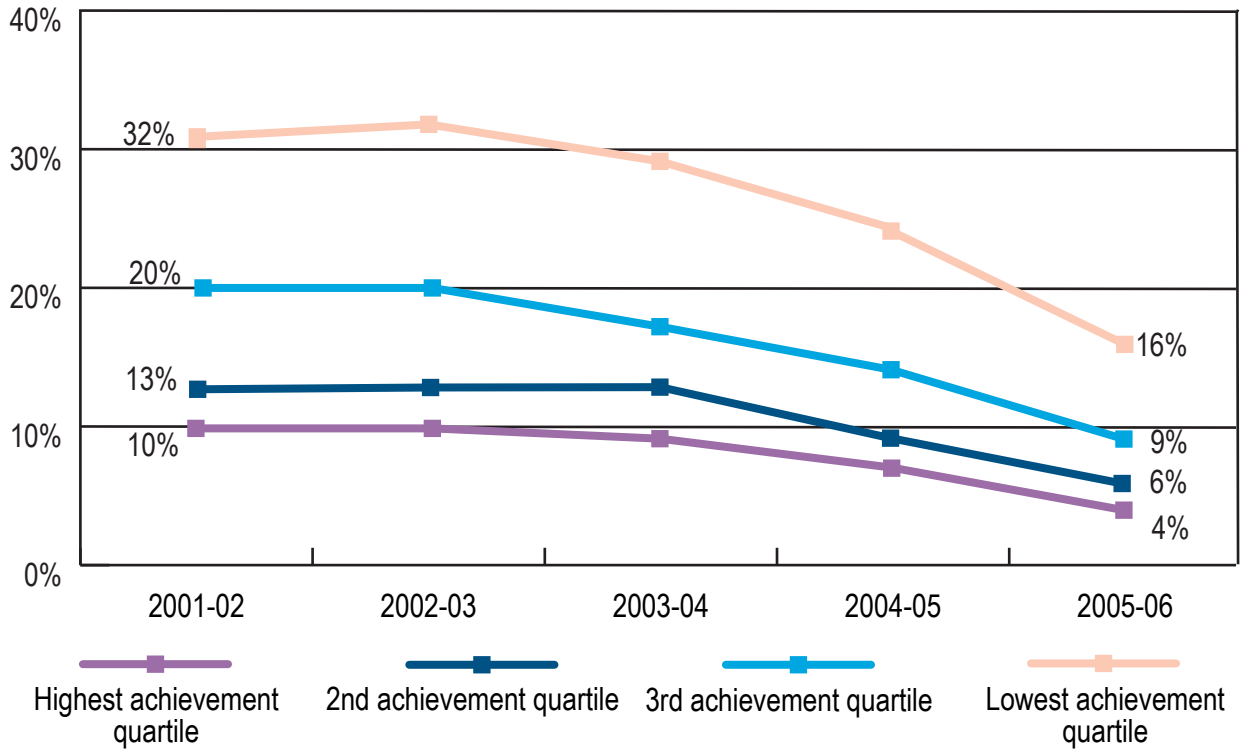

Figure 3.6: Underprepared Science Teachers by Academic Performance Index (API), 2001-02 to 2005-06

Source: SRI (2006)

3.4 Out-of-Field Science and Mathematics Teachers

Out-of-field teachers are those who hold a full credential in some subject area, but do not have the proper credential for one or more classes they are teaching. Out-of-field assignments typically arise in middle schools and high schools as a result of scheduling problems and limited budgets, not necessarily teacher shortages.[28] High school and middle school administrators report that they are commonly faced with a staffing dilemma when devising their master schedules. Frequently there is a need to staff an additional one or two classes in a particular subject, yet it does not make fiscal sense to hire another full-time teacher to cover the classes, and finding a part-time, appropriately credentialed teacher is difficult. Delays in finalizing the budget and processing transfers may also aggravate the problem. If districts are delayed in identifying their precise hiring needs, they may scramble when the school year begins to find a teacher with the appropriate credentials.

Trends in out-of-field teaching in high school science and mathematics do not mirror those of underprepared teachers. First, out-of-field teachers are found in most California high schools, not just those with chronic staffing problems. Second, the percentage of out-of-field teachers has remained relatively steady over the last five years (Figure 3.7). In 2004-05, approximately 9% of science teachers and 11% of high school mathematics teachers were out-of-field.[29] Some specific science fields, however, are more impacted than others. For example, 12% of life science teachers and 20% of physical science teachers were out-of-field.

Determining the extent to which middle school teachers are underprepared in science and mathematics is more challenging because of the different types of credentials allowed at this level. Middle school teachers can teach with either a multiple-subject or a single-subject credential. Under No Child Left Behind (NCLB), districts must determine which credential appropriately authorizes a teacher to teach middle school grades and classes. Thus, for example, some districts may determine that a single-subject credential is needed to teach algebra or 7th-grade science; others may determine that a multiple-subject credential is appropriate.

Mathematics professionals argue that given the demands of middle school mathematics, middle school mathematics teachers need to be specialists in their field. The Conference Board of the Mathematical Sciences (CBMS) stated, "The more sophisticated content of middle grades mathematics necessitates that mathematics specialists teach in these grades and that these specialists have a well-developed understanding of the mathematics they teach."[30] However, fewer

[28] Esch et al.

[29] Science teachers were determined to be out-of-field if they taught at least one science class and indicated on the PAIF that they did not have either a "life science" credential or a "physical science" credential.

[30] Conference Board of the Mathematical Sciences [CBMS], The Mathematical Education of Teachers (Providence RI and Washington DC: American Mathematical Society and Mathematical Association of America, 2001), 25.

than half of middle school mathematics teachers hold such a single-subject mathematics credential. As recent data from SRI indicate, 44% of middle school mathematics teachers have a single-subject mathematics credential (18% of these also have a multiple-subject credential) (Figure 3.8). At the other extreme are teachers with little or no preparation to teach mathematics. In California's middle schools, 10% of the mathematics teachers have no credential, and another 9% have a credential in another field.

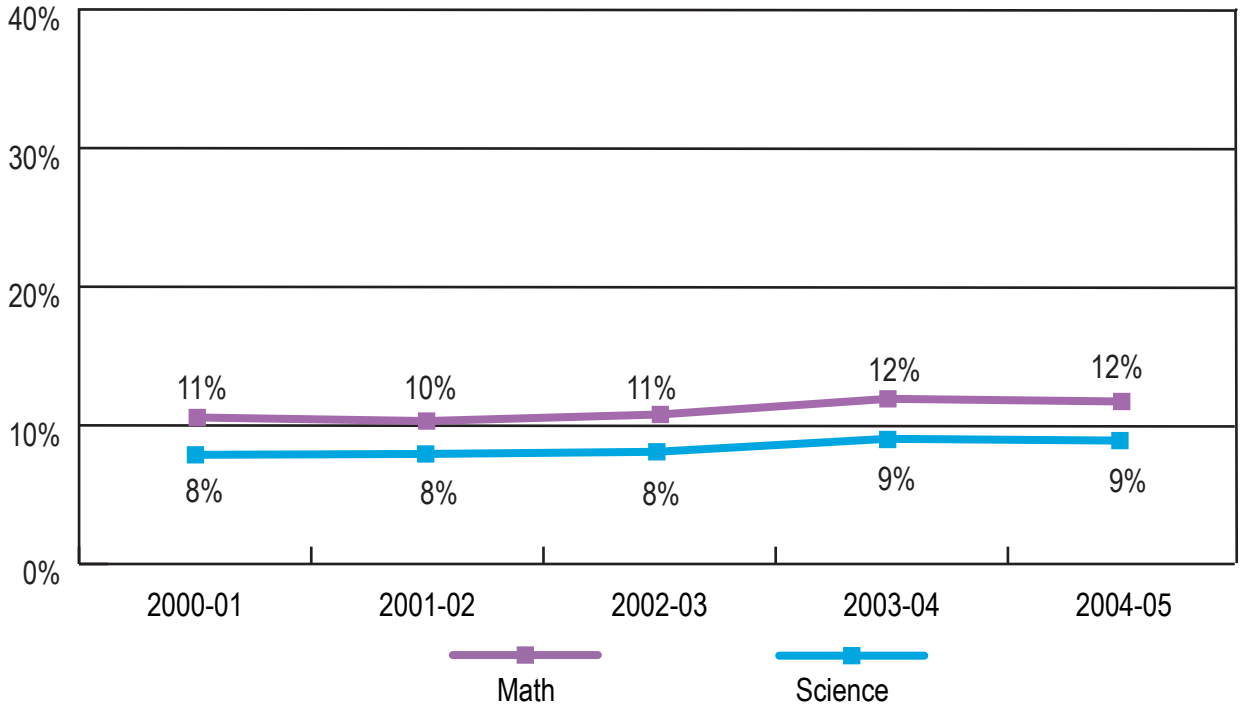

Figure 3.7: Out-of-Field High School Science and Mathematics Teachers, 2000-01 to 2004-05

Source: SRI (2006)

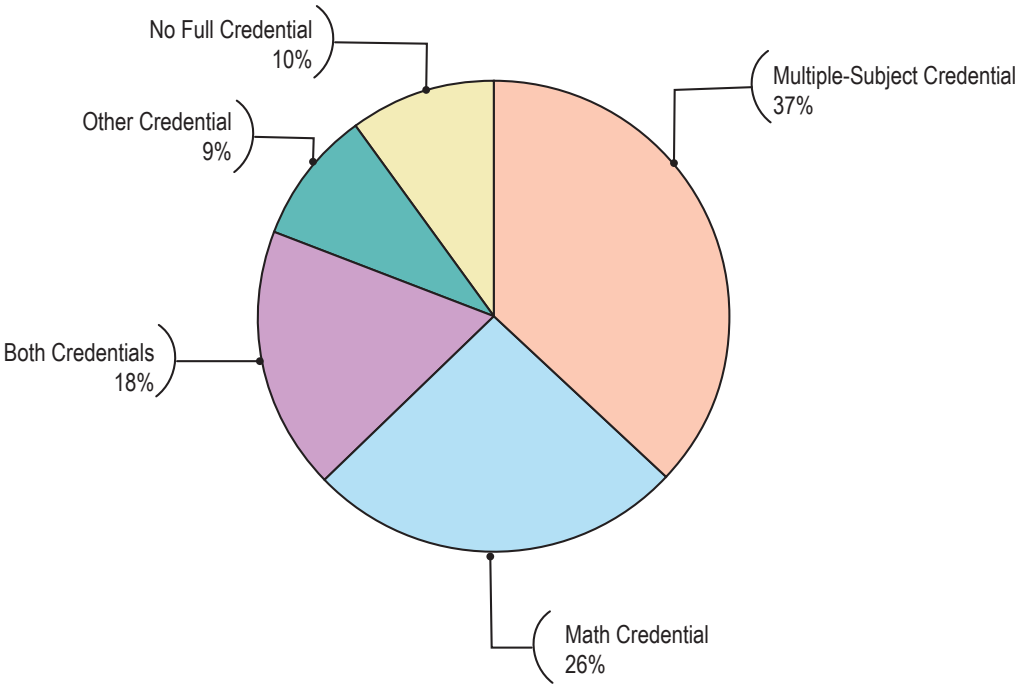

Figure 3.8: Middle School Mathematics Teacher Credentials, 2004-05

Source: SRI (2006)

ALTHOUGH THEY MAY BE AUTHORIZED TO TEACH MATHEMATICS AT THE MIDDLE SCHOOL LEVEL, THE EXTENT TO WHICH THESE TEACHERS ARE PREPARED TO TEACH MIDDLE SCHOOL MATHEMATICS VARIES.

But what about the remaining 37% of mathematics teachers (nearly 3,900) who hold a multiple-subject credential? These teachers represent a broad spectrum with regard to their mathematical content knowledge and knowledge of how to teach mathematics. Some may have mathematics degrees or have years of experience teaching high-level mathematics. Others may have limited mathematical content knowledge. Although they may be authorized to teach mathematics at the middle school level, the extent to which these teachers are *prepared* to teach middle school mathematics varies.

Consider, for example, the case of Algebra I. Historically taught at the high school level, Algebra I content has been moved into the 8th-grade curriculum in recent years. However, little has been done to prepare or support middle school mathematics teachers for the change. It may be unreasonable to expect teachers with multiple-subject credentials to successfully teach more specialized content.

Like mathematics, middle school science teachers hold various credentials (Figure 3.9). Not quite half hold a single-subject science credential (34% have just a single-subject credential; 12% hold both a single- and a multiple-subject

credential). Eighteen percent are not credentialed to teach science — of those, 10% are not credentialed, and 8% are credentialed in a different field. And, over one-third of middle school science teachers have a multiple-subject credential. Again, the teachers in this group may or may not have the appropriate knowledge to teach their science classes.

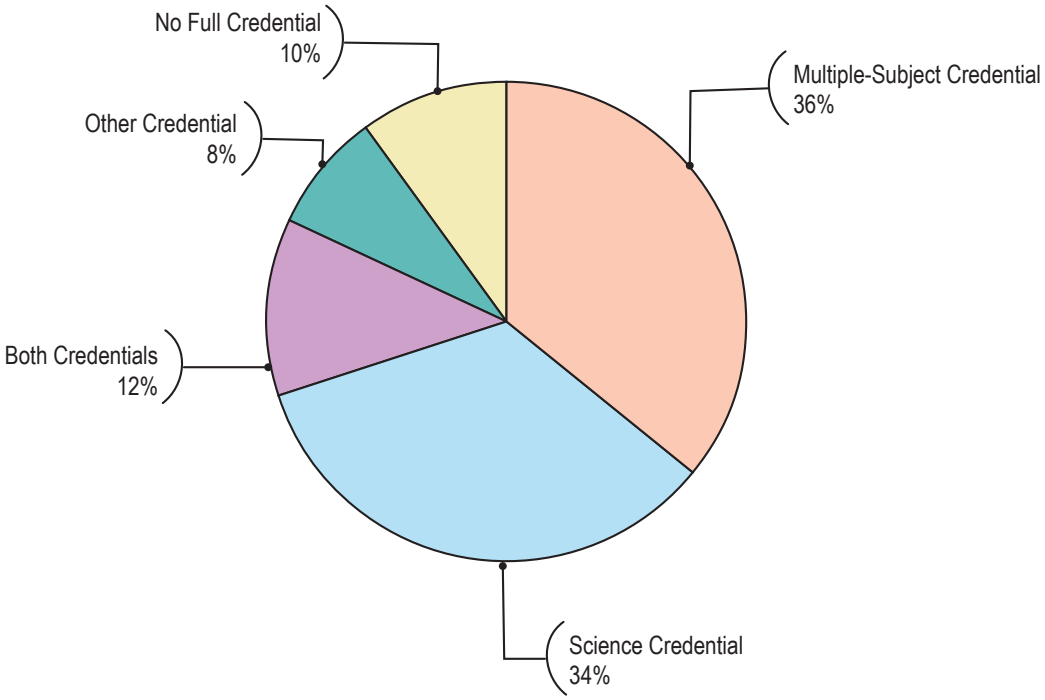

Figure 3.9: Middle School Science Teacher Credentials, 2004-05

Source: SRI (2006)

In order to address the challenge of underprepared and out-of-field teaching in science and mathematics, California has stepped up efforts to increase the production of new science and mathematics credentials. In particular, it has instituted a new mathematics credential, the Foundational Mathematics Credential, targeting middle school teachers. In 2004-05 the state granted 384 Foundational Mathematics credentials, out of a total 1,417 mathematics credentials.

3.5 The Demand for Science and Mathematics Teachers

Predicting the demand for science and mathematics teachers is critically important — and challenging. Although precise estimates are not possible, reasonable estimates can be made based on what is known about demographic reports of the student population, changes in state curricular policies that resulted in the need for more teachers in certain fields, and predictions of teacher attrition and retirement. To determine whether or not there is a shortage, the demand must then be compared with the supply of new teachers being produced through various teacher-preparation routes.

Student Population

In the last decade, an increasing student population has resulted in a demand for new teachers. Although enrollment has leveled off in the past few years, increases in California's student enrollment have been steeper than the national average in the last two decades, rising over 40% from 1987 to 2005 (compared to less than a 20% rise nationwide.) This increase in students required a rapid increase in the teacher workforce, resulting in some of the issues of underpreparation and maldistribution discussed earlier.

Changes in State Policy

Another factor that created a greater need for science and mathematics teachers was curricular policy changes. In December 1997, the State Board of Education adopted academic content standards in mathematics that established the completion of Algebra I as the standard for all 8th grade students, [31] a policy shift which should have been coupled with a major investment in professional development for 8th grade mathematics teachers. In addition, the California High School Exit Exam (CAHSEE) was established by the Legislature in 2000. Passage of this exam, which covers English and mathematics content, is a requirement for a diploma beginning with the class of 2006. [32]

In the period from 1996-2004, the number of teachers in grades 7 and 8 with main assignments in mathematics increased by nearly 31% (from 3,900 to 5,700). In the same period, the number of teachers in grades 9-12 assigned to teach mathematics as their primary assignment increased by 34% (from 7,300 to 11,100). During the same time frame, an increase in demand for science courses resulted in an increase in the number of science teachers in grades 7 and 8 of 36% (from 3,800 to 5,900), and in grades 9-12 of 20%. [33]

As shown in Figure 3.1, the percentage of underprepared science and mathematics teachers has receded, but new challenges have resulted from federal legislation in 2001. The No Child Left Behind Act required states to ensure that all teachers in core subjects, such as science and mathematics, are "highly qualified." [34, 35] California is working to comply with this federal mandate, and phased out the

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[31] SRI International. By June 2005, the state expected implementation of the Algebra I standard and required scoring of the annual California Standards Test (CST) in Mathematics. Those scores would be used in the computation of the Academic Performance Index (API).

[32] Ibid. Students may start taking the test as 10th graders. The CAHSEE has two parts: English-language arts and mathematics. The mathematics portion of the CAHSEE addresses state standards in grades 6, 7 and 8, and Algebra I is the state standard for grade 8.

[33] Council of Chief State School Officers, State Indicators of Science and Mathematics Education 2005 (Council of Chief State School Officers: Washington, D.C., 2005) Tables 2.1 and 2.3.

[34] SRI International. "Each state educational agency receiving assistance under this part shall develop a plan to ensure that all teachers teaching in core academic subjects within the state are highly qualified not later than the end of the 2005-2006 school year." U.S. Department of Education, No Child Left Behind Act of 2001 (PL107-110), §1119.2. The U.S. Department of Education extended by one year, until June 2007, a deadline for ensuring that all students have "highly qualified" teachers.

[35] According to No Child Left Behind, all public elementary and secondary students must have a "highly qualified teacher." California policymakers defined "highly qualified" teachers as those who 1) have a bachelor's degree; 2) have demonstrated competence in each subject area they teach; and 3) have at least a preliminary credential or are working toward one in an

granting of emergency permits in July 2006. Although the number of emergency permits has declined dramatically since the 1990s,[36] in 2005-06 there were still approximately 8,000 teachers in California holding emergency permits and other non-NCLB-compliant authorizations.[37, 38] The goal is for all teachers to be certified in the field to which they are assigned to teach. Unfortunately, California is still falling short of that goal.

Attrition

Available statewide data sources do not permit precise analyses of rates of teacher attrition. However, a study by the California Commission on Teacher Credentialing (CTC) in 2002 found that 94% of 1995-1996 newly credentialed teachers were still employed one year later and that 84% were still working in education four years later. A 2002 CFTL report estimated the annual attrition rate to be 4.5%. While no specific data are available for science and mathematics teachers, some compelling anecdotal evidence indicates that they leave the profession in greater numbers to accept higher-paying private-sector employment. For purposes of this analysis, we use a conservative attrition rate of 5% for science and mathematics teachers.[39] Thus we estimate that over 2,000 middle and high school science and mathematics teachers per year leave the profession in California.[40]

Retirement

We know, as seen in Figure 3.10, that a third of California's teachers are older than 50, and half of those are older than age 55.[41] We also know that about a third of California's science and mathematics teachers are older than 50 and can be expected to retire in the next ten years.[42] This means that in addition to the normal demand caused by growth in the student population and career

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approved alternative certification program. New teachers have to meet all three tests in order to be considered NCLB-compliant. See The Center for the Future of Teaching and Learning, CenterView (August 2006).

[36] California Commission on Teacher Credentialing, Teacher Supply in California 2004-2005: A Report to the Legislature (California Commission on Teacher Credentialing: Sacramento, 2006), 12. Emergency permits declined from 32,573 in 2000-01 to 7,766 in 2004-05.

[37] California Commission on Teacher Credentialing.

[38] See Esch et al. for a thorough analysis of California's underprepared teachers.

[39] California Postsecondary Education Commission. Winter 2006 Request for Proposals. Retention of Science and Mathematics Teachers. Commission Report 06-05, p. 1.

[40] As noted earlier, the precise number of science and mathematics teachers is difficult to ascertain because the state's data collection system identifies as science and mathematics teachers those assigned to teach at least one course in those fields. Because teachers may teach both science and mathematics, or science or mathematics and other subjects, the number of science and mathematics teachers cannot be added to determine a total number. To estimate attrition, we used an attrition rate of 5% in each group (mathematics teachers in middle and high school, and science teachers in middle and high schools). We acknowledge the risk of double counting some teachers not assigned to teach science and mathematics courses; we also acknowledge CPEC's estimate of 5% in its recent Request for Proposals (see Footnote 39.).

[41] Guha et al., 30.

[42] Council of Chief State School Officers, State-Level Data on State Science-Mathematics Indicators from the 2004-2005 School Year (Council of Chief State School Officers: Washington, D.C. 2005), Table 3.11. Age of Science and Mathematics Teachers, Grades 9-12, 2004.

California likely will need an additional 6,600 new science and mathematics teachers in the next five years, and over 13,200 in the next ten years due to retirement.

changes (attrition), California likely will need an additional 6,600 new science and mathematics teachers in the next five years, and over 13,200 in the next ten years due to retirement.

Taking into account attrition and retirement, a conservative estimate of the demand for new science and mathematics teachers in California in the next ten years would be approximately 33,200 (20,000 due to attrition; 13,200 due to retirement).

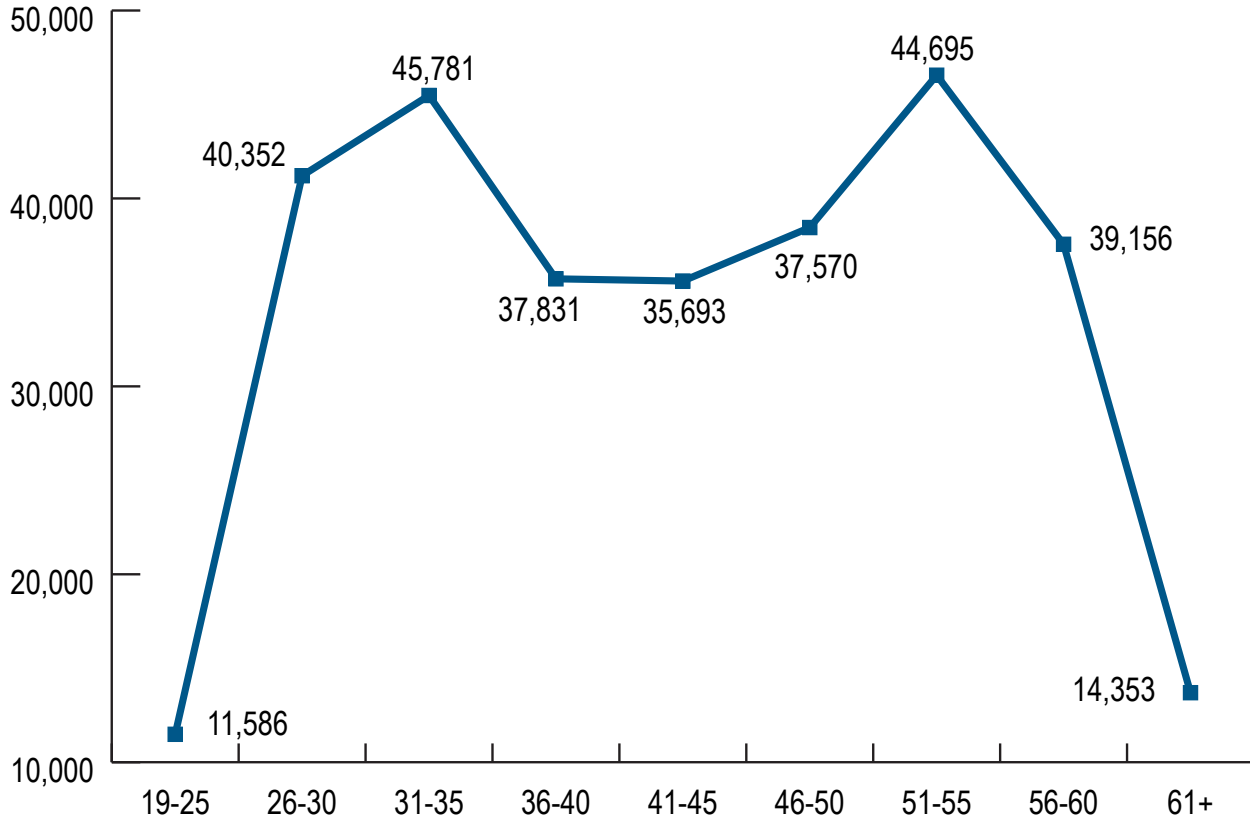

Figure 3.10: Age Distribution of K-12 Public School Teachers, 2005-06

Source: CFTL (2006)

Numbers of Science and Mathematics Credentials

Figure 3.11 shows the new science and mathematics teaching credentials issued in 2004-05, by field and by route of preparation.[43] The CTC issued 1,417 mathematics credentials (including 384 in Foundational Mathematics) and 1,553 science credentials (nearly 65% in biological sciences) for a total of 2,970 science and mathematics credentials.

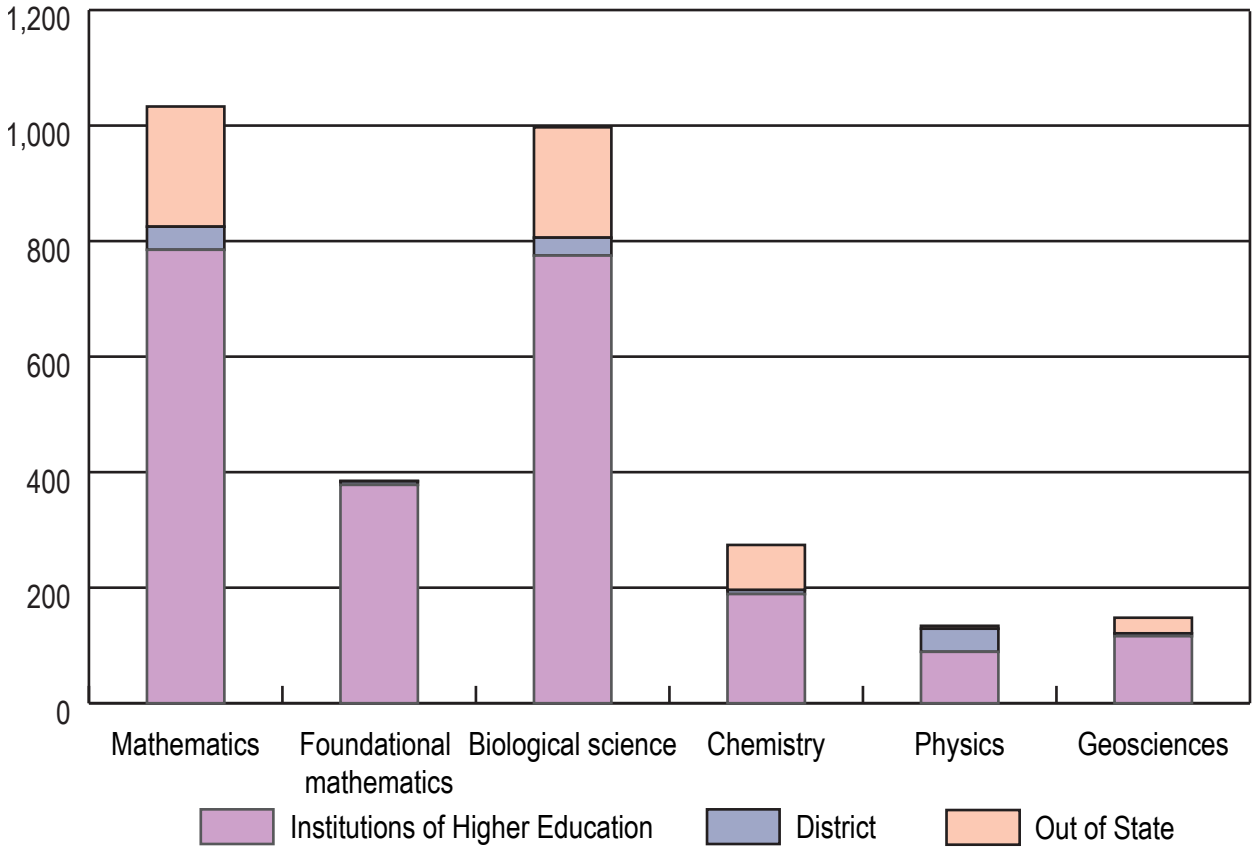

Figure 3.11: New Science and Mathematics Teaching Credentials Issued, 2004-05

Source: CTC (2006)

The current level of production is not sufficient to meet the demand for fully prepared science and mathematics teachers. Table 3.2 shows the number of credentials issued in 2003-04 compared to the number of new hires in 2004-05. Based on these numbers, it appears that California is preparing about 70% of the teachers needed to meet the demand. However, not all newly credentialed teachers choose to take a job immediately after earning their credential, which

[43] SRI International. The CTC also established specialized credentials in each science discipline (biological sciences, chemistry, geosciences, and physics) that authorize instruction in the specific science area, but not in general, introductory, or integrated science. Specialized science credentials have been added to the credential numbers in each discipline. Thus, for example, biological sciences include credentials issued in biological sciences and biological sciences (specialized). See CTC's Coded Correspondence #3-0010 issued April 14, 2003 for more information about these new credential types. The data include individuals who also may have received single-subject authorizations in non-science and mathematics fields, such as English, foreign language, social studies, or business.

means the state is actually providing even fewer teachers for classrooms than the numbers indicate.

Table 3.2: New Credentials Issued in 2003-04 Compared to New Hires in 2004-05

Mathematics		Science	
New credentials in 2003-04	1,222	New credentials in 2003-04	1,313
New middle school hires in 2004-05	992	New middle school hires in 2004-05	717
New high school hires in 2004-05	1,146	New high school hires in 2004-05	835

Source: SRI (2006)

Understanding the supply and demand of science teachers is even more complicated because teachers get credentialed in specific content areas (e.g., biological sciences, chemistry, geosciences, or physics). Like mathematics, however, the production of new teachers is insufficient to fill the demand for science teachers, as indicated by the ongoing numbers of underprepared teachers in the state's high school and middle school science classes.

The bottom line, however, is that there are a considerable number of teachers in both science and mathematics, at both the middle and high school levels, who are either underprepared or teaching out-of-field. Until all California students have fully credentialed and prepared science and mathematics teachers, there will be a need for the state to increase the number of teachers with appropriate preparation and credentials.

3.6 Implications

The evidence presented in this chapter indicates that California faces an enormous challenge to ensure that all science and mathematics teachers are fully prepared to move into the teaching workforce. An estimated 6,600 science and mathematics teachers at the middle and high school level may retire within the next five years. In addition, an estimated 10,000 more may leave the classroom due to attrition. This means that in the next five years, we estimate that over 16,600 new science and mathematics teachers will be needed in California. Within ten years, that estimate jumps to over 33,200. This number is higher than California's current capacity to prepare science and mathematics teachers.

A Third of California's teachers are older than 50, and half of those are older than age 55.

Figure 3.12 compares the demand for teachers with the supply, and shows the projected gap between these two numbers. Although this chart represents

projections for all teachers, we do not predict the picture for science and mathematics teachers to be much different. Moreover, and of particular concern, is that the gap will almost inevitably be filled by underprepared teachers — those who have not met California's minimum qualifications for a teaching credential.

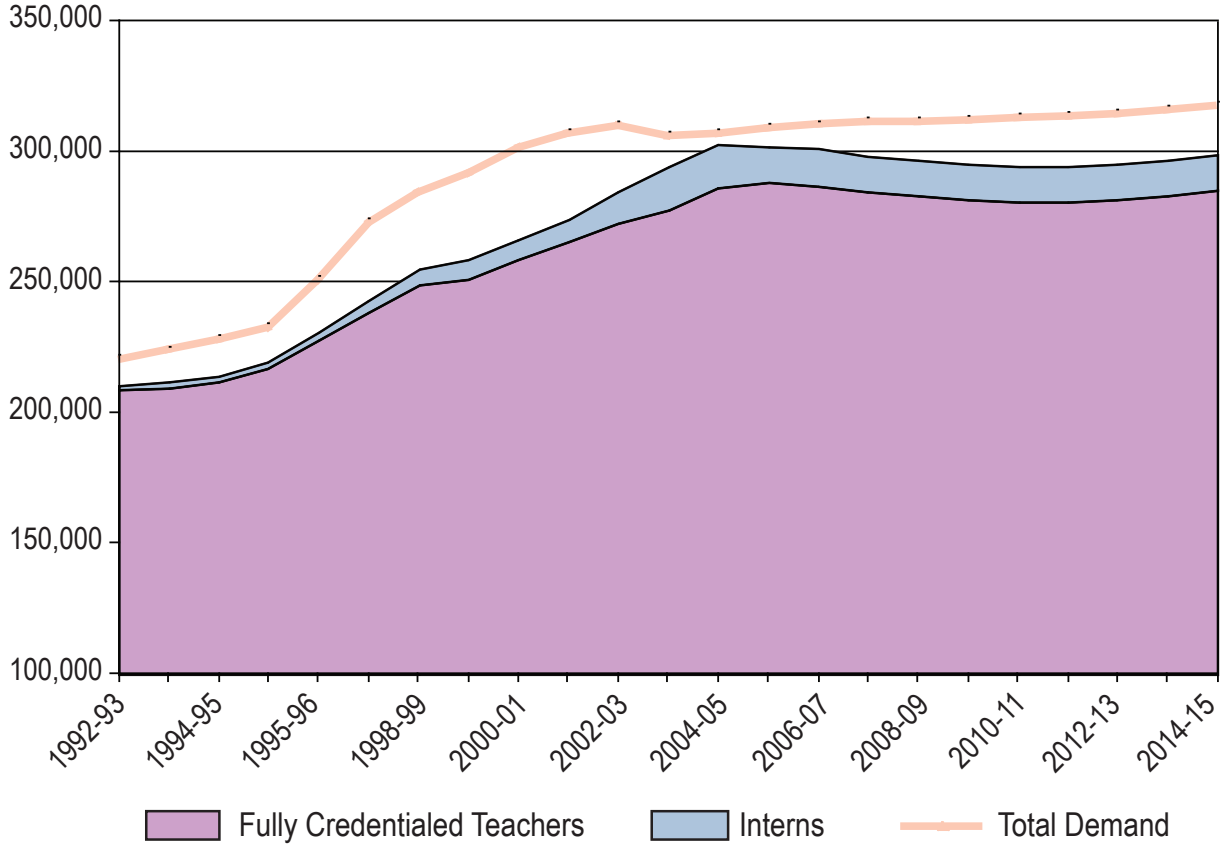

Figure 3.12: K-12 Public School Teacher Workforce through 2013-14

Source: CFTL (2005)

California, cognizant of this need, has taken steps to increase its supply of teachers in these fields. The 2004 Higher Education Compact called for the California State University (CSU) and University of California (UC) systems to collaborate with the state, K-12 constituencies, and California business and industry leaders on a new initiative to increase the supply, and improve the quality, of science and mathematics teachers. In 2005, the Governor joined with university systems and business leaders to announce an initiative to bolster the state's science and mathematics teacher workforce. These efforts are described in Chapter 4. Both CSU and UC committed to more than doubling their annual production of credentialed science and mathematics teachers — from 1,000 (750 by CSU; 250 by UC) to 2,500 (1,500 by CSU; 1,000 by UC) per year by 2010. It will take time, however, to scale those programs to meet the demand and gauge

their impact. Even if these programs meet their goals, California will still face a shortage of science and mathematics teachers.

3.7 Conclusions

In recent years, California has made great strides to provide its students with fully prepared science and mathematics teachers; yet, the state still has work to do. Despite improvements in the percent of credentialed science and mathematics teachers over the past five years, they still have higher underprepared rates than the teacher workforce as a whole. Science and mathematics fields have higher percentages of underprepared and novice teachers than the overall teacher workforce, and a steady count of out-of-field teachers. Further, underprepared teachers are inequitably distributed so that they are much more prevalent in high-minority and low-performing schools. And, the state has not produced enough credentialed science and mathematics teachers to meet demand.

In recent years, California has made great strides to provide its students with fully prepared science and mathematics teachers; yet, the state still has work to do.

The forecast for the future is worrisome. The loss of science and mathematics teachers due to retirement and attrition — estimated to be more than 16,600 over the next five years — far outstrips California's current capacity to prepare new credentialed teachers. In 2003-04, the state issued fewer than 2,600 science and mathematics credentials, even though the demand for teachers in those fields at the middle and high school level was nearly 3,700. If the state continues at this rate of credentialing, it will meet nearly 70% of the need for credentialed teachers in the next five years.

Clearly, the supply of new science and mathematics teachers at the middle and high school level is not going to meet demand in the next five to ten years. If current trends continue without policymakers taking corrective measures, California will continue with a persistent condition of underprepared science and mathematics teachers, especially in low-performing, high-minority schools, and out-of-field teachers widely distributed around the state.

Data

For this analysis, data were gathered from publicly available databases, reports from state agencies and institutions of higher education, and from independent analyses conducted by private not-for-profit organizations. The ability to gather current and complete data on science and mathematics teachers in California is limited by a number of factors: the distribution of data across many state agencies; the inability to disaggregate data about science and mathematics teachers from the overall teacher population, and the inherent inconsistencies between

teacher production on the one hand (as discussed in Chapter 4) and teacher credentialing, hiring and assignments on the other. The improvements in data collection envisioned by SB 1614 (Chapter 840, Statutes of 2006) are needed to enable better analysis, and thus the ability to better inform policymakers about trends in supply and demand. For the important issue of ensuring an adequate supply of fully prepared science and mathematics teachers, the capacity to gather and analyze appropriate data is critical.

CHAPTER 4 - THE TEACHER PRODUCTION PROCESS: OVERVIEW

Key Points:

- Traditional, or 5th-year programs, in institutions of higher education produce the largest number of science and mathematics teachers in the state.
- Alternative routes have become the second largest producer of science and mathematics teachers and produce a greater percentage of science and mathematics teachers than the overall teaching population.
- University internships are the most popular kind of alternative route for new science and mathematics teachers.
- Integrated programs play a growing role in the production of teachers with multiple-subject credentials, but only 1% of credentials currently awarded from integrated programs are for single-subject credentials of any kind.

To receive a credential to teach in California's public schools, a teacher must be certified by the California Commission on Teacher Credentialing (CTC). A teacher candidate must complete a baccalaureate degree, a CTC-approved teacher-preparation program, demonstrate subject matter competency, and pass the California Basic Educational Skills Test. A multiple-subject credential allows a teacher to teach grades K-8. A single-subject credential certifies a teacher to teach specific courses in middle or high school. Generally a middle school teacher (grades 6-8) can hold either a multiple-subject or single-subject credential.

To become certified in California, teacher candidates can follow any one of four routes — traditional, integrated (or blended), alternative, and out-of-state transfers. Whichever route is selected, the candidate's goal is to earn a preliminary credential and ultimately, after several years of experience that includes beginning teacher support (induction), earn a professional clear credential in a field certified by the CTC.

Figure 4.1 shows the number of preliminary credentials produced by various teacher-preparation programs in public and private institutions of higher education from 1999-2004. These programs issued approximately 27,000 new preliminary teaching credentials in 2003-04, of which approximately 2,500 were single-subject science or mathematics credentials.

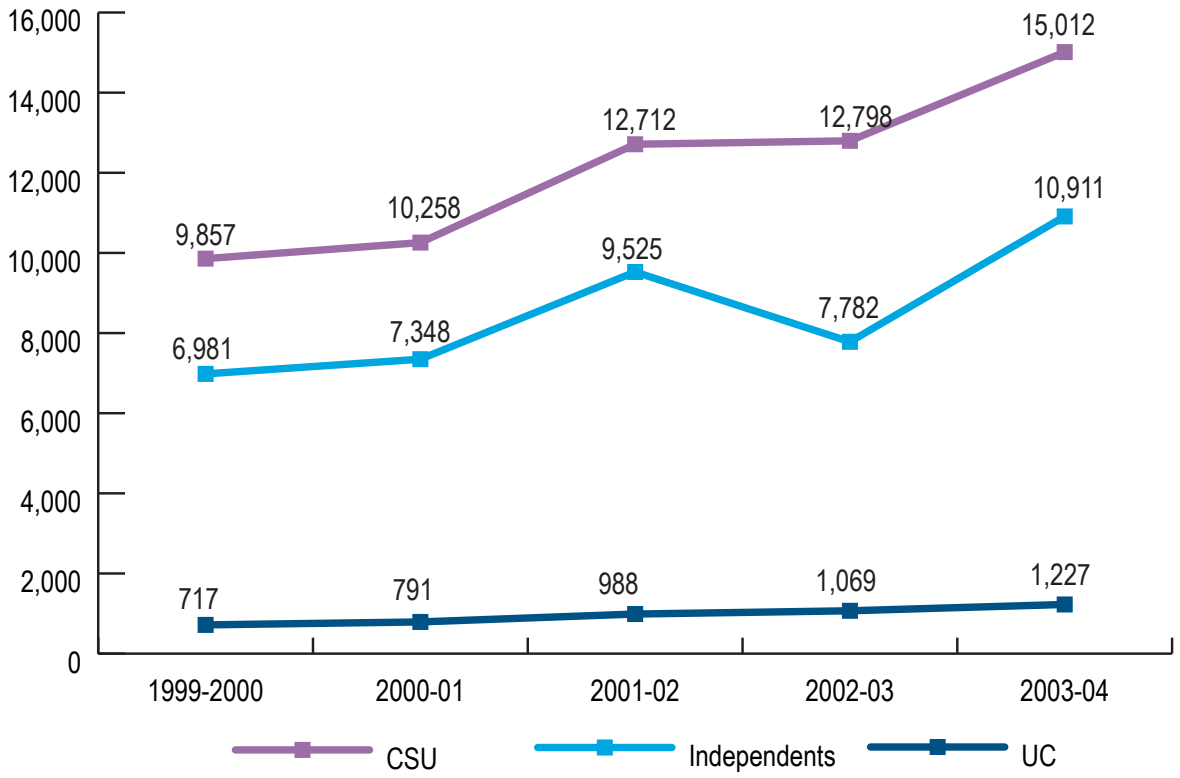

Figure 4.1: New Teaching Credentials issued, by Institution, 1999-00 to 2003-04

Sources: CFTL (2005)

4.1 The "Traditional" Route

The traditional progression [44] towards becoming certified as a teacher in California, outlined in Figure 4.2, entails completing a baccalaureate degree, and an additional "5th year" teacher-preparation program leading to a preliminary credential. Through this route, prospective teachers can complete one of the following educational pathways prior to their 5th year:

- High school to a campus of CSU, UC, or private university to earn a baccalaureate degree.
- High school to a community college then to a public or private four-year institution to earn a baccalaureate degree. [45]

[44] California Commission on Teacher Credentialing, http://www.ctc.ca.gov/credentials/leaflets/cl560c.pdf (accessed 3/28/06).

[45] California Council on Science and Technology, 63. One study indicates that almost 50% of university graduates with STEM degrees began their undergraduate education in community colleges.

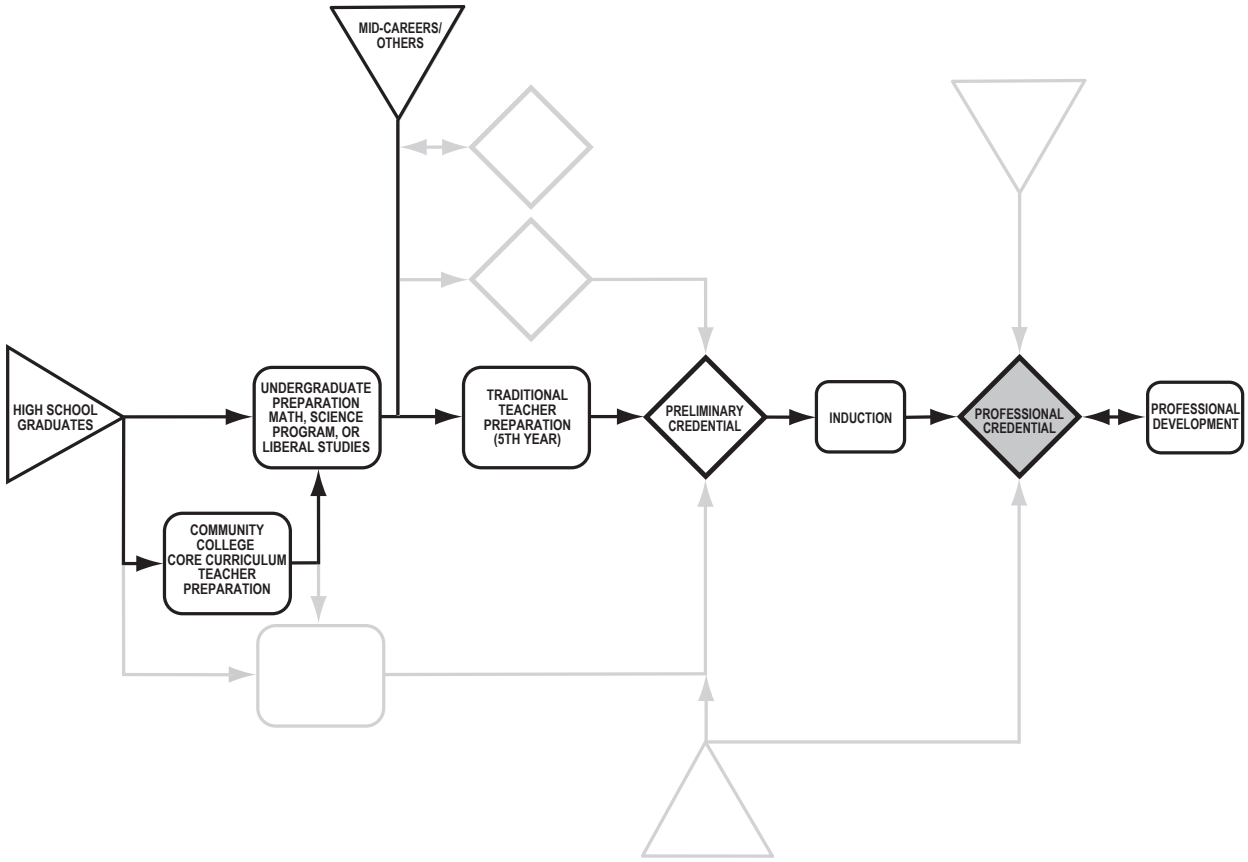

Figure 4.2: Schematic Diagram of Traditional Teacher Production Route

Prospective teachers then attend a post-baccalaureate CTC-accredited teacher-preparation program, often called the "5th year" program. Accredited 5th-year teacher-preparation programs offer both multiple- and single-subject credentials, and include a clinical, or "in-school," student-teaching experience, during which the prospective teacher does not have primary responsibility for any classes in the school.[46, 47] Prospective teachers must also verify their knowledge in developing English language skills, the U.S. Constitution, their respective subject matter, and pass the California Basic Educational Skills Test (CBEST).[48]

After completing the 5th-year program, the teacher receives a preliminary credential and can begin working in the classroom. This credential lasts for up to five years, during which time the teacher must successfully complete an approved induction program for beginning teachers (discussed in Chapter 6). Upon completion of an approved induction program, teachers receive a professional clear credential from the CTC.

[46] California Commission on Teacher Credentialing Approved Professional Preparation Programs.

[47] Jennifer Kuhn, Modernizing the Functions of the Commission on Teacher Credentialing (Legislative Analyst's Office: Sacramento, 2006).

[48] California Basic Educational Skills (CBEST) Homepage, http://www.cbest.nesinc.com (accessed 1/10/07).

4.2 Integrated (Blended) Programs

The Integrated (Blended) Program combines the baccalaureate and teacher-preparation into a unified program that enables a student to graduate in four years with the requirements necessary to achieve a preliminary credential. This program began in 1998 in response to the increased need for teachers due to the Class Size Reduction (CSR) Act.[49] The idea was to move prospective teachers into the classroom faster, saving the time and expense of pursuing a 5th-year teacher-preparation program. Figure 4.3 shows the progression from an integrated program to a preliminary credential.

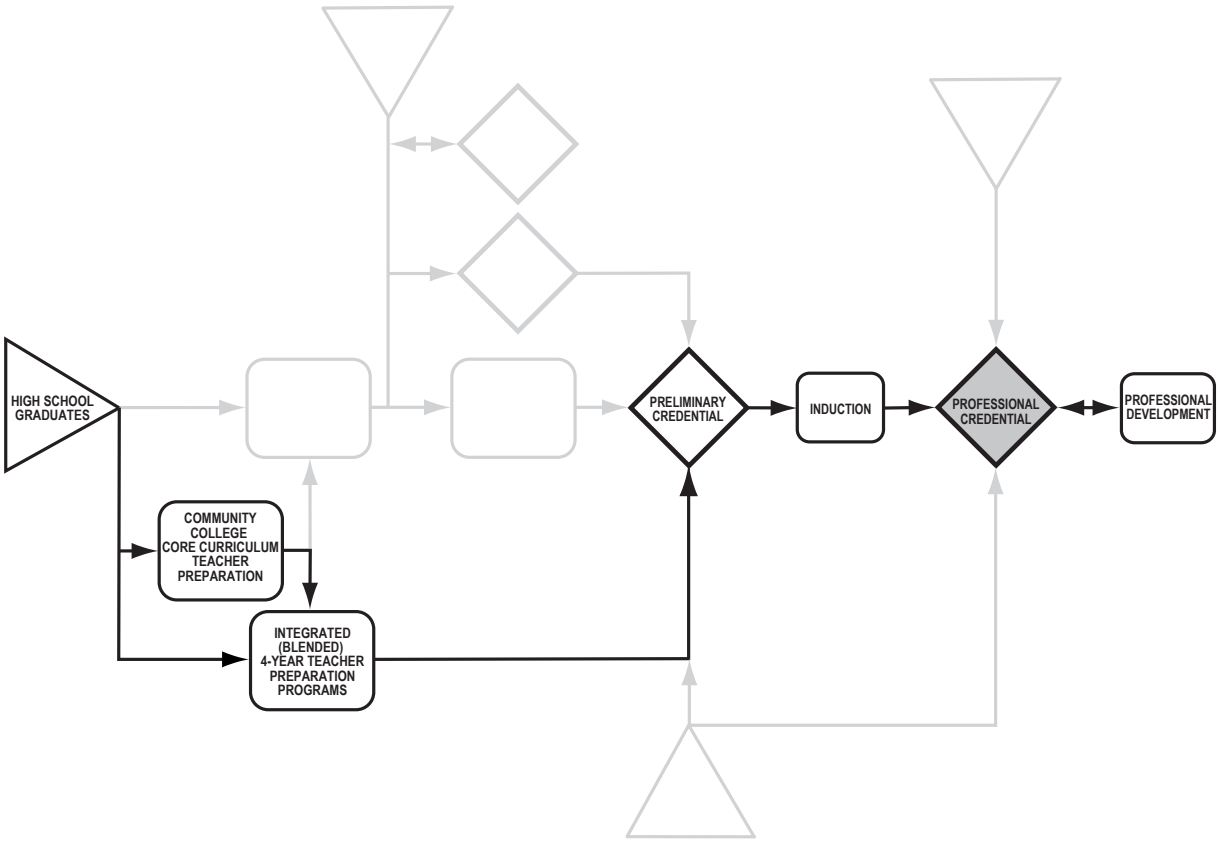

Figure 4.3: Schematic Diagram of Integrated Teacher Production Route

Statewide, there are 33 CTC-approved Integrated Programs at 26 CSU, UC and private institutions. Twenty-five are multiple-subject credential programs and eight are single-subject credential programs.

[49] In the mid 1990s, there was a dramatic need for classroom teachers statewide. The California Commission on Teacher Credentialing (CTC) sponsored a review of the requirements for earning multiple and single-subject credentials during the period 1994-1997, and many of the recommendations were enacted into law in September 1998. This legislation focused new attention on programs that combined content and pedagogical preparation into a single integrated, or blended, program. Five years later, Senate Bill 81 (Chapter 896, Statutes of 2003), resulted in more specific laws directed at colleges and universities and their integrated programs.

Table 4.1 shows the number of students enrolled in integrated programs from the time the program began through 2003-04. In this period, over 6,700 candidates were enrolled in Integrated Programs; 98% of program participants sought a multiple-subject credential. During that period, the integrated pathway was not a significant avenue for the production of secondary science and mathematics teachers in California. Only 1% of program participants sought single-subject credentials that may have included science or mathematics.

Table 4.1: Number of Prospective Teachers Enrolled in Integrated (Blended) Programs

Type of Program	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	Total: 1999-2004
Multiple-Subject	412	658	995	1,898	2,634	6,597
Single-Subject	5	3	7	32	44	91
Education Specialist	1	0	0	18	30	49
Total Enrollment	418	661	1,002	1,948	2,708	6,737

Source: CTC (2005)

Participation in this route entails the challenges of integrating the teacher-preparation curriculum into a standard four-year baccalaureate framework, and of identifying prospective teachers early enough in their baccalaureate careers to enroll them in the proper track to finish in four years. A number of promising integrated models are being established that will provide the opportunity to assess the extent to which this route can, over the long-term, provide a new pathway that contributes measurably to increasing the number of single-subject science and mathematics teachers in California. This has been a focus within the California State University Mathematics and Science Teacher Initiative (MSTI), and new integrated (blended) programs are being established on at least ten campuses.

4.3 Alternative Routes

Alternative routes are another way to enter the teaching profession. They require the prospective teacher to hold a baccalaureate degree and demonstrate subject matter knowledge and may lead to a preliminary credential. Alternative routes draw from a diverse pool of prospective teachers, such as out-of-state teachers, former members of the military, mid-career entrants from other fields to the teaching profession, and teachers who have already begun teaching with emergency permits. These routes also seem to be attractive to new degree holders who do not choose a traditional or blended program. Figure 4.4 shows the pathway for prospective teachers to enter the workforce through either intern programs or other alternative routes.

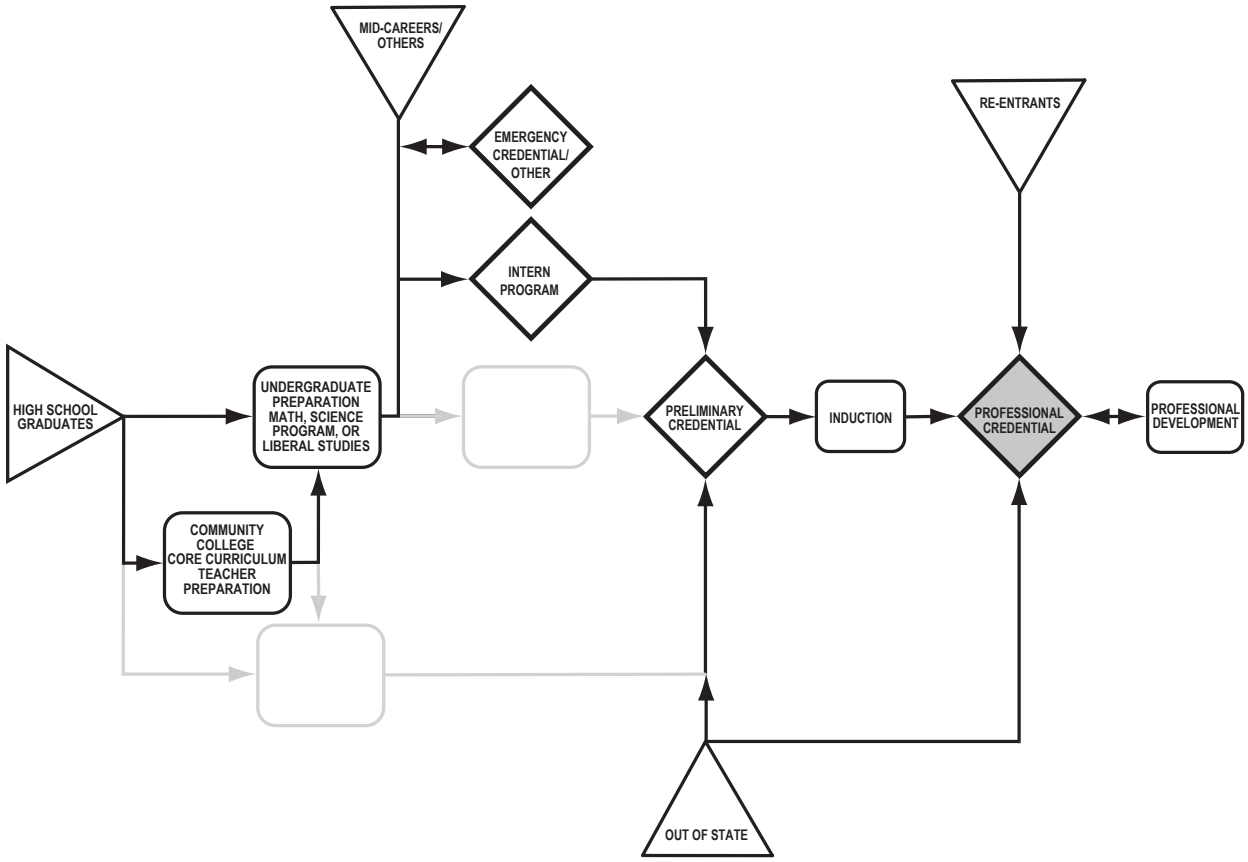

Figure 4.4: Schematic Diagram of Alternative Teacher Production Routes

With university or district internships, prospective teachers are authorized to begin teaching while they participate in programs to prepare them for certification. These internships are compliant with the federal No Child Left Behind Act (NCLB) and are offered by institutions of higher education or school districts for prospective teachers who have demonstrated subject matter competency either by completing a CTC-accredited program or by passing the California Subject Exam for Teachers (CSET) or an exam approved by CTC and designed for interns, such as the Teaching Foundations Exam administered by the Educational Testing Service. Since these teachers are working in the classroom while still earning their preliminary credentials, we consider them to be underprepared. The distribution of these teachers was discussed in Chapter 3.

Alternative teacher production routes are increasingly popular. One nationwide survey found that nearly half of those entering teaching through alternative routes say they would not have become a teacher if an alternative route had not been available. [50] Moreover, nationally the percentage of minorities who pursue alternative routes to teaching is nearly three times higher than that of traditional

[50] C. Emily Feistritzer, Profile of Alternate Route Teachers (Washington, D.C.: National Center for Education Information, 2005).

routes. Overall, however, CFTL's research has found intern programs to vary widely in structure, effectiveness and responsiveness to individual needs.[51]

As shown in Figure 4.5, the number of university and district internships has increased dramatically in the last decade. In particular, university internships have become an important path to certification in the state, with 74 programs operating in 842 out of the state's 1,000 school districts.[52] The number of intern credentials (both university and district) has grown from approximately 1,100 in 1994-95 to nearly 7,100 in 2003-2004.[53] In 2004-05, the number decreased.[54]

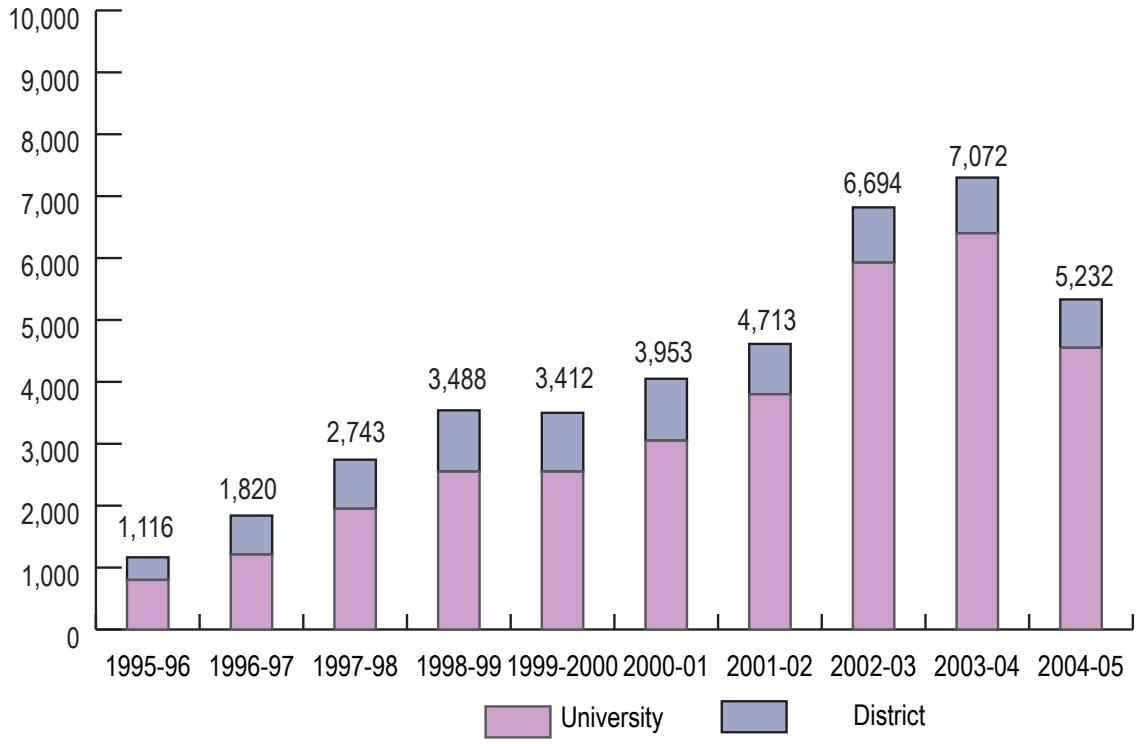

Figure 4.5: New University and District Intern Credentials Issued, 1995-96 to 2004-05

Source: CFTL (2006)

In addition to the internship route that leads to preliminary certification, teachers are able to enter the teaching profession through waivers, short-term permits, and provisional intern permits. These authorizations allow placement of a teacher in the classroom at the discretion of the district or school who is not formally on track to work towards an authorized teacher credential. This

[51] Esch et al., 39.

[52] Commission on Teacher Credentialing, "Pre-intern and intern program participants, 2004-06 and 2005-06" http://www.ctc.ca.gov (accessed 1/10/07).

[53] Camille E. Esch, Christopher M. Chang-Ross, Roneeta Guha, Juliet Tiffany-Morales, and Patrick M. Shields, California's teaching force 2004: Key issues and trends (Santa Cruz: The Center for the Future of Teaching and Learning, 2004) 48.

[54] California Commission on Teacher Credentialing, Teacher Supply in California 2004-2005, 5.

means that not all teachers who are in the classroom are on a track to become credentialed. The emergency permit route was phased out in 2006 in order to comply with the federal No Child Left Behind Act, and two others (pre-internship and waivers) have seen their numbers decline in recent years. However, some districts expressed a need for an alternative means of hiring people who have not completed all the necessary teacher preparation. One example is the provisional intern permit, an alternative used when a credentialed teacher can not be found. [55]

Alternative routes have become an important pathway for new science and mathematics teachers.

Alternative routes have become an important pathway for new science and mathematics teachers. In 2004-05, the CTC awarded over 890 university intern credentials in science and mathematics; district internships accounted for another 160 science and mathematics teachers. [56]

As Figures 4.6 and 4.7 indicate, a substantial proportion of science and mathematics teachers hired in 2004-2005 were either interns or were hired with an emergency permit. Figure 4.6 shows that for science, 31% of new hires entered classroom teaching through emergency permits; an additional 23% were university or district interns or held a pre-intern certificate. A total of 54% of novice science teachers were underprepared, that is, did not hold even a preliminary credential. [57]

For mathematics, shown in Figure 4.7, 37% of new hires in 2004-05 entered the classroom through emergency or other credentials. An additional 29% were university or district interns. In total, 66% of first-year mathematics teachers were underprepared. By way of comparison, only 25% of the overall new teacher hires were underprepared.

Although the percentage of underprepared teachers has decreased since early in the decade, when California faced a shortfall of 40,000 credentialed teachers overall (1999-2002),[58] underprepared rates in science and mathematics are still significantly higher than other subject areas. Clearly, more examination is needed to determine why such a high percentage of new science and mathematics teachers are choosing alternative routes over the traditional programs.

[55] Esch et al., California's Teaching Force 2004, 41.

[56] CTC, 2006.

[57] As these percentages focus only on new hires, they are somewhat higher than those indicated in Guha et al. Exhibit 27, Percent of Underprepared First- and Second-Year Science and Mathematics Teachers, 2001-02 to 2005-06.

[58] Esch et al., The Status of the Teaching Profession 2005, Exhibit 14.

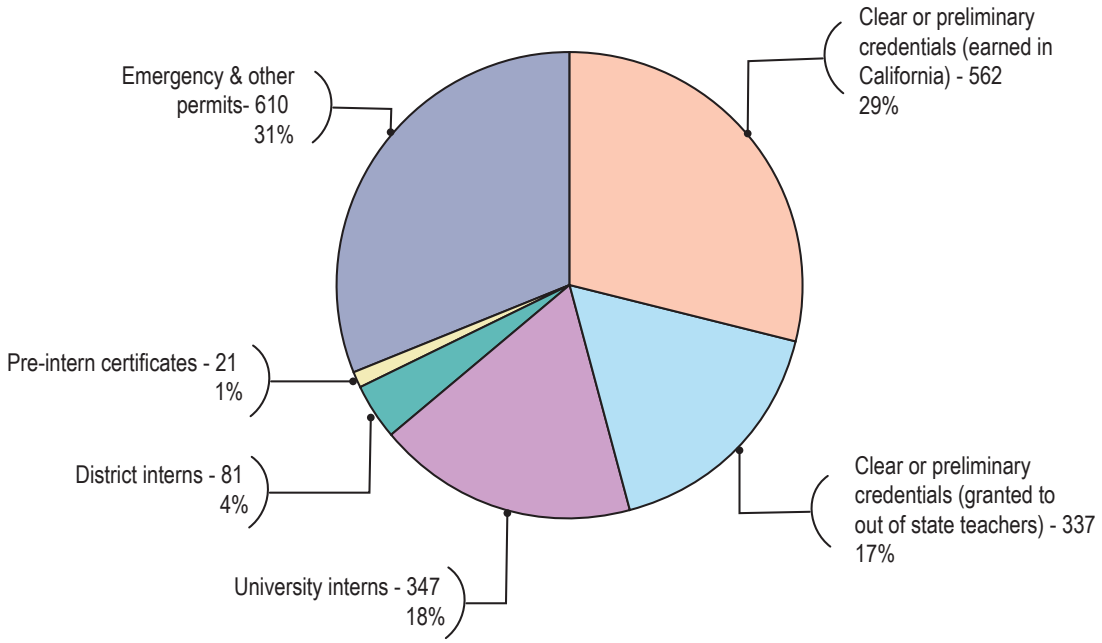

Figure 4.6: Estimated Number of Science Teachers Hired in 2004-05 in California, by Credential Type

Source: CDE (2006); CTC (2006)[59]

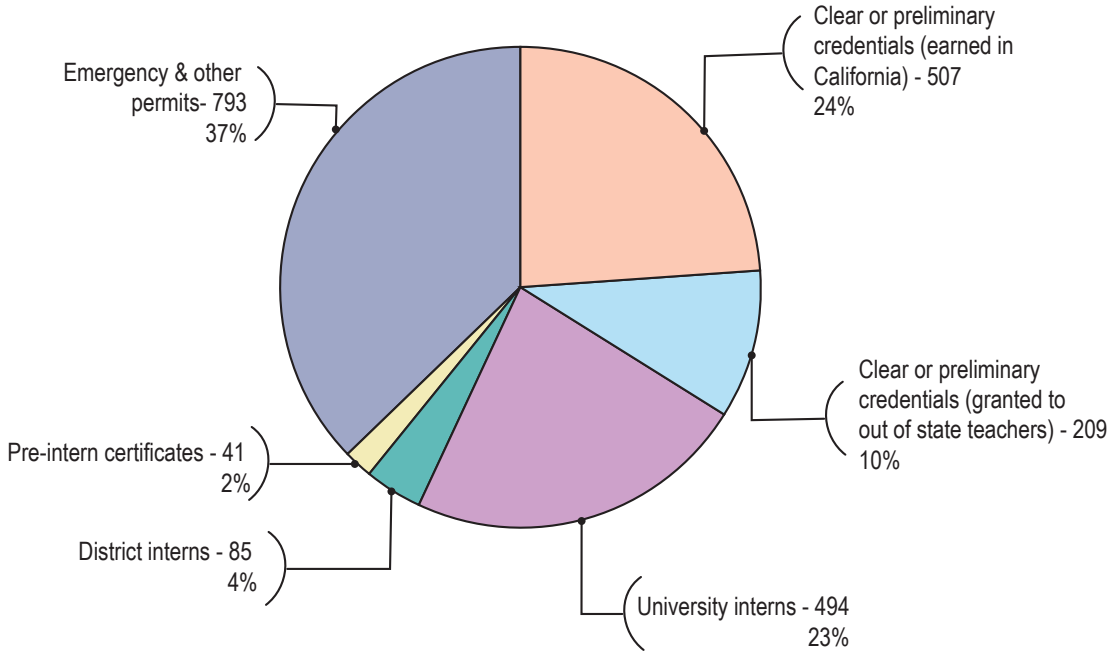

Figure 4.7: Estimated Number of Mathematics Teachers Hired in 2004-05 in California, by Credential Type

Source: CDE (2006); CTC (2006)[60]

[59] Total number of hires from the California Department of Education Dataquest: Projected Teacher Hires in California, 2004-5 (http://dq.cde.ca.gov); number of emergency & other credentials from California Commission on Teacher Credentialing (CTC), 2004-2005 Emergency Permits and Credential Waivers (2006); intern credentials from CTC, Teacher Supply in California: A Report to the Legislature, 2004-2005 (2006), Table 5.

[60] Ibid.

Out-of-state Prepared Teachers

Teachers with certifications from other states have several options to become certified in California, depending on their years of experience and the type of teacher-preparation program they attended. Recent legislation has streamlined this process. Table 4.2 shows the number of out-of-state teachers who received credentials in California since 2000-01. In 2004-05, the CTC awarded single-subject credentials to 337 science teachers and 208 mathematics teachers from out-of-state, combining for 17% of all out-of-state credentials granted and 35% of all single-subject credentials awarded to out-of-state teachers that year. [61] This number of out-of-state teachers corresponds to 18% of all science and mathematics credentials awarded in the state that year. These data suggest that out-of-state prepared teachers are an important source of science and mathematics teachers for California. Recent legislation (SB 1209) will further facilitate the credentialing of out-of-state teachers, expanding this potential source of experienced science and mathematics teachers.

Table 4.2: Total California Teaching Credentials Issued to Out-of-State Prepared Teachers

	2000-01	2001-02	2002-03	2003-04	2004-05
Out-of-State Prepared	4,724	5,629	4,856	3,575	3,304 (Includes 208 mathematics and 337 science teachers)

Source: CTC (2006)

4.4 Which Institutions are Producing What Kinds of Teachers?

California State University

The largest producer of teachers in the state is the California State University System, which prepared over 13,000, or 56% of all new teachers in 2004-05. CSU also prepares the most science and mathematics teachers in the state, producing nearly 750 per year.

CSU outlined its commitment to increasing credential production in its 1998 policy statement, *CSU's Commitment to Prepare High-Quality Teachers*, and since 2000, CSU has succeeded in increasing credential production by 46% overall.

Moreover, CSU has taken steps to focus on doubling science and mathematics teacher production through its new Science and Mathematics Teacher Initiative (MSTI), described below, as a response to the Governor's Higher Education Compact announced in 2004. The Initiative has resulted in an increase of 32% in science and mathematics teachers produced annually to-date.

[61] California Commission on Teacher Credentialing, Teacher Supply in California 2004-5, 191.

Independent Institutions

The next largest producers of teachers are the independent universities, which produce approximately 9,000, or 39% of the credentials issued in California, with the largest percentage (39%) from National University. The percentage of teachers earning credentials has remained essentially unchanged for the past five years. Of California's 105 private universities, 39 with departments, schools, or colleges of education offer a single-subject credential program in many science and mathematics disciplines. In the past ten years, however, the private universities have not produced significant numbers of teachers with single-subject science and mathematics credentials. Data collection from private universities, which do not have the same reporting requirements to state agencies as public universities, is indirect, thus making analysis of enrollment and degree trends inconclusive.

University of California

The University of California produces the remainder of new credentials. In 2004-05, the number was approximately 1,100 new credentials, or 5% of the total. Of these, about 250 were in science or mathematics. UC has made a commitment to quadrupling their numbers as part of the Governor's Higher Education Compact in 2004. In 2005, UC launched this new program, California Teach: One Thousand Teachers One Million Minds, with new programs on nine campuses, and has recruited about 200 students thus far.

4.5 State Responses to Needs for New Science and Mathematics Teachers

In recent years, the state has responded to the need for new teachers in various ways. As described above, the demand for new teachers caused by the Class Size Reduction Act in the mid 1990s resulted in an increase in waivers and emergency permits, as well as the introduction of a new integrated program, which has been most attractive to those interested in teaching at the elementary level.

Around the same time, another initiative — The California Mathematics Initiative for Teaching [62] — was created with the intent to increase the number of teachers competent and certified to teach mathematics in K-12 classrooms. Legislation authorized the CTC to administer a loan forgiveness program through school districts and county offices of education, and to establish standards for supplementary authorizations in mathematics. Although the announcement of this program was widely distributed throughout the state, only 70% of the allocated $5,000,000 funds were distributed to 41 local school agencies. The program met with limited success with regard to increasing the number of mathematics teachers in California. [63]

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[62] Senate Bill 496 (Chapter 545, Statutes of 1998).

[63] Specifically, of the 204 participants seeking single-subject mathematics credentials, 61 were awarded. All 24 of the experienced mathematics teachers who entered the program to update their mathematics knowledge finished their coursework. However, of the 330 who planned to obtain supplementary authorizations in mathematics, only 94 were

More recently, California has taken steps to increase its supply of science and mathematics teachers. The 2004 Higher Education Compact called for the CSU and UC systems to collaborate with the state, K-12 constituencies, and California business and industry leaders on a new initiative to improve the supply and quality of science and mathematics teachers. In 2005, the Governor joined with the public university systems and business leaders to announce a new program to bolster the state's science and mathematics teacher workforce. Both CSU and UC committed to increasing their annual production of credentialed science and mathematics teachers. Specifically, these new program aim to increase, by 2010, the number of credentialed secondary science and mathematics teachers produced by UC from 250 to 1,000 per year, and by CSU from 750 to 1,500 (see Figure 4.8).

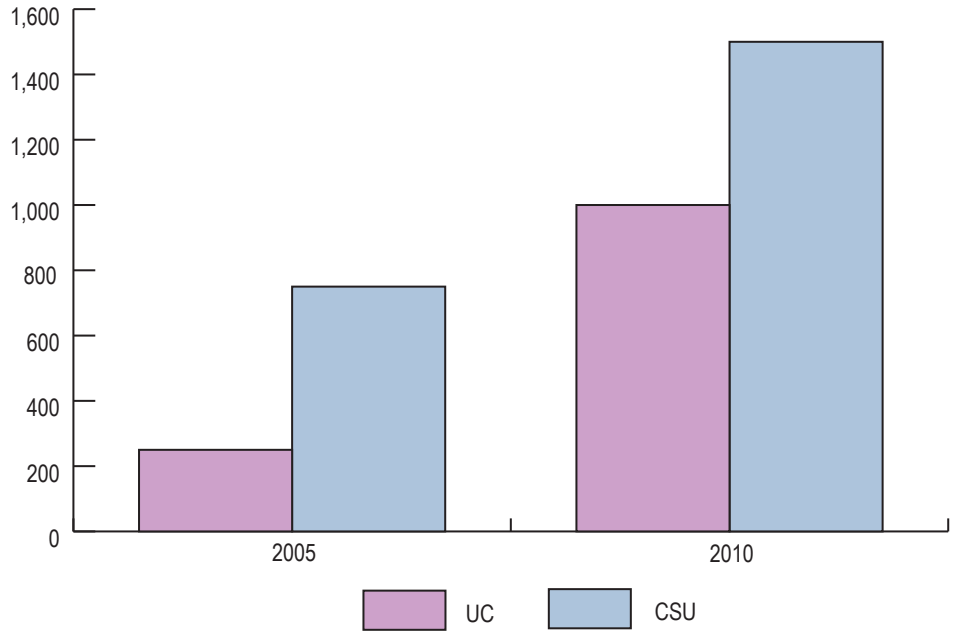

Figure 4.8: Planned Increases in Science and Mathematics Teacher Production by 2010 through the Governor's Science and Mathematics Teacher Initiative

Source: UC/CSU (2006)

To support these initiatives, the 2005-06 state budget allocated CSU $250,000 (to be equally matched by the university) to develop "blended" credential programs that culminate in an undergraduate science or mathematics degree and a teaching credential.[64] CSU funded ten different pilot programs at various CSU campuses, with a goal of identifying models that would be sustainable,

issued. And, only two individuals were successful in completing a mathematics specialization as part of their multiple-subject credential. The inherent difficulties of participants completing their courses within the loan forgiveness deadlines and limited number of local agencies submitting proposals resulted in the termination of this program in June 2004.

[64] California Department of Finance, 2005.

scalable to the entire system, and most effective by the metrics of increased science and mathematics teachers production established from the outset.

The 2005-06 state budget also allotted UC $750,000 (to be equally matched by the university) to establish nine Science and Mathematics Resource Centers that will provide student advising, school placement, and other related services. Students will also participate in field experiences in K-12 classrooms supervised by mentor teachers; attend summer institutes focusing on effective teaching methodologies; and receive financial incentives. During a fifth year, participants would complete a yearlong paid internship as a teacher in one of California's public schools, after which they would be awarded a preliminary credential. In its first year (2005), over 200 students across the UC system started the program.[65] To support the state level efforts, business leaders also pledged $4 million over a five-year period. Funds have been provided by many of the largest employers in California.

In the 2006-07 budget, additional support was allocated for the efforts. CSU was allocated an additional $1.365 million to expand its campus-based initiatives. The additional Science and Mathematics Initiative funding was provided to 18 of its campuses. UC was allocated an additional $375,000 to expand its efforts to the final three campuses in the system.

Although it is too early to gauge the success of these programs in creating a sufficient supply of science and mathematics teachers to meet the projected demand, they do have the potential to attract individuals into science and mathematics teaching who otherwise might not have thought of K-12 teaching as a career option. Moreover, it is possible that these new programs have the potential to attract more students from underrepresented groups into studying science and mathematics, and to enter teaching careers. Rigorous evaluation of these efforts will be needed to ensure that successful models are highlighted and scaled to meet the state's large demand for new science and mathematics teachers.

In addition to these university initiatives, the Assumption Program of Loans for Education (APLE), a longstanding education forgiveness loan program, assumes an additional $1,000 of loans per year for each of four years for participants who teach mathematics, science, or special education. Participants meeting this requirement who teach in a school ranked in the lowest two deciles of the state's Academic Performance Index (API) can receive an additional $1,000 per year for the four-year period. For 2005-06, additional APLE awards were available for teachers participating in the new California Science and Mathematics Initiative.

[65] Correspondence with Elaine Darrah, UCOP, 5/26/05.

4.6 Science and Mathematics Preparation for Elementary School Teachers

As efforts emerge to improve the science and mathematics teacher workforce, the science and mathematics preparation of California's elementary teachers should not be overlooked. Elementary teachers are responsible for teaching science and mathematics as part of a comprehensive elementary curriculum and providing students with a foundation upon which to build in their later years. Most teachers at this level hold a multiple-subject teaching credential that authorizes the holder to teach in a self-contained classroom. Unlike single-subject credential holders, multiple-subject credentials do not specialize in a content area; rather, they have, at a minimum, familiarity with all subject areas.

The multiple-subject credential requires some demonstration of content knowledge of science and mathematics and how to teach these subjects. Specifically, the Standards of Program Quality and Effectiveness for the Subject Matter Requirement for the Multiple-Subject Teaching Credential, approved by the California Commission on Teacher Credentialing in 2001, include "Content Domains for Subject Matter Understanding and Skill" in both science and mathematics. [66] The content domains are aligned with the state's academic content standards. As a part of a multiple-subject teacher-preparation program, teachers may take one methods- or content-specific course in science and/or mathematics, but coursework requirements vary across programs. To demonstrate content-specific knowledge, candidates for the multiple-subject credential must pass the California Subject Examinations for Teachers (CSET) multiple-subject exam, which includes a subtest for science and mathematics.

Although most elementary teachers (97%) are fully credentialed, [67] more analysis is needed to understand the extent to which teacher-preparation programs provide elementary teachers with a deep understanding of science and mathematics content that enables them to fully prepare students for the more advanced coursework they will face in middle and high school.

Once in the classroom, teachers can enhance their content and pedagogical knowledge in science and mathematics through specific professional development initiatives. For example, in 2001-02, Assembly Bill 466 (Chapter 737, Statutes of 2001) established the Mathematics and Reading Professional Development Program for teachers in high-priority or low-performing schools. The California Subject Matter Projects aim to improve teachers' content knowledge in nine subject areas, including science and mathematics. And the California Science and Mathematics Partnership Program allows districts serving high-need student populations to partner with mathematics, engineering, or science departments at institutions of higher education to provide standards-based professional

[66] See California Commission on Teacher Credentialing, http://www.ctc.ca.gov/educator-prep/standards/AdoptedMSStandards.pdf for more detailed information about the content specifications for science and mathematics needed to earn the multiple-subject credential.

[67] Guha et al., 22.

development of science teachers in grades 4 through 8 and mathematics teachers in grades 5 through 9. These professional development initiatives are limited, however, and not all elementary teachers have the opportunity to participate in mathematics or science-focused programs.

The teaching of science and mathematics by elementary school teachers warrants more systematic examination.

The teaching of science and mathematics by elementary school teachers warrants more systematic examination. Elementary school teachers are key in the K-12 science and mathematics continuum, yet not enough is known about how they are prepared to teach science and mathematics in the lower grades, or what is expected of them as part of their preparation for a multiple-subject credential.

4.7 Summary

In summary, to earn a teaching credential in California, candidates must complete one of four certification routes: 1) A traditional teacher-preparation program at a public or private college or university, which includes a 5th-year of study and leads to a preliminary credential; 2) An integrated (blended) program that unifies the baccalaureate and teacher-preparation into a four-year program and leads to a preliminary credential; 3) An alternative program that involves internship programs offered by universities or school districts that lead, upon completion of requirements in a set period of time, to a preliminary credential; or 4) Options for out-of-state prepared teachers to become certified in California.

Table 4.3 shows the total of science and mathematics credentials issued in California in 2004-05 via the various routes. Institutions of higher education (IHEs) issued 2,330 science and mathematics credentials, an additional 546 credentials were issued to teachers coming from out-of-state, and districts recommended 94 of the credentials.

Table 4.3: Total California Science and Mathematics Teaching Credentials Issued, 2004-05

California IHE-Prepared*	2,330
District Prepared	94
Out-of-State Prepared	546
TOTAL	2,970

** Note that IHE-prepared includes students attending traditional, integrated, or university internship programs.*
Source: CTC (2006)

4.8 Conclusions

There is no single system of teacher-preparation for science and mathematics teachers. Instead, the current variety of teacher-preparation programs reflects responses to changes in demand for teachers and the popularity of new kinds of programs. The primary route to certification has been and continues to be the traditional 5th-year program. Alternative pathways — especially university internship programs — have increased quite rapidly in popularity in the last decade as districts attempt to ensure that their classrooms have enough staff.

Available data estimates show that prospective science and mathematics teachers are choosing alternative routes nearly half the time.

Available data estimates show that prospective science and mathematics teachers are choosing alternative routes nearly half the time.

Data also suggest that the integrated program is an attractive route for teachers seeking a multiple-subject credential, which enables them to teach in elementary school. New programs have been established which will allow for a determination of whether it is an attractive option for science and mathematics students seeking single-subject credentials.

California State University, the University of California, and private institutions potentially have an important role to play in responding to shortages in teacher-preparation in California. Currently, however, the latter are not producing significant numbers of single-subject science and mathematics teachers, and we do not know the extent to which private institutions of higher education can create teacher-preparation programs to help meet the predicted demand due to attrition and retirement.

For new science and mathematics teachers, internship programs and waivers have become significant alternative routes to entry into the teaching profession. These programs warrant closer examination, as the trend is toward university internship, rather than waivers, because of new state and federal requirements. We need to know more about which institutions are responding to the demand for more teachers. We also need to know more about the kind of new teacher support being provided by universities to underprepared science and mathematics teacher interns, the success rate of earning a preliminary and then full credentials in science and mathematics, and the retention (or attrition) rate of science and mathematics teachers who enter through that pathway.

Although interns are considered underprepared, this route generally leads to a preliminary credential, and ultimately a professional clear credential, and thus a fully prepared teacher after several years. This route may also be especially promising for teaching candidates who are entering the profession from second careers. Of particular concern, however, is the need for a high-quality teacher

support for interns until they earn their preliminary credential, a process that may take two to three years, at a time when new teachers need the most support. Recent legislation Senate Bill 1209 (Chapter 517, Statutes of 2006) and Senate Bill 1133 (Chapter 751, Statutes of 2006) is intended to increase new teacher support for all new teachers (not just those with preliminary credentials), so mitigation in this area of concern will occur soon.

Data show that in the early 2000s, waivers and emergency permits were issued extensively for new science and mathematics teachers, but these permits do not typically lead to a preliminary credential. New requirements have started to reverse this trend, but the rates are still much higher than for teachers in other fields. It is important to know why this route seems to be more attractive to prospective science and mathematics teachers.

Another important group of teachers is out-of-state prepared teachers who meet California's credentialing requirements. In 2004-05, this group comprised over 18% of new science and mathematics credentials in the state. Clearly, this group is potentially important, and more must be known about strategies to recruit these teachers to California.

This report has focused on the quantity of science and mathematics teachers produced in California, and the routes they take to become credentialed. As a follow up, a companion systematic examination of the content and pedagogy of the preparation programs for science and mathematics teachers is needed — at both the elementary and secondary levels. With the diversity of pathways into the classroom that currently exists (multiple pathways through hundreds of accredited preparation programs in all kinds of institutions), a thorough review is needed to ensure that the critical talent pool of science and mathematics teachers in all grades are supported to become a fully prepared workforce by the time they earn their full credential.

CHAPTER 5 - RECRUITMENT AND RETENTION

Key Points:

Recruitment

- Many teacher recruitment programs operate in California; they vary greatly in size and level of funding and little is known about their effectiveness.
- In the past, there was little coherent strategy to link recruitment efforts with anticipated demand, location of demand, and the availability and types of teacher-preparation programs. Programs, other than the state's Assumption Program of Loans for Education (APLE), did not focus on recruiting science and mathematics teachers.
- This year, significant new recruitment efforts for science and mathematics teachers have begun. Both UC and CSU are designing new programs to double the number of teachers they prepare in these fields by 2010. And, the California Department of Education has started a new program to recruit more teachers to decile 1-3 schools, with primary areas of focus including science and mathematics teachers in middle and high schools.

Retention

- California does not have a system to track teacher retention.
- Teacher turnover costs money and impedes districts' ability to maintain a fully prepared and effective teacher workforce.
- This year, the California Postsecondary Education Commission allocated $10.5 million for new programs to support retention of science and mathematics teachers with a primary focus on grades 6-12.

This chapter describes strategies currently used to recruit new science and mathematics teachers in California and retain them in the teaching profession. There is always a need for new, fully prepared teachers. As noted earlier, the need within the next decade will be especially high for science and mathematics teachers with a single-subject credential who will be able to teach at the middle and high school levels due to attrition and retirement. In addition, nearly all of the new elementary school teachers must also have some mastery of science and mathematics in order to teach the state content standards in those disciplines.

New elementary school teachers must have some mastery of science and mathematics in order to teach the state content standards in those disciplines.

5.1 Recruitment

The Current Context

In his 2006 State of the Union, President Bush noted the importance of science and mathematics education. His American Competitiveness Initiative (ACI) launched new proposals addressing teacher recruitment including: 1) the development of the Adjunct Teacher Corps, which would provide grants to districts and states to encourage up to 30,000 STEM professionals across the nation to become part-time high school teachers by 2015, and 2) expansion of the teacher loan forgiveness program, which would target teachers who choose to teach in low-income schools. In addition, the National Academies, in its report *Rising Above the Gathering Storm*, recommended that the nation's number one action item should be to improve K-12 science and mathematics education. Congress responded with S. 3936, the National Competitiveness Investment Act. Education is one of the four principal areas of S. 3936, which would nearly double the budget for the National Science Foundation (from $6.2 billion in FY 2007 to $11.2 billion in FY 2011) and the Department of Energy's Office of Science (from $4.1 billion to over $8 billion) over five years, among other things. This legislation did not pass in the 109th Congress. However, due to its strong bipartisan support, it may be revisited in the 110th Congress.

The National Academies, in its report *Rising Above the Gathering Storm*, recommended that the nation's number one action item should be to improve K-12 science and mathematics education.

At the state level, the California Department of Education (CDE) requested proposals for new programs to recruit teachers to decile 1-3 schools, with two of the primary areas of focus being science and mathematics teachers in grades 7-12. The contract for this almost $3 million program was awarded to a consortium involving the Tulare County Office of Education, the California County Superintendents of Education Services Association, and the California State University. It will focus on three geographic areas: the Los Angeles region, the greater Inland Empire, and the Central Valley. The contract is administered through the Sacramento County Office of Education.

The state also identified recruiting and retaining teachers as a priority in the 2006-07 budget.[68] A school enrichment block grant is the largest program, at $100 million, targeted to school districts in the bottom 3 deciles of student performance, although no specific targets for recruitment are included. Instead, as is customary with block grants, localities set priorities and goals. While this diversity of approaches enables districts to respond to local needs, it also makes assessing the effectiveness of strategies and the overall return on the state's investment in recruiting challenging at best.

[68] 2006-07 California Governor's Budget, http://www.dof.ca.gov/Budget/BudgetDocuments.asp (accessed 1/10/07).

Through the 2004 Higher Education Compact, specifically the Governor's Science and Mathematics Teacher Initiative, the state is investing about $2.6 million in UC and CSU from 2006-2007 to build programs to recruit and prepare additional science and mathematics teachers. Industry is providing additional funding of $4 million over five years. A portion of this funding will be used for recruitment. As noted earlier, UC's goal is to quadruple production of science and mathematics teachers to 1,000 annually by 2010 and for CSU to increase production from 750 to 1,500 per year during the same period.

In addition, CSU has aligned its Teacher Recruitment Project (TRP) funding with its Science and Mathematics Teacher Initiative in support of its goal of doubling teacher preparation. CSU historically has allocated $75,000 of lottery funds annually to each of its 22 campuses having credential programs for teacher recruitment activities. This TRP funding, totaling over $1.6 million, in 2006-07 is targeted to science and mathematics teacher recruitment and is being administered by local campuses.

Previous Efforts to Recruit Teachers in California

When California faced acute widespread teacher shortages in the 1990s due to the Class Size Reduction Act, state policymakers adopted several measures at the state and local levels to enhance recruitment. These initiatives, summarized in Table 5.1, included the California Center for Teaching Careers (Cal Teach), the Teacher Recruitment Incentive Program (TRIP), and the Teaching As a Priority (TAP) program. At their peak in 2000-01, state spending for significant recruitment initiatives surpassed $150 million. However, most programs were discontinued in 2003-04 because they were not consistently targeted on high-need schools and the press of the state's budget crisis. Of the five largest programs begun by the state since 1997, none survive today (see Table 5.1).

Existing Recruitment Pathways

Much of our understanding of the recruitment of science and mathematics teachers is based on indirect evidence derived from studies of teachers generally, and not of specific disciplines. A full understanding of science and mathematics teacher recruitment is limited for two reasons. First, evaluations of the effectiveness of recruitment programs that measure the increase in teacher supply tell inconclusive stories. Second, it is not yet possible to follow individual teachers from preparation programs, whether through traditional or alternative routes, into positions within districts and throughout their career, further confounding efforts to assess recruitment strategies and subsequent retention rates. Without more data, and focused and detailed research, only tentative correlations can be made between the recruitment into various teaching pathways and the success of those pathways in preparing and retaining teachers.

Table 5.1: Discontinued and Inactive State-Sponsored Recruitment Programs

Program	Description	Funding History
California Center for Teaching Careers (Cal Teach)	Created in 1997 to serve as a 'one-stop' information, recruitment, and referral service for prospective teachers. The program maintained a call center, a website, and two regional offices, and engaged in outreach and advertising to recruit individuals to the profession.	Funding peaked at $11 million in 2000-01 and 2001-02, but was suspended in 2003-04. (Note: Cal Teach's website was replaced by the TEACH California website, which provides information to prospective teachers.)
Cal Grant T	Created in 1998 to provide tuition and fee assistance to students in teacher-preparation programs who agreed to teach in low-performing schools for at least one year.	Funded at $10 million annually between 1998-99 and 2001-02; the program was discontinued in 2003-04.
Teacher Recruitment Incentive Program (TRIP)	Created in 2000; established six regional teacher recruitment centers to address the teacher shortage. Centers assisted school districts in recruiting qualified teachers to low-performing and hard-to-staff schools.	Funded at $9.4 million from 2000-01 to 2002-03, funding was suspended in 2003-04. A few centers continue to exist, but they are no longer funded by the state.
Teaching As a Priority Block Grant Program (TAP)	Created in 2000 to provide competitive block grants to districts for providing incentives to recruit and retain credentialed teachers to teach in low-performing schools. Incentives included signing bonuses, improved working conditions, teacher compensation, and housing subsidies.	Funding peaked in 2000-01, the first year of the program, at $118.7 million. The program stopped receiving funding in 2003-04. In 2005-06, it was incorporated into the Professional Development Block Grant.
Governor's Teaching Fellowship	Created in 2000 to attract and retain qualified individuals to the teaching profession. Provided $20,000 for tuition and living costs to individual pursuing a first teaching credential if they agreed to teach for at least four years in a low-performing school.	Funded for only two years. The program received $21.1 million in 2001-02, but was suspended in 2002-03.

Sources: Excerpted from CFTL (2006).

Recruitment programs have targeted the following groups:

- Community college students into an undergraduate program that leads to a traditional teacher-preparation program.
- STEM professionals from other careers into teaching, or STEM students directly from undergraduate degrees into preparation programs.
- Former teachers back into the teaching profession.
- Out-of-state teachers.

Recruitment out of High School or Community College into an Undergraduate Program that Leads to a Teacher-preparation Program

Community colleges are a particularly important recruitment location for future science and mathematics teachers. A large number of students in teacher-preparation programs — approximately 38% — begin their undergraduate work in a community college.[69] And, we know that nearly 50% of STEM graduates from UC and CSU began their postsecondary studies in community colleges.[70] Some community colleges are beginning to offer education courses. This means that transfer students will be a key component of any new efforts to produce more science and mathematics teachers. It also means that close working relationships will be needed between four-year undergraduate institutions and local community colleges resulting in new articulation agreements that facilitate the transfer of appropriate credits. At present, no statewide standards for articulation agreements exist, and reciprocity for courses is still negotiated on a campus-by-campus basis. However, CSU and the California Community College System recently entered into a Memorandum of Understanding intended to put in place a seamless articulation between these two systems at the local campus level. And, UC has begun a pilot program, through its California Teach initiative, to identify potential science and mathematics teachers through collaborations with community colleges.

COMMUNITY COLLEGES ARE A PARTICULARLY IMPORTANT RECRUITMENT LOCATION FOR FUTURE SCIENCE AND MATHEMATICS TEACHERS. A LARGE NUMBER OF STUDENTS IN TEACHER-PREPARATION PROGRAMS — APPROXIMATELY 38% — BEGIN THEIR UNDERGRADUATE WORK IN A COMMUNITY COLLEGE.

Recruitment into Teaching from Other Careers or Directly from Undergraduate Degrees into a Traditional Preparation Programs

Although it is conceivable that individuals with STEM backgrounds might choose to enroll in a 5th-year program when making a career change, a more likely route to take is a university or district internship. This route allows them to continue earning a salary while simultaneously earning a teaching credential. In 2006-07, the state allocated $31.7 million for intern programs based either in universities or at the district level.[71] University internships comprise 85% of all internships; district internships comprise 14%.

Below are examples of other recruitment programs that offer alternative pathways, primarily into internships. These programs were designed to supplement, rather

[69] Judy Kasabian, Descriptive Analysis of Mathematics Teacher-preparation at California Public Colleges and Universities (2006).

[70] California Council on Science and Technology.

[71] Guha et al., p.40..

than replace, the standard flow of students into programs where they would earn a preliminary credential. They are characterized by their small scale and limited duration. Some examples are:

- Troops-to-Teachers. This program was established in 1994 by the U.S. Department of Defense, in response to downsizing of military personnel. Its goal is to recruit former military or reserve personnel to become teachers. The program is meeting its goal for 75% of recruits to become "highly qualified teachers" according to the NCLB definition.[72] In 2004, 22% of recruits became science or mathematics teachers, less than the program goal of 30%.[73] The total number of teachers recruited statewide was 70.
- New Teacher Projects. The Oakland Teaching Fellows is an example of a local program that places mid-career professionals into high-need classrooms, including science and mathematics. Between 40 and 50 teachers enter the classroom through this program per year.
- Teach for America. This national program places recent graduates from over 500 colleges and universities in high-need school districts for two years. The program is highly competitive, with over 19,000 students applying for 2,400 slots nationwide in 2006. In California, Teach for America (TFA) teachers are placed in Los Angeles and in the Bay Area.[74] In the last year, recruiting for science and mathematics teachers has been a special focus, resulting in 20% of this year's applicants coming from STEM fields. Teacher training is accomplished through a five-week summer program, after which students are placed as interns. In 2005-06, TFA added over 200 teachers in California. There are currently approximately 375 active TFA teachers in the state, and 20% teach science or mathematics. However, while TFA places teachers in the classroom annually, it is not a recruitment program per se, in that participants commit only to a short period of time teaching.

Recruitment of Out-of-state Teachers

Another way to increase the pool of teachers is to recruit teachers from other states. A key issue is the acceptance of credentials issued by other states. In 2001-2002, California embarked on an $11 million advertising campaign to attract teachers into the workforce, with $2 million focused on recruiting teachers from out-of-state. As noted earlier, out-of-state prepared science and mathematics teachers who receive credentials in California comprised over 16% of all out-of-state credentials granted in 2004-05.

5.2 Retention

At the other end of the workforce continuum is retention — keeping experienced fully prepared teachers in the classroom for as long as they have a commitment to teaching.

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[72] In California, this would include those with preliminary, professional, or intern credentials. Please note that the definition of "fully prepared" teachers in this report, however, excludes interns.

[73] Department of Education Troops to Teachers webpage, http://www.ed.gov/about/reports/annual/2005report/edlite-g2eseatroops.html (accessed 1/10/07).

[74] Teach for America, http://www.teachforamerica.org (accessed 1/10/07).

Attrition before the traditional retirement age exacerbates the challenge of recruiting new teachers that can be anticipated due to regular retirement, especially when the supply through current routes is insufficient. Attrition seems to be particularly troublesome in low-performing schools, where there already is a shortage of fully prepared science and mathematics teachers and where the percentage of underprepared and novice teachers is higher than in other schools, as noted earlier.

There are many reasons to focus on ways to retain fully prepared science and mathematics teachers longer. One is the cost of replacing them. Turnover carries at least three different types of costs: the direct instructional costs for the students who would have been taught by the departing teacher; the financial costs to the school and/or district to recruit and support new teachers; and the organizational cost, as staff turnover impedes a school's ability to maintain consistent procedures and practices.[75]

Turnover carries at least three different types of costs: the direct instructional costs for the students who would have been taught by the departing teacher; the financial costs to the school and/or district to recruit and support new teachers; and the organizational costs.

Another reason to focus on retention is that our analysis shows that the supply of new science and mathematics teachers provided through existing preparation programs may not be large enough over the next decade to meet the demand for new teachers. And, current recruitment strategies, as described above, are not yet robust enough to expand the supply significantly. Efforts in the near term must focus on keeping fully prepared teachers in classrooms.

Third, as novice teachers enter the profession, it takes at least several years for them to earn their professional clear credentials. The state cannot afford to lose its fully prepared teachers before new teachers are ready to fill their shoes.

What Do We Know about Teacher Recruitment and Retention?

Little independent research exists about the relative effectiveness of various recruitment strategies or the retention of science and mathematics teachers recruited through different pathways.

Some research shows that the annual attrition rate of teachers generally is about 4%;[76] other research suggests that the rate is much higher.[77]

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[75] Susan M. Johnson, Jill H. Berg, and Morgaen L. Donaldson. Who Stays in Teaching and Why: A Review of the Literature on Teacher Retention (Harvard Graduate School of Education: February 2005) 10.

[76] Center for the Future of Teaching and Learning, California's Teaching Force: Key Trends and Issues, 2002 (Santa Cruz: Center for the Future of Teaching and Learning, 2002) 5.

[77] National Commission on Teaching and America's Future. No Dream Denied: A Pledge to America's Children (Washington, D.C.: 2003) 26.

One reason for the paucity of research is the short duration of many programs while another may be the difficulty in obtaining data that systematically tracks teachers. As noted earlier, there is no single agency or organization in California charged with that kind of data collection and analysis. While CSU has been conducting a survey of recent graduates from its own teaching programs for several years, the predictive value of those data is limited because participation in the survey is voluntary and there is no equivalent mechanism in place for teachers prepared by other public or private systems. We were unable to find any analyses of the retention of science and mathematics teachers who enter the teaching profession through any route.

Clearly, recruitment and retention efforts would benefit from a review as part of the annual budget process.

5.3 Factors Affecting Recruitment and Retention

Factors that affect science and mathematics teacher recruitment and retention include the difficulty of determining the size and distribution of the demand for new science and mathematics teachers; strategies to recruit STEM talent into the teaching profession and accessible information about pathways to becoming a teacher; working conditions in schools; new teacher support; and incentives, including teacher compensation.

First is the difficulty of determining the size and distribution of the demand for new science and mathematics teachers. As noted elsewhere in this report, estimating demand is difficult, yet ensuring that state policymakers are able to closely approximate the need is critical to ensuring that teacher-preparation programs can adjust and respond in a timely way.

Second is the need for a variety of strategies to recruit STEM talent into the teaching profession. One size does not fit all. As noted earlier, most of the existing recruitment efforts that we found focused on attracting teachers — either recent baccalaureates or mid-career candidates — into alternative pathways. More explicit efforts, however, are needed to inform potential candidates from a variety of pools — high school students, community college students, students in four-year institutions, and mid-career professionals — about careers in science and mathematics teaching.

A key source of future teachers is undergraduate STEM students — both in community colleges and in four-year institutions. Specific strategies must be developed to alert them early in their college years to the availability of teacher-preparation programs in their institutions, as well as incentives that may exist in the form of scholarships/fellowships or loan forgiveness programs tied to working in certain locations.

Another source of talent is STEM professionals seeking a second career in teaching. Recruitment efforts targeted to this group must be tied to information about the various routes to licensure, as well as incentives, such as salary scales that reflect years of experience in other professions.

For all potential candidates, readily available online recruitment resources are essential, and can build on the many online resources that already exist to help potential teachers find training programs, financial assistance, and information on the credentialing process. The primary site in California is Teach California (http://teachcalifornia.org), which is maintained by the Sacramento County Office of Education. Others are EdJoin.org and RNT.org.

A third factor is the working conditions in schools. It stands to reason that fully prepared teachers, when they have a choice in times of high demand for their skills, will be more inclined to choose to work in schools with better working conditions. The organization of schools contributes to teacher satisfaction.[78] For example, in a national survey, teachers working in high poverty, urban public schools cited with greatest frequency the lack of administrative support as the reason for being dissatisfied with their jobs, while teachers from low poverty suburban districts cited most frequently poor salaries as a source of dissatisfaction (see Figure 5.1). For teachers in high poverty schools, other factors that led to dissatisfaction included policies that de-professionalize teaching and limit autonomy, such as lack of faculty influence in decision-making, inadequate time, classroom intrusions, and student discipline, as well as salary.

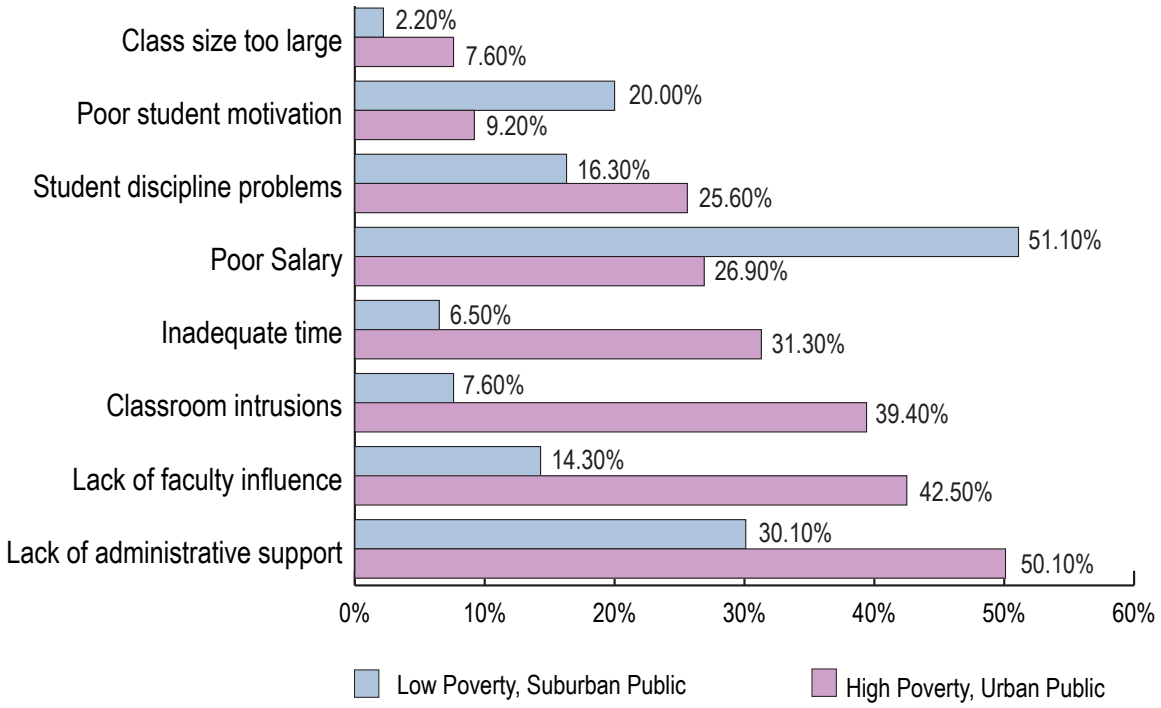

Figure 5.1: Percent of Teachers Giving Reason for Dissatisfaction

Source: NCTAF (2004)

[78] Samantha Bartholomew, Pamela Clute, and Judy Lee, Science and Mathematics Teacher Recruitment: A Report Prepared for the California Council on Science and Technology (2006).

A fourth factor is the level of induction support available to novice teachers, as described in Chapter 6, especially those who enter the teaching profession through alternative routes such as internships or through waivers. As shown in Chapter 4, these alternative routes are particularly attractive to new science and mathematics teachers, but the level of induction support can differ depending on whether or not a teacher has a preliminary credential. It seems reasonable to assert that high-quality support for all new teachers, irrespective of the route of teacher preparation, is another critical factor in maintaining the supply of science and mathematics teachers. Fortunately, new legislation (Senate Bill 1209; Chapter 517, Statutes of 2006) addresses this disparity in the availability of new teacher support.

A fifth factor is incentives. Some incentives are already offered to teachers who complete a science or mathematics credential, but many of these are created with specific staffing targets, are not tied to a particular preparation pathway, and exist for limited time periods. Incentives include scholarships/fellowships, loan forgiveness, bonuses, and housing stipends or assistance with buying homes in some areas. However, more research is needed on the impact of such incentives on either teacher recruitment or retention.

Teacher compensation is linked strongly with incentives. Increased pay is often cited as an incentive to recruit fully prepared science and mathematics teachers. Pay issues, however, are difficult to address. Teacher salaries are set by school districts through the collective bargaining process between a school district's administration and teachers' unions. Salary schedules have graduated steps based on educational credits and length of service *in the district*. In general, compensation is not linked to subjects taught, and salaries, benefits and seniority do not fully transfer to other school districts, although SB 1209 addresses some of these issues. This long-standing system is a significant disincentive for more experienced teachers to transfer to hard-to-staff districts. A recent Harvard study found that the problem with teacher pay in traditional public schools "is not its overall level, but its rigid structure…A more productive discussion concerning teacher pay would focus on its inefficient structure and the benefits of a more market and performance-based system."[79]

Certainly some hard-to-staff districts offer higher beginning salaries as an incentive to meet their workforce demands. For example, in some cases districts have contracted specifically with Teach for America (e.g., the Los Angeles Unified District), paying $3,000 for each teacher assigned to high-need schools. Research suggests, however, that teacher pay is only one factor to consider. A recent Public Policy Institute of California (PPIC) study looking at all teachers found that investing approximately $3,300 per teacher on induction did more to enhance teacher retention over the first five years than investing $4,500 in a salary increase.[80]

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[79] Michael Podgursky, Is Teacher Pay 'Adequate?' (Boston: Harvard Kennedy School of Government, 2005) 35.

[80] Deborah Reed, Kim S. Rueben, and Elisa Barbour, *Retention of New Teachers in California*. Public Policy Institute of California: San Francisco, 2006, p.19.

This year, the California Postsecondary Education Commission (CPEC) requested proposals for new projects aimed at the retention of science and mathematics teachers. The goal of this $10.5 million program, administered through the California Science Project (CSP) and the California Mathematics Project (CMP), is primarily to fund local UC and CSU projects designed to support retention of science and mathematics teachers in grades 6-12. The CPEC-funded projects this year as well as those funded earlier might include novice teachers during induction or immediate post-induction, teachers lacking credentials or who have not yet met requirements as "highly qualified" under the No Child Left Behind Act, teachers in very low-performing schools, or other retention initiatives supported by research. CPEC's efforts reflect research identifying practices that are effective in reducing attrition and helping to meet the need for fully prepared and effective science and mathematics teachers.

The inability to assess the effectiveness of specific recruitment and retention efforts impedes the ability of state agencies to respond effectively when a teacher shortage emerges.

5.4 Conclusions

California needs to build a coherent approach to recruitment and retention of science and mathematics teachers at the K-12 level. The current teacher-preparation system, with its multiple entry routes into the teaching profession, reveals a diverse response to addressing the on-going challenge of recruiting enough science and mathematics teachers into the workforce and ensuring they are prepared to teach or become prepared within a few years. Moreover, not enough is known about teacher retention, especially strategies that are effective in reducing attrition and increasing retention. Responding to teacher shortages is complicated by the difficulty of obtaining data about supply and demand for science and mathematics teachers. In addition, the inability to assess the effectiveness of specific recruitment and retention efforts impedes the ability of state agencies to respond effectively when a teacher shortage emerges.

In the past, California has responded to teacher shortages through a steady flow of legislation intended to target mathematics, science and special education teachers and to provide incentives to work in hard-to-staff districts. Appendix C is a summary of major pieces of legislation since 2001 that focus on addressing specific, incremental needs in teacher recruitment or preparation. The number is staggering, yet this *ad hoc* approach of responding to real needs does not also include a way to systematically assess over time the effectiveness of specific interventions or programs, or to gather data from key institutions in order to anticipate better future needs. Without ways to assess programs, potentially good programs, that lack demonstrable success may be unduly susceptible to the loss of funding; alternatively, ineffective programs may continue to be funded long beyond their usefulness. Moreover, without good data about supply and

demand, *ad hoc* efforts to respond to crises will continue, and opportunities to design effective recruitment and retention strategies will be missed.

New efforts by CDE and CPEC this year to fund new programs for recruitment and retention of science and mathematics teachers are encouraging — yet highlight the importance of building coherence in the state's approach to recruiting and retaining science and mathematics teachers at the K-12 level. These two important new activities are housed in different agencies with missions to serve different parts of the educational system. These efforts, and others like them, could be maximized if the currently disconnected system were transformed into a coherent system that addresses, consistently and continuously, issues such as:

- Creating better methods for estimating the demand for science and mathematics teachers, and where they will be needed.
- Collecting better data to estimate the supply of science and mathematics teachers through the various teacher-preparation routes in both public and private institutions of higher education in the state.
- Examining which routes of entry into the teaching profession are most attractive to science and mathematics teachers, and why.
- Developing new recruitment strategies for future science and mathematics teachers targeted at several teacher candidate populations, such as high school students, undergraduate STEM students, and mid-career STEM professionals looking to change careers.
- Evaluating more systematically recruitment efforts, especially the critical elements of successful programs.
- Evaluating teacher attrition and retention more systematically, with a particular focus on factors that could increase retention of the most prepared and effective science and mathematics teachers.

CHAPTER 6 - INDUCTION

Key Points:

- Teachers entering the classroom from different routes need different kinds of new teacher support and assistance, or induction.
- Induction support for novice teachers with a preliminary credential is provided through the state-funded Beginning Teacher Support and Assessment (BTSA) program.
- Support for intern science and mathematics teachers is provided through their internship program, but these programs may vary in scope and effectiveness.
- Other novice science and mathematics teachers who enter the profession through alternative routes such as waivers and emergency permits may not receive any support at the school level.

6.1 What is Induction and Why is it Important?

Induction is the process of systematic support and continuing education for novice teachers. Figure 6.1 shows where in the system of science and mathematics teacher-preparation induction usually occurs.

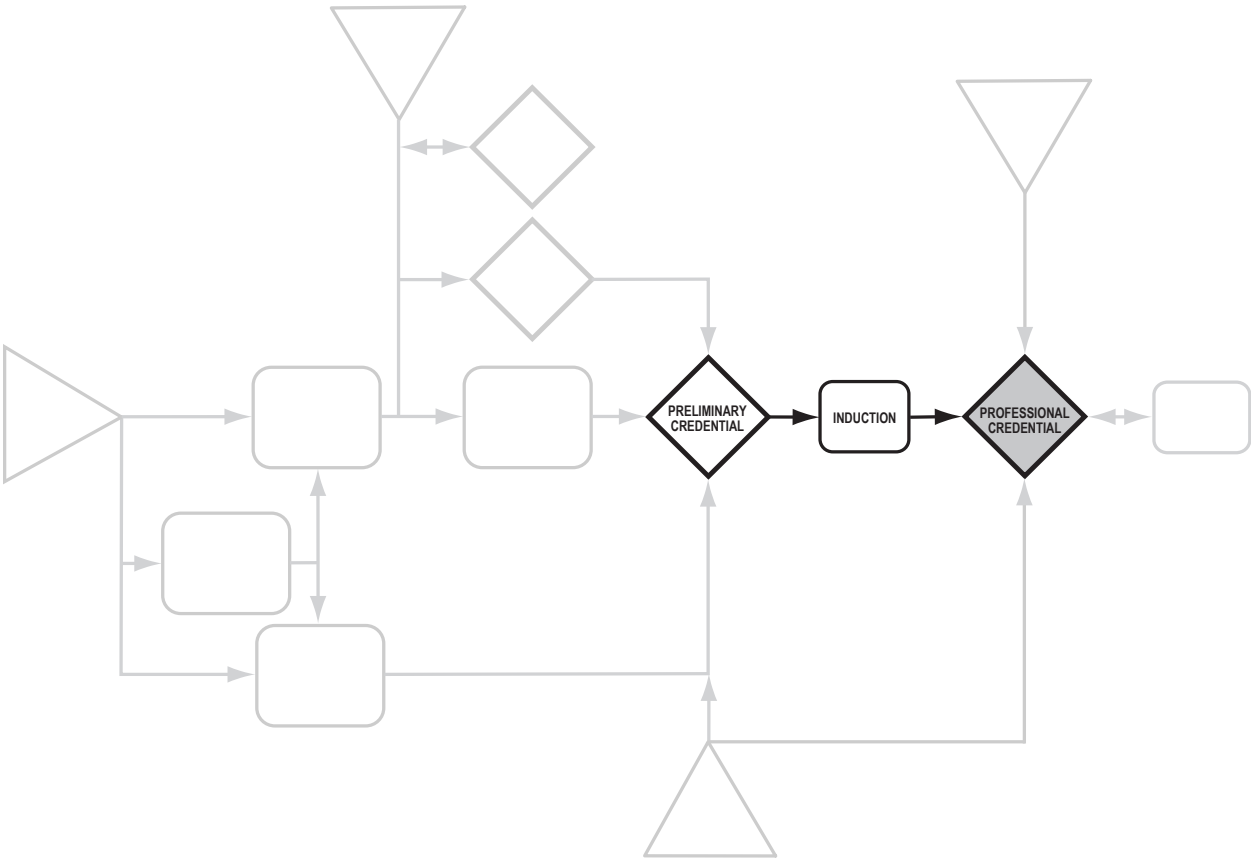

Figure 6.1: Schematic Diagram of Induction

The first few years of teaching are challenging, as teachers learn their craft in the classroom while also having the responsibility to educate their students. In addition, novice teachers are often given difficult assignments, which may include larger classes, more courses to prepare for, and larger numbers of low-performing students.

Given the challenges a novice teacher faces, participation in a new teacher support or induction program increases the chances that a teacher will remain in the profession. According to one report, in California new teachers completing a two-year support program had a retention rate of 84% after five years; those who failed to complete such a program had a 50% chance of leaving the profession within two years. [81]

There are no specific induction programs per se for novice science and mathematics teachers in California; however, a review of the general induction programs reveals different levels of support for novice teachers depending on which route they take into the teaching profession.

6.2 Options for Induction in California

Induction for Novice Teachers with a Preliminary Credential

The Commission on Teacher Credentialing (CTC) provides several induction options for teachers who begin their teaching career with a preliminary credential. The three primary options are designed to provide the same suite of new knowledge.

The first and most widespread option enables new teachers to fulfill state requirements by completing a CTC-approved professional teacher induction program through a school district, county office of education, college or university, consortium, or private school. This option, called the Beginning Teacher Support and Assessment (BTSA) Program, is jointly administered by CTC and the California Department of Education (CDE) and includes the advanced study of health education, special populations, computer technology, and teaching English learners. [82]

In 1992, the Legislature funded the CTC/CDE to initiate and sponsor BTSA as a statewide comprehensive support program for new teachers with a preliminary credential. [83] This program was a response to the plight of new teachers and the resulting early attrition from teaching. Legislative changes were made to the program in 1998, including requirements for school districts to provide funding to complement CTC's commitments and for new teachers with a preliminary credential

[81] Yvonne Lux, A Descriptive Analysis of Professional Development and Induction for Teachers of Mathematics in California (2006) p.5.

[82] California Commission on Teacher Credentialing requirements, http://www.ctc.ca.gov/credentials/requirements.html (accessed 1/10/07).

[83] See Senate Bill 1422, 1992.

to participate in a two-year induction program leading to the professional clear credential.[84] Teachers enrolled in BTSA complete a two-year formative assessment program that is aligned with the California Standards for the Teaching Profession.[85] They also are supposed to receive support and mentoring from experienced teachers and participate in seminars and workshops on classroom management and instructional strategies that focus on their teaching content areas.

WITHIN THE PROGRAM'S FIRST FEW YEARS, THE PROBABILITY OF LEAVING DECLINED BY 26% FOR TEACHERS WITH MULTIPLE-SUBJECT CREDENTIALS, AND 16% FOR TEACHERS WITH SINGLE-SUBJECT CERTIFICATIONS IN DISTRICTS THAT ADOPTED BTSA.

Within the program's first few years, the probability of leaving declined by 26% for teachers with multiple-subject credentials, and 16% for teachers with single-subject certifications in districts that adopted BTSA, as shown in Figure 6.2.[86]

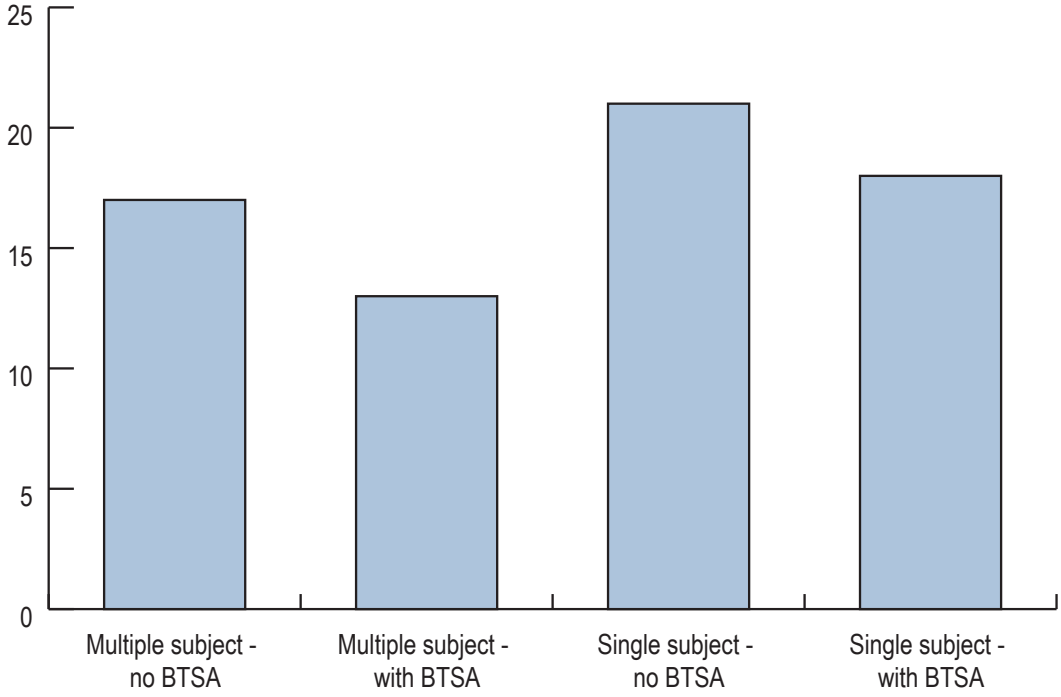

Figure 6.2: Percentage of Teachers Leaving by their Second Year, before and after Implementation of BTSA

Source: PPIC (2006)

From an initial budget of $4.9 million serving approximately 1,100 new teachers in 1992-93, the program expanded in the late 1990s, and has had fairly stable

[84] See Senate Bill 2042, 1998.

[85] Beginning Teacher Support and Assessment, http://www.btsa.ca.gov (accessed 1/10/07).

[86] Reed et al.,15.

funding (between $80—90 million per year) since 2000. In 2004-05, 22,947 eligible novice teachers participated in 148 approved BTSA programs. This number represents approximately two-thirds of the nearly 37,000 full-time first and second-year teachers in California. The percentage of science and mathematics teachers participating in the program has not varied significantly over the past four years.

A second option for induction, which applies only to teachers who earned a preliminary credential prior to January 1, 2004, allows candidates to take advanced study at a California college or university with a CTC-approved teacher-preparation program, and thus secures that institution's formal recommendation for the professional clear credential. [87]

A third option is available to teachers who are certified by the National Board for Professional Teaching Standards. They are issued a professional clear credential in the subject area in which they receive national certification. [88]

Other options for induction are also available to smaller numbers of teachers to accommodate the various teaching backgrounds of people from other states or countries, and are designed to require that incoming teachers complete any requirements of both the California preliminary and professional clear credentials that they did not complete in their out-of-state teacher-preparation program.

Induction for Novice Teachers without a Preliminary Credential

As shown in Chapter 4, in 2004-05, over 50% of new science and mathematics teachers were either interns or held an emergency permit or waiver. None of these new teachers were eligible for BTSA support since they did not yet have a preliminary credential. [89]

However, due to SB 1209, beginning this year, novice teachers without a preliminary credential will now be eligible for new teacher support. The 2006-07 budget allocated $11.2 million for the Certificated Staff Mentoring Program.

6.3 Evaluating Effectiveness of Induction Programs

Measuring the effectiveness of teacher induction programs is difficult due to the challenges of establishing reliable metrics. Some assessments focus on instructional success; others focus on fiscal impacts of improving retention of teachers, and thus saving considerable resources (time and money). Moreover, funds for induction often come from a variety of state and federal sources, each with different reporting requirements with no coherent statewide monitoring

[87] Ibid.

[88] Ibid.

[89] Lux, p.7.

effort. It is not possible to assess the impact of most of these induction funds because few if any mechanisms provide accountability for how the funds are spent or on documenting effectiveness. Federal funds and grants require only superficial evaluation efforts, and these reports go only directly to the funding source, not to a statewide monitoring effort. Funds from the CDE or from local districts require no systematic evaluation efforts. The BTSA program provides some information, such as data on the number of participants, the amount of funding spent, and an evaluation consisting of surveys of participants and some retention data. A new evaluation of the Beginning Teacher Support and Assessment Program, as well as university and district intern programs, is funded as a result of SB 1209 (Chapter 517, Statutes of 2006).

There have been, however, some independent analyses that show a positive impact of induction. The National Commission on Teaching and America's Future (NCTAF) found that $50,000 in taxpayer money is lost for each teacher who leaves in the first five years of a teacher's career.[90] NCTAF concluded that good induction programs can improve retention and investment in induction programs creates a payoff of $1.50 for every one dollar invested. NCTAF also found that to be successful, "A system of induction should include a network of supports, people, and processes that are all focused on assuring that novices become effective in their work. An induction system is both a phase — a set period of time — and a network of relationships and supports with well defined roles, activities, and outcomes."

6.4 Conclusions

The state has an immediate need to recruit fully prepared and effective science and mathematics teachers through the various teacher-preparation routes, and then to retain them once they are in the classroom. The state's goal should be to retain teachers and support them to earn professional clear credentials, and thus increase the pool of fully prepared and effective science and mathematics teachers.

BTSA appears to provide a benefit resulting in the retention of new teachers in California. It is credited with most of the improvement in new teacher retention through the 1990s.[91] California should insure that interns and other novice teachers entering the profession through alternative routes also receive high quality support, mentoring and assistance through their internship program (in the case of interns) or through district mentoring efforts (in the case of individuals who do not qualify for internships).

[90] NCTAF (National Commission on Teaching and America's Future). Induction into Learning Communities. (Washington, D.C.: NCTAF, 2005) 9.

[91] Reed et al., 16.

CHAPTER 7 - PROFESSIONAL DEVELOPMENT

Key Points:

- Science and mathematics teachers in California receive professional development from a number of providers supported by federal, state, and private funding.
- Although professional development programs are hard to categorize, many are designed to meet district goals and requirements, while others address the individual needs of the teachers.
- State funding for professional development has been significantly reduced in the past three years, particularly for science.

Professional development (PD) is the process of continuing education for all teachers. In California, "Developing as a Professional Educator" is one of six standards in the Standards for the Teaching Profession. The standard includes the following:

> *"Teachers reflect on their teaching practice and actively engage in planning their professional development. Teachers establish professional learning goals, pursue opportunities to develop professional knowledge and skill, and participate in the extended professional community."* [92]

Professional development includes all activities aimed at enhancing teachers' knowledge and pedagogical skills. Early in a teacher's career, beginning teacher support — called induction — can be considered a type of professional development leading to a clear credential (see Chapter 6). In this chapter, professional development refers to activities offered to teachers beyond the induction period, generally after they have earned their professional clear credential. It also focuses primarily on professional development activities for science and mathematics teachers funded by the state, with some discussion of other activities for teachers offered by universities through federal grants, industry and federal laboratories.

Although professional development programs are difficult to categorize, many are designed with a "top-down" approach from school and district leaders that aim to ensure teachers have the same base of knowledge, whether on district or state policy, assessment protocols, or pedagogical strategies. In contrast, a "bottom-up" approach to professional development indicates that teachers have selected and designed the professional development to best meet their own content and pedagogical needs.

[92] California Commission on Teacher Credentialing, California Standards for the Teaching Profession (Sacramento: California Commission on Teacher Credentialing, 2001) 20.

7.1 Federal and State Funded Professional Development

Table 7.1 shows the major state and federal professional development programs and levels of funding in 2006-07. Clearly, state funding predominates, but the distribution of funding across disciplines is revealing.

In 2006-07 California invested just over $850 million in professional development for all teachers. The largest block of state and federal funds for professional development, $579.7 million, was sent to directly to school districts. These two funds, the Teacher and Principal Training and Recruiting (TPTR) Funds and the Professional Development Block Grant, are used by districts to meet their needs for all teacher and administrator professional development and recruitment categories. In addition, state legislation [93] permits districts to transfer up to 15% of the funds from the professional development block grant to other programs.

In 2006-07 California invested just over $850 million in professional development for all teachers.

Table 7.1: Mathematics & Science Teacher Professional Development 2006-07

		All Subjects	Math	Science	Total
STATE FUNDING	AB 466 (Mathematics and Reading Professional Development Program)		16,000 teachers 40 hours		$56.7 million
	CPEC portion of Teacher and Principal Training and Recruiting (TPTR)	459 teachers 380 pre-service teachers			$2 million
	California Subject Matter Projects		~$1.3 million 7,200 teachers	~$1.2 million 3,700 teachers	~$2.5 million
	Professional Development Block Grant				$264 million*
FEDERAL FUNDING	Mathematics & Science Partnerships		~2,500 science & math teachers	~2,500 science & math teachers	$25.8 million
	Federal Laboratories			~5,500 teachers	~$2 million
	Teacher and Principal Training and Recruiting (TPTR) Funds				$315 million*

Source: CFTL (2005); CPEC (2006); CCST (2006)
**Funding includes PD for other subjects*

The next largest block of state funds for professional development, $56.7 million, is the Mathematics and Reading Professional Development Program (MRPDP),

[93] See Assembly Bill 825.

commonly known as AB 466.[94] AB 466 reimburses districts for professional development undertaken by teachers of reading and mathematics. Only providers approved by the California State Board of Education can provide training. The program includes participation in a 40 hour summer institute and 80 hours of follow-up during the school year that is specific to teachers' grade levels and their schools' curricular adoption.

Provisions in the TPTR allocate 2.5% of the funds to improve teacher quality and instructional leadership through partnerships between high-need elementary and secondary schools and postsecondary education institutions. It was reauthorized under the NCLB Act, which pledges federal support to states and local educational agencies to assist in improving the subject matter knowledge of the nation's current and prospective K-12 teaching professionals.

While much of that funding is allocated directly to K-12 agencies, a portion continues to be granted to institutions of higher education through the California Postsecondary Education Commission (CPEC).[95] Since the program's creation, CPEC has received approximately $75 million from the TPTR, and has awarded more than 200 competitive grants to partnerships between California institutions of higher education, local education agencies and non-profit organizations for the professional development of current and prospective teachers. Currently, approximately 30 projects established during the past three years are operated throughout California by institutions in all three systems of public higher education (UC, CSU and the California Community Colleges) as well as various independent institutions and non-profit organizations. The CPEC TPTR grants provided $2 million for the professional development of 459 teachers and 380 pre-service teachers in 2005-06, including science and mathematics teachers. In 2006, CPEC made the focus of its request for proposals the retention of science and mathematics teachers through California Mathematics Project (CMP) and California Science Project (CSP) programs offered by UC and CSU campuses.

Mathematics

The predominant mathematics professional development currently organized and offered by state or local officials is the Mathematics and Reading Professional Development Program. This professional development program is required by the state through AB 466 to meet new state and federal accountability standards for mathematics and reading. The mathematics activities are designed to support the adopted mathematics curriculum, and are provided by state-approved vendors. Most participants are elementary school teachers who teach in low-performing schools. By September 2005, about 16,000 K-8 teachers of mathematics had participated in at least 40 hours of training offered by vendors approved by CDE.

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[94] See Assembly Bill 466 (Mathematics and Reading Professional Development Program).

[95] California Postsecondary Education Commission Improving Teacher Quality Project homepage, http://www.cpec.ca.gov/FederalPrograms/ITQProgram.asp (accessed 1/10/07).

The California Mathematics Project (CMP) is one of the nine subject matter projects in the California Subject Matter Project (CSMP), initiated in 1988 by the California State Legislature as a discipline-based system for the professional development of teachers. The projects are directed by and funded through the University of California Office of the President (UCOP). In the first 13 years the focus was on "...developing teacher leadership, providing programs to individual teachers, and maintaining professional networks of teachers and (university) faculty in the relevant disciplines." [96] In 1997-98 the projects were reauthorized by the state legislature with a significant change in direction. In response to the establishment of the California Academic Content Standards and the goal of increasing the achievement of all students, the CSMP "...emphasized greater alignment with California's content standards, a team approach to training teachers, partnering with low-performing schools and districts, [and] provision of content-based literacy activities to teachers of English Language Learners (ELLs)." [97] With the authorization of the NCLB legislation, the CSMPs also provide technical assistance to low-performing schools and teachers who do not meet the highly qualified teacher requirement.

In 2004-05, the California Mathematics Project (CMP) was funded at $1.3 million and provided 7,238 participants with an average 35 hours of intensive professional development. Elementary teachers comprised 58.3% of the participants, middle school (grades 6-8) 19.3%, high school 13.3%, and other (private, alternative etc.) 9.1%.[98] The teachers represented by these percentages constitute only 10% of middle and high school mathematics teachers in California.

Professional organizations, such as the National Council of Teachers of Mathematics (NCTM), the California Mathematics Council (CMC) and the National Board for Professional Teaching Standards (NBPTS) also provide a number of professional development activities for mathematics teachers. Teachers find these activities particularly useful because the groups address individual teacher needs and development with the understanding that enhanced teacher skills and satisfaction will result in higher quality instruction for students. One example is workshops offered by CMC, during which teachers learn how to improve their skills in teaching problem solving, hands-on learning, and making mathematics relevant and meaningful for all children. Another is the process of becoming certified by NBPTS. The career teacher who has mastered the content and the day-to-day classroom operation is stimulated

ANECDOTAL INFORMATION SUGGESTS THAT PARTICIPATION IN THESE PROFESSIONAL OPPORTUNITIES RESULTS IN MASTER TEACHERS STAYING IN THE CLASSROOM FOR MORE YEARS, AND ALSO DEVELOPS THEIR ABILITY TO MENTOR NEW TEACHERS.

[96] California Subject Matter Projects (CSMP), 2005.

[97] Esch et al., California's teaching force 2004, 64.

[98] The number of teachers served in 2004-05 may be higher than the funding would suggest as most CMP sites were still using carry-over funds to carry out their work.

and challenged by the requirements for National Board Certification. In addition, anecdotal information suggests that participation in these professional opportunities results in master teachers staying in the classroom longer, and also develops their ability to mentor new teachers.

Science

The predominant state-funded program for science teachers is the California Science Project (CSP), which was created over a decade ago as a part of the California Subject Matter Projects. It is administered by the University of California, and programs are offered through both UC and CSU campuses.

The CSP began as a professional development program for experienced science teachers, most of whom were high school teachers with single-subject credentials or accomplished middle school teachers. Since 2003-04, and with an infusion of federal funding through No Child Left Behind (NCLB), however, the project has changed markedly. NCLB funding required the program to expand its earlier objectives to "place greater emphasis on service to the state's lowest-performing schools, to the teachers with the toughest student assignments (including large proportions of English learners), and to teachers who lack adequate subject matter preparation." [99] Also, NCLB added two new teacher groups to CSP: teachers who needed to achieve "highly qualified" status, and teachers in schools that missed their targets for Adequate Yearly Progress.

The result of these changes was that the population of teachers served by the CSP programs shifted from mostly experienced high school teachers to large numbers of elementary school teachers. Data from 2003-04 show that of the 2,221 teachers who participated in CSP, 66.6% were elementary school teachers who had or were pursuing the multiple-subject credential, whereas only 19% were science teachers who had or were pursuing the single-subject credential. [100] The remaining 14% of teachers were typically in a variety of fields and pursuing highly qualified teacher status in science. In contrast to the early years of the CSP, these shifts show a trend away from professional development designed for experienced teachers to a training and even remediation for the purposes of assisting teachers to obtain a credential. Moreover, the small number of participants reveals a relatively small percentage of California science teachers — less than 2.5% — who participated in this state-funded professional development for science.

State funding for the CSP plummeted from just over $4 million in 2002-03, to $1.2 million in 2004-05. In 2003-04, federal funding from NCLB and a state English-learner's grant augmented the state's $625,000 contribution for a one-

[99] H. Alix Gallagher, T. Price, Patrick Shields, Juliet Tiffany-Morales, Marjorie Wechsler, Katherine Baisden, Christopher Chang-Ross, Heather Hough, Paul Hu, Cimone Satele, and Heidi Skolnik, Evaluation of the California Science Project: Final Report (Menlo Park, CA: SRI International, 2005).

[100] UCOP, Data Activity Report for California Science Project.

year program total of $6.5 million. But most of those funds lasted for only one year, and the budget shrank to $1.2 million. Some school districts and regional CSP sites have subsequently contributed additional resources from discretionary or grant funds to help keep programs operational.

In ways similar to mathematics, professional organizations such as the National Science Teachers Associations (NSTA) and the California Science Teachers Association (CSTA) offer annual meetings and workshops for teachers. Sometimes districts will pay for teachers to attend these professional meetings, and teachers attend sessions that match their interests and needs. Until a few years ago, the U.S. Department of Education's Eisenhower Funds were often used to support teachers' attendance at conventions offered by groups such as these. With the passage of NCLB, the Eisenhower program was folded into the TPTR. Because of different reporting requirements, it is not possible to determine how much funding is allocated for professional development specifically for science teachers.

Science and Mathematics

The federally funded Science and Mathematics Partnership (MSP) program "is intended to increase the academic achievement of students in science and mathematics by enhancing the content knowledge and teaching skills of classroom teachers. Partnerships between high-need school districts and the science, technology, engineering, and mathematics (STEM) faculty in institutions of higher education are at the core of these improvement efforts. Other partners may include state education agencies, public charter schools or other public schools, businesses, and non-profit or for-profit organizations concerned with science and mathematics education...MSP is a formula grant program to the states, with the size of individual state awards based on student population and poverty rates." [101]

Since 2003, the California State Board of Education has received over $84 million in funding for MSP from the National Science Foundation and the U.S. Department of Education. With these funds, the state is responsible for administering a competitive grant competition, in which grants are made to partnerships to improve teacher knowledge in science and mathematics.

The Federal Laboratories and Professional Development

Each of California's major federal laboratories has programs designed for science and mathematics teachers. In 2005-06, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratories/ California, the Stanford Linear Accelerator Center, Ames Research Center, and the Jet Propulsion Laboratory collectively spent close to $2 million on teacher professional development programs. Funding comes primarily from NASA

[101] See program description at http://www.ed.gov/programs/mathsci/index.html.

and the Department of Energy (DOE), although some partner organizations contributed substantially both with direct financial and with in-kind contributions to the programs. [102]

More than 5,500 teachers were involved during 2005-06 in a variety of programs ranging from brief one-hour workshops to multi-week internships. Most of the federal laboratories seek to leverage their own resources and expertise directly with teachers, offering content-knowledge training tied in to the actual research being conducted at the facility; this approach is based on the premise that "effective teachers of a discipline must have hands-on experience with the practice of that discipline." [103]

For example, one of Lawrence Livermore National Laboratory's programs, the Teacher Research Academy, gives teachers hands-on experience with cutting edge research; this program involves about 100 teachers a year. The Lawrence Berkeley National Laboratory also has a number of teacher professional development programs including the Laboratory Science Teacher Professional Development Program, which enables teachers from K-12 schools and community colleges to spend four to eight weeks in the summer at Berkeley Lab and continue to work with the lab or another DOE laboratory for a total of three years.

7.2 Industry-Supported Professional Development

Professional development programs for science and mathematics are also offered by a variety of private high-tech companies; one example is the Intel® Teach Program, a nationwide program that focuses on technology integration into the classroom. [104] Other examples are various teacher professional development programs supported by The Boeing Company and Edison International.

A few of these programs have a state-specific focus. The latter two firms, for example, have worked with the California State University in offering mathematics professional development as part of the Early Assessment Program. It has been aimed at equipping teachers to prepare high school students to achieve college readiness in mathematics and avoid the need for remedial course work in college. In view of the value of these and other investments by industry in professional development, it is important to recognize and foster the continued roles of current and additional private sector partners in teacher professional development in California.

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[102] California Council on Science and Technology, California's Federal Laboratories: A State Resource (Sacramento: California Council on Science and Technology, 2006).

[103] Richard Farnsworth and Stanley F. Hitomi, Improving Science Teaching in California, American Physical Society (APS) Newsletter (UCRL-AR-222287), June 20, 2006.

[104] Intel Teach Program, http://www97.intel.com/education/teach/ (accessed 1/10/07).

7.3 Conclusions

California has a wide range of professional development programs, but these vary considerably in target audience, purpose, pedagogical approach and funding. Without comprehensive review of these programs it is difficult to know which programs should be maintained, consolidated or expanded with state funding. While districts arguably are in a better position to assess the needs of their teacher workforces than the state, the preponderance of block grants in statewide professional development funding limits the degree to which the state can assess the effectiveness of the funded activities. Given the scope and scale of the need for fully prepared and effective science and mathematics teachers, and the important role that professional development will play in enabling the workforce to meet this need, it seems logical to consider a more systematic approach to implementing and monitoring the administration of professional development programs.

The preponderance of block grants in statewide professional development funding limits the degree to which the state can assess the effectiveness of the funded activities.

Earlier in this report, we described the importance of science and mathematics teachers for the state's economy, as well as the current shortage of science and mathematics teachers and trends toward attrition and retirement. It is obvious that the state needs to retain as many experienced teachers as possible.

Current state priorities for professional development that focus on helping especially elementary teachers in low-performing schools, while important, neglect the needs of experienced science and mathematics teachers in middle and high schools. Even modest allocations of new funding for professional development would enable expansion of well-regarded programs — such as the California Science and Mathematics Projects — for experienced teachers. Moreover, investments now being made by federal laboratories and industry, designed with and for experienced teachers, may help to stave off the retirement of experienced teachers long enough for much-needed novice teachers to become fully prepared and effective.

CHAPTER 8 - FINDINGS AND RECOMMENDATIONS

California's economy depends heavily on the science and technology sectors. Policies that affect the number and quality of science and mathematics teachers are one critical mechanism to ensure that California remains a national and world leader in STEM fields and in economic competitiveness.

Teachers have a key, proactive role to play in ensuring the delivery of high-quality science and mathematics instruction in elementary and secondary schools that serves as the building block for success in those fields in higher education and in the workplace. It simply makes sense for the state to develop and support policies that prioritize high-quality science and mathematics education for all students, particularly as the state considers strategies to avoid a predicted decline in educational attainment.

California is facing a critical challenge to produce enough fully prepared and effective science and mathematics teachers to meet the demand — both in the short term and the long term. There is a demonstrable, chronic shortage of fully prepared teachers in these areas at the middle and high school level. Our analysis reveals the following:

- **In general, California lacks a coherent system to consistently produce fully prepared teachers, especially science and mathematics teachers.** The current array of teacher-preparation programs (traditional, integrated, and alternative), the placement of out-of-state hires, induction programs, especially those for teaching interns; and professional development for veteran teachers is insufficient to meet the need for effective science and mathematics teaching in all of California's classrooms.
- **The state lacks the data necessary to monitor the supply and demand for teachers.** The recently approved California Longitudinal Teacher Integrated Data Educational System (CALTIDES) is a step in the right direction, but must be fully supported and sustained over time.
- **The state has passed promising legislation to bolster the teacher workforce, but the success of these bold policies is dependent on thoughtful and thorough implementation at the local level.** The omnibus teacher workforce bill (Senate Bill 1209; Chapter 517, Statutes of 2006) and the Quality Education Investment Act of 2006 (Senate Bill 1133; Chapter 751, Statutes of 2006), among other measures, have the potential to bring teachers to high-need schools and encourage them to accept jobs in shortage areas such as science and mathematics.
- **California's teacher-preparation programs do not currently have the capacity to meet the demand for fully prepared science and mathematics teachers.** The various teacher-preparation programs in institutions of higher education (and to some extent, school districts) are not meeting the demand for fully prepared science and mathematics teachers. By fully prepared, we mean teachers who have at least a preliminary credential and are teaching in their field of certification. Instead, there are large numbers of underprepared

teachers who are assigned disproportionately to high-schools with large numbers of poor, minority and English learning students.

- **There is a large percentage of teachers who may be fully prepared, but are assigned to teach science and mathematics out of their area of expertise.** Out-of-field teaching is not limited to urban areas, but is common in districts throughout the state.
- **Although traditional teacher-preparation programs are still the primary routes for entering science and mathematics teachers, there is a strong trend toward alternative routes such as internships.** The demand for new science and mathematics teachers in the late 1990s and early 2000s led to a large number of waiver and emergency hires whose training did not include earning a preliminary credential before entering the classroom. Those authorizations have all but been eliminated as a result of the highly-qualified teacher provision of the federal No Child Left Behind Act, but university and district internships have emerged as an important alternative pathway, especially for science and mathematics teachers. Internships allow novice teachers to work in the classroom full time while simultaneously earning a preliminary credential.
- **Until recently, new teacher-support programs have not been adequate to accommodate novice science and mathematics teachers who are entering the profession as interns.** However, new legislation enacted this year provides money for induction support for interns, but successful implementation of this Mentor Teacher Program will require some changes in infrastructure at the local level, including the recruitment and training of qualified mentor teachers in high-need areas.
- **Professional development opportunities for middle and high school science and mathematics teachers fall short of meeting the increasing need for deeper subject matter content knowledge and pedagogical skill.** There is a need for more high-quality, content-based professional development for science and mathematics teachers, especially those at the middle and high school levels. Federal and state policies are largely focusing resources and attention on elementary school teachers, especially in mathematics and reading. Programs originally designed for middle and high school teachers, especially the California Science and Mathematics Projects, have been re-cast to accommodate state priorities for elementary school teachers. As a result, high-quality experiences for middle and high school science and mathematics teachers are being cut back.
- **California will experience a shortage of new, fully prepared science and mathematics teachers in the next decade due to attrition and retirement of the existing teacher workforce.** A conservative estimate is that there will be a shortage of 33,200 single-subject middle and high school science and mathematics teachers over ten years. Significant issues emerge as to whether or not current teacher-preparation programs can meet the demand for fully prepared teachers. If internship programs expand to meet the need, the problem of underprepared novice teachers may be exacerbated. It is to soon to tell if current efforts within teacher-preparation institutions to increase the numbers of science and mathematics teachers will meet the demand. Increasing the numbers of interns working toward a preliminary

credential while teaching a full load may help to address, but not solve, the shortage problems.

- **California policymakers need to carefully assess the preparation of elementary science and mathematics teachers**. Elementary school teachers play a key role in science and mathematics education, yet not enough is known about how they are prepared to teach science and mathematics in the lower grades, or the skills and knowledge they bring to the classroom.

Recommendations

In light of these findings, we strongly encourage education leaders and policymakers to take the following actions:

8.1 State-wide Education Leadership and Policy Organizations

1. As part of a broader effort to bolster supply of science and mathematics teachers, support the development of programs designed to encourage experienced retirees to enter teaching. Specifically, establish public-private partnerships with industry and business in the areas of science and mathematics to actively recruit retiring professionals to the classroom and place them in internship programs with highly accomplished veteran mentor teachers.
2. Reinstate the Science and Mathematics Summer Institutes offered through the California Subject Matter Projects as a means of increasing support for high-quality, content-based professional development for veteran teachers. Also provide a one-time planning grant for California Subject Matter Project personnel to design and implement just-in-time professional development opportunities to ensure that out-of-field science and mathematics teachers receive the support they need to deliver the required curriculum content effectively so that all students succeed.
3. Build on progress made during the last legislative session to establish a coherent system to recruit, prepare, assign, and retain K-12 science and mathematics teachers, by fully funding the new California Longitudinal Teacher Integrated Data System (CALTIDES) to gather and analyze data and report annually on:
   - The supply and demand of science and mathematics teachers in elementary and secondary schools.
   - The production of single-subject science and mathematics credentials, by field and institution.
   - The numbers of single-subject science and mathematics credentials awarded by institution and type of teacher-preparation program (e.g., traditional, integrated or internship) or to out-of-state prepared teachers.
4. Implement the Memorandum of Understanding (MOU) between the California Community Colleges and the California State University to create a streamlined and strengthened pathway for aspiring teachers by extending these efforts to address articulation agreements between the two systems to support a pipeline for aspiring teachers of science and

mathematics. Coordinate MOU activities with the University of California's program to develop new pathways into the teaching profession by identifying community college students interested in both STEM fields and teaching.

5. As part of the monitoring implementation of SB 1209 and SB 1133, review during budget hearings the extent to which fully prepared science and mathematics teachers are distributed evenly throughout participating school districts.

8.2 Institutions of Higher Education (IHE)

6. As part of the annual self-study put forward by institutions with teacher-preparation programs, examine current teacher-preparation programs to determine how they can be expanded to produce more single-subject science and mathematics teachers. Examine the content and pedagogy elements of these programs for multiple-subject credentials to ensure that all elementary school teachers are prepared to teach science and mathematics. Use the results of the self-study as base upon which improvements to the science and mathematics preparation programs are made.
7. Expand exemplary California Academic Partnership Programs as a means of encouraging IHE campuses to work collaboratively with school districts to ensure that teachers delivered to the classroom are well prepared and supported as new teachers, in both content and pedagogy.

8.3 School Districts

8. Ensure a coordinated, cohesive induction into the profession by using the new Mentor Teacher Support Program established in SB 1209 to offer support for all science and mathematics intern teachers and coordinate this program with the district's existing BTSA program. Fund Subject Matter Projects and other professional development organizations to provide training for mentor teachers to ensure they have the subject matter content knowledge, pedagogical skill and ability to work successfully with adults.
9. Utilize the new professional development block grant funding, the new latitude for developing locally-based professional development programs provided in SB 1209, and resources available to identified schools in SB 1133 to design and implement coordinated, cohesive, coherent professional development programs throughout the districts.
10. Make use of the new provisions in SB 1209 that enable districts and their bargaining units to develop incentive pay systems to encourage teachers to take assignments in shortage areas and attract them to high-need schools.

8.4 Industry, Federal Laboratories, and Informal Science Learning Centers

11. Expand support for professional development of science and mathematics teachers. In particular, provide authentic research and work experiences, especially during the summer months, and build on successful work experience models that integrate the learning of new content with teaching strategies.

APPENDIX A: THE CRITICAL PATH METHOD

A critical path analysis is a method used in the field of project management to define the sequence of tasks in a process or project. A critical path starts with the first step in the project, and follows through in sequence to the final task. By defining each step of the process, it is possible to evaluate the effect of each task or step on the whole system and therefore to identify points along the way where efficiencies can be introduced or improvements can be made.

History: the critical path analysis in industry

Project management and analysis techniques underwent a period of significant development in the 1950s as U.S. military contractors pursued large-scale defense research projects. [105] The critical path analysis method (CPM or CPA) was originally developed in 1957-58, by the Sperry Rand Corporation for the industrial company DuPont, Inc. It was intended for use on construction projects with fixed end dates.

Originally, the CPA was a computer-based scheduling tool that relied on analyzing the process backwards and forwards on an underlying logic network. CPM differs from other scheduling methods because of the separation of planning (the development of the logic network) and scheduling. Essentially, it was a simplified computer simulation of the construction process, which allowed companies to run through the task sequence repeatedly and project how different variables in the tasks would affect the completion date. As the model was dynamic and could be adjusted with new data as the process continued, new outcomes could be projected on an ongoing basis.

Since its creation, the use and application of the CPA has grown tremendously in industry, partly as a result of the more widespread availability of computer power; by the 1990s, over 98% of the top 400 contractors in the U.S. used CPM as a part of project management. [106]

The CPM beyond industrial applications

The government began examining the potential for CPA in analyzing the efficiency of government operations by the late 1960s. [107]

Although generally the CPA refers to computer simulations, the methodology has been adapted as an approach to analyze processes that by their nature are less controlled than industrial contracts, or where insufficient data are present

[105] Kevin Aguanno, Understanding the Critical Resource Path (Hyderabad, India: Institute of Chartered Financial Analysts of India - Center for Management Research, 2002).

[106] A. Tavakoli, and R. Riachi, "CPM Use in ENR Top 400 Contractors." Journal of Management in Engineering, ASCE, 6(3) (1990): 282-295.

[107] Anthony James Catanese and Alan Walter Steiss, Programming for Governmental Operations: The Critical Path Approach, Public Administration Review, Vol. 28, No. 2 (Mar. - Apr., 1968) 155-167.

to enable such a simulation. In essence, the first step in building a critical path model — that of constructing the logic network — is itself useful and can be the foundation for more sophisticated simulations down the road.

In its most basic form, a CPA consists of (1) a breakdown of tasks or steps in a process directed toward one or more definable objectives; and (2) attaching cost and resource estimates to each element in this process. By the early 1990s, this method was being applied to patient care as a quality management tool. [108]

CCST: Critical Path Analyses and the Systems Approach

In the case of statewide "projects" such as education, there seems to be a system in place. Closer examination, however, reveals a patchwork accretion of decades of policy initiatives, often incompatible data systems, and state and local agencies with different authorities, responsibilities and data requirements. Despite the overall vision set forth in the California Master Plan for Education in the 1960s, which defines the roles of UC, the CSU and community colleges, public education in the state is beyond the purview of any single agency, data source, or policymaking body.

CCST has long advocated a "systems approach" in developing comprehensive state strategies for issues such as education. CCST's approach differs from that of the typical CPA in that it applies a critical path analysis as a means of understanding an existing system, rather than planning a new one or streamlining a sequence of procedures (such as that involved in patient care) where procedures are carried out at an individual level and can be more easily rearranged.

With the critical path analysis, CCST studies the education system, consisting of hundreds of institutions responsible for educating millions of students. Unlike finite construction projects, the system cannot be stopped, modified, tested, and restarted. However, by bringing into focus the disparate institutions and agencies as components of a single system, the critical path method is a useful tool to identify key pathways where resources need to be allocated for improvement and to understand the limitations of current data. Perhaps eventually, a more truly dynamic interactive system model may be achieved, one that would enable policymakers to understand and respond to the functioning of the overall system on an ongoing basis.

Methodology

This critical path analysis was a collaborative effort that enlisted principal investigators from institutions around the state to address specific components

[108] P.A. Hofmann, "Critical path method: an important tool for coordinating clinical care," Joint Commission Journal on Quality Improvement, 19(7) (1993): 235-46.

of the teacher development, production and professional development systems. The principal investigators were:

- Herbert Brunkhorst, Professor, Department Chair, Science, Mathematics & Technology Education (CSU San Bernardino): *Science Teacher-preparation in California*
- Pamela Clute, Assistant Vice Provost, Academic Outreach and Educational Partnerships (UC Riverside): *Science and Mathematics Teacher Recruitment*
- Judy Kasabian, Professor of Mathematics (El Camino College): *Descriptive Analysis of Mathematics Teacher-preparation at California Public Colleges and Universities*
- Yvonne Lux, Project Director, The Educational Research and Leadership Institute (California Lutheran University): *A Descriptive Analysis of Professional Development and Induction for Teachers of Mathematics in California*
- Eugenia Mora-Flores, Associate Professor, Rossier School of Education (USC): *Descriptive Analysis of Science and Mathematics Teacher-preparation through Credentialing in the State's Private Colleges and Universities*
- Patrick Shields, Director, Center for Education Policy (SRI International): *The Supply, Demand and Distribution of Science and Mathematics Teachers in California*
- Dan Walker, Director, Science and Mathematics Teacher-preparation (SJSU): *Science Teacher Induction and Professional Development*

In addition, Patrick Callahan, Mathematician in Residence (UCOP), provided important data and guidance for the project.

APPENDIX B: DATA ABOUT SCIENCE AND MATHEMATICS TEACHERS

Why California Needs Good Data on Science and Mathematics Teachers

Effectively planning the statewide production and retention of elementary and secondary science and mathematics teachers will require the collection of more data, such as how many individuals enter science and mathematics teacher-preparation programs, how many go on to take teaching jobs, how many leave teaching before retirement, and why. This kind of information, readily available to policymakers, institutions of higher education, and school districts, will help identify weak points in the science and mathematics teacher pipelines, and can ultimately be used to strengthen the system through strategic policymaking. A better data system for teachers in all grades and subject areas would serve other administrative purposes, such as helping the state and localities comply with the reporting requirements of NCLB and The Williams settlement.[109]

The Current Data System

The following state agencies are the primary collectors and repositories of information about the teacher workforce in California. Data generally are housed by the agencies that collect them, and there currently is no common platform at the state level to link and analyze data from different sources.

- California Department of Education (CDE)
  - One of the major sources of teacher assignment and credential data, CDE's Personnel Assignment Information Form (PAIF), does not differentiate among the different science credentials — all sciences are classified as either physical science or life science. In addition, PAIF data on credential status is inconclusive for teachers with multiple authorizations.
- California Commission on Teacher Credentialing (CTC)
  - CTC houses data on all credentials recommended by institution and credential type (e.g. single-subject, multiple-subject).
  - CTC's assignment monitoring system examines one-fourth of districts per year. Annual monitoring of teacher assignments under the Williams settlement examines schools with APIs in deciles 1-3.
- California State Teachers' Retirement System (STRS)
  - Maintains data on retired teachers from the K-12 and California Community College Systems.
- Institutions of higher education (IHE) that prepare teachers
  - Data on enrollment and completion is provided to the California Postsecondary Education Commission (CPEC). However, reporting from private and independent institutions is not consistent.

[109]The Eliezer Williams, et al., vs. State of California, et al. (Williams) case was filed as a class action in 2000 by nearly 100 San Francisco County students, who filed suit against the State of California and state education agencies, including the California Department of Education (CDE). The basis of the lawsuit was that the agencies failed to provide public school students with equal access to instructional materials, safe and decent school facilities, and qualified teachers. The case was settled in 2004, resulting in the state allocating $138 million in additional funding for standards-aligned instructional materials for schools in the first and second deciles; an additional $50 million was allocated for administration costs, and $800 million is to be provided for critical repair of facilities in future years for schools in deciles one through three. See http://www.cde.ca.gov/eo/ce/wc/wmslawsuit.asp.

- Individual school districts
- At the county level, data are housed in systems that vary in sophistication and are incompatible with one another.

New Chaptered Legislation

Legislation passed in 2006 will, for the first time, allow unique identifiers to be assigned to teachers in California with the creation of the California Longitudinal Teacher Integrated Data System (CALTIDES), which will gather and analyze data from existing sources. CALTIDES, established by Senate Bill 1614 (Chapter 840, Statutes of 2006), is scheduled to be fully functional by 2010. The system is designed only to collate and make accessible data that is currently being collected by the CTC, CDE, and districts, and is not intended to gather new or different data.

Questions that a Unified Data System Should Address

As currently constructed, this distributed data system means that there is limited capacity to answer easily or quickly important questions about science and mathematics education in the state. For example, there is no definitive source of information on out-of-field teaching. CTC's assignment monitoring system examines only one-fourth of districts per year. Annual monitoring of teacher assignments under the Williams settlement examines only schools with APIs in deciles 1-3.

A Unified Data System Would Provide Policymakers with Key Information on Such Issues as:

- How many individuals who begin science and mathematics teacher-preparation programs in California actually complete them?
- Are science and mathematics teacher candidates more likely to take alternative routes into teaching than teachers in other subject areas?
- How many science and mathematics teacher credential program graduates actually take teaching jobs?
- How many science and mathematics teachers hold undergraduate degrees in the subject area they are teaching? How many hold advanced degrees?
- How many people change careers to go into science or mathematics teaching? What are their reasons for doing so?
- How many science and mathematics teachers leave the profession before retirement each year? Why?
- How many of these teachers eventually return to the workforce? Why?
- What is the age distribution of the current science and mathematics teacher workforce? What is their average retirement age?
- How many total science and mathematics teachers will be needed in the next five years? Ten years?
- How many science and mathematics teachers are teaching "out-of-field?" What are the characteristics of these teachers? What kind of experience and education do they have?

A better data system also could serve other general functions. It could:

- Simplify the process of aggregating local teacher data for reporting requirements under NCLB.
- Allow local education agencies to quickly and easily access information from state agencies (such as whether teachers are NCLB-compliant).
- Facilitate the transfer of teacher information across districts and counties.

CALTIDES, once it becomes fully operational, should enable the state to assess the status of its teacher workforce to a much greater extent and fulfill many of the functions listed above. However, the currently planned scope of CALTIDES will only include those who receive a credential of some kind from the CTC, and hence will not address many questions about the teacher-preparation system.

APPENDIX C: SELECTED CALIFORNIA LEGISLATIVE ACTIVITY RELATED TO TEACHERS FROM 2001-06

Since 2001, state legislative activity in California pertaining to teacher recruitment and production has occurred in three categories: incentives for prospective teachers, inducements to increase teacher supply, and policies that would influence teacher quality by modifying or adding requirements for teacher credentialing. The table below charts this activity, highlighting the number of bills that became state law between 2001 and 2006. The bills listed here have impacted teacher recruitment by providing financial incentives to new teachers or school districts, encouraging improved articulation between community colleges and IHEs, or aligning credentialing requirements to federal No Child Left Behind requirements. Few of the bills required any significant appropriation of funds, with most calling for changes in CTC requirements and thus, minimal administrative costs.[110]

2001		
Incentives	**Supply**	**Quality**
AB 1241 (Robert Pacheco): Teacher Preparation Programs Requires Community Colleges in consultation with universities to submit a report to the Legislature on the feasibility of the development of a model teacher preparation curriculum for community college students. This would establish financial incentives and transferability to CSU's for community college students who want to become teachers.	**AB 1307 (Goldberg): Teacher Credential Candidates** Requires the (CTC) to adopt regulations to provide credential candidates enrolled in CTC-accredited preparation programs with time of not less than 24 months to complete the programs without meeting new requirements.	**SB 837 (Scott): Teacher Credentialing: Emergency Permits** Authorizes the CTC to deny a request for an emergency permit that does not meet this justification.
AB 1499 (McLeod): TAP Grants: CLAD/BCLAD Authorizes school districts receiving Teaching as a Priority Block Grant funds to offer incentives to recruit and retain credentialed teachers interested in attaining CLAD/BCLAD.	**SB 57 (Scott): Teachers: Private Schools: Interns** The bill states legislative intent to provide quality standards-based alternative options to teacher credentialing to address the acute shortage of qualified teachers in California's public schools. **SB 321 (Alarcon): Teacher Training: Emergency Credentials: LAUSD** Authorizes the LAUSD to develop, on a pilot 30-day training program for the teachers it hires on an emergency basis and who will be assigned to schools that have 20% or more teachers on emergency permits.	**AB 466 (Strom-Martin): Professional Development** Establishes the Mathematics and Reading Professional Development Program to provide incentive funding for professional development in mathematics and reading to teachers, instructional aides, and paraprofessionals.

[110] Bartholomew et al., 10-11.

2002		
Incentives	**Supply**	**Quality**
AB 2444 (Dutra): State Special Schools: Salaries Requires the consideration of making salaries for teachers, specialists, and administrators of the state special schools and diagnostic centers competitive with the salaries of similarly qualified personnel who are employed by nearby school districts.	No applicable legislation	**SB 319 (Alarcon): Teaching as a Priority Block Grant** Requires, in order to receive a full block grant in the third year of participation, that a school district demonstrates a net decrease in the number of teachers holding an emergency permit or waiver at each school ranked in the bottom half of the API.
2003		
Incentives	**Supply**	**Quality**
SB 162 (Alarcon): Home Purchase Program: Eligible Employees Expands eligibility for federal mortgage credit certificates and reduced interest rate loans, under the Extra Credit Teacher Home Purchase Assistance Program, to include classified employees employed in low performing schools.	No applicable legislation	**SB 187 (Karnette): District Interns: NCLB Act** Clarifies and aligns provisions of the district internship program with university credentialing programs and the federal NCLB Act.
2004		
Incentives	**Supply**	**Quality**
No applicable legislation	**SB 1208 (Vincent): CBEST Exemption: Retired Teachers** Exempts a retired teacher from passing CBEST as a condition of employment in a school district if the teacher has been out of the profession for more than 39 months, as long as the teacher has met certain requirements.	No applicable legislation
	SB 1658 (Karnette): Credentials: Emergency Permits This bill allows the State Commission on Teacher Credentialing to issue emergency permits for a period of less than one year, but not to exceed one year (to allow for the hiring of emergency credentialed teachers in an academic year prior to the NCLB cut-off date for "highly qualified teachers.")	

2005		
Incentives	**Supply**	**Quality**
No applicable legislation	No applicable legislation	No applicable legislation
2006		
Incentives	**Supply**	**Quality**
SB 1209 (Scott): Teacher Credentialing, Training, and Recruitment This bill streamlines duplicate preliminary credential requirements for new teachers who have completed state-adopted credentialing requirements in another state, consolidates testing requirements for teacher credential candidates, provides incentives to strengthen the preparation of teacher interns and induce experienced teachers to teach and mentor new teachers in high priority schools, among other revisions of teacher credentialing law.	**SB 1614 (Simitian): California Longitudinal Teacher Data System** This bill requires the California Department of Education to contract for the development of a teacher data system to be called the California Longitudinal Teacher Integrated Data Education System to serve as a central state repository of information on the teacher workforce to inform policy, identify trends, and identify future teacher workforce needs.	**SB 472 (Alquist): Mathematics and Reading Professional Development Program (MRPDP)** Existing law, AB 466 (Strom-Martin), Chapter 737, Statutes of 2001, establishes the Mathematics and Reading Professional Development Program (MRPDP) to provide local education agencies with incentives to offer high-quality training, including 40 hours of professional development and 80 hours of follow-up training, for teachers in mathematics and reading to be administered by the Superintendent of Public Instruction with the approval of the State Board of Education (SBE). This bill reauthorizes the MRPDP until July 1, 2012
	SB 1209 (Scott): Teacher Credentialing, Training, and Recruitment This bill streamlines duplicate preliminary credential requirements for new teachers who have completed state-adopted credentialing requirements in another state, consolidates testing requirements for teacher credential candidates, provides incentives to strengthen the preparation of teacher interns and induce experienced teachers to teach and mentor new teachers in high priority schools, among other revisions of teacher credentialing law.	**SB 937 (Wyland): Instruction: Science** This bill allows the governing board of a school district to designate a credentialed science teacher to act as a science resource teacher or to provide science staff development for each elementary school.
	SB 1292 (Scott): Teachers: Limited English-proficient Pupils This bill would repeal previous restrictions and authorize a teacher with a designated subjects teaching credential or a service credential with a special class authorization to be assigned to provide specially designed content instruction delivered in English, as defined, if the teacher completes, or enrolls in, specified staff development training.	**SB 1655 (Scott): Teachers: Voluntary Transfers** Prohibits the voluntary transfer of a teacher to a school ranked in deciles 1 through 3 on the Academic Performance Index (API), if the principal of the receiving school refuses to accept the transfer and prohibits a school district from giving priority to a teacher who requests to be transferred over other qualified applicants, as specified.

Source: San Bernardino County Superintendent of Schools (2006); Legislative Counsel (2006).

APPENDIX D: ACRONYM TABLE

Acronym	
ACI	American Competitiveness Initiative
API	Academic Performance Index
APLE	Assumption Program of Loans for Education
BTSA	Beginning Teacher Support and Assessment
CAHSEE	California High School Exit Exam
Cal Teach	California Center for Teaching Careers
CALTIDES	California Longitudinal Teacher Integrated Data Educational System
CBEST	California Basic Educational Skills Test
CBMS	Conference Board of the Mathematical Sciences
CCSSO	Council of Chief State School Officers
CCST	California Council on Science and Technology
CDE	California Department of Education
CFTL	Center for the Future of Teaching and Learning
CMC	California Mathematics Council
CMP	California Mathematics Project
CPA	Critical Path Analysis
CPEC	California Postsecondary Education Commission
CPM	Critical Path Analysis Method
CSET	California Subject Exam for Teachers
CSMP	California Subject Matter Project
CSP	California Science Project
CSR	Class Size Reduction Act
CST	California Standards Test
CSTA	California Science Teachers Association
CSU	California State University
CTC	California Commission on Teacher Credentialing
ELLs	English Language Learners
IHEs	Institutions of Higher Education
ITSDF	Instructional Time and Staff Development Funds
LAUSD	Los Angeles Unified School District
MRPDP	Mathematics and Reading Professional Development Program
MSP	Mathematics and Science Partnership
MSTI	Mathematics and Science Teacher Initiative
NBPTS	National Board for Professional Teaching Standards
NCLB	No Child Left Behind
NCTAF	National Commission on Teaching and America's Future

NSTA	National Science Teachers Association
PD	Professional Development
PPIC	Public Policy Institute of California
S&T	Science and Technology
SBE	State Board of Education
SMI	Science Math Initiative
STEM	Science, Technology, Engineering and Mathematics
STRS	California State Teachers' Retirement System
TAP	Teaching As a Priority
TPTR	Teacher and Principal Training and Recruiting
TRIP	Teacher Recruitment Incentive Program
UC	University of California
UCOP	University of California Office of the President

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In all, this report reflects the input and expertise of nearly 50 people in addition to the principal investigators. Reviewers include experts from academia, state agencies, 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. 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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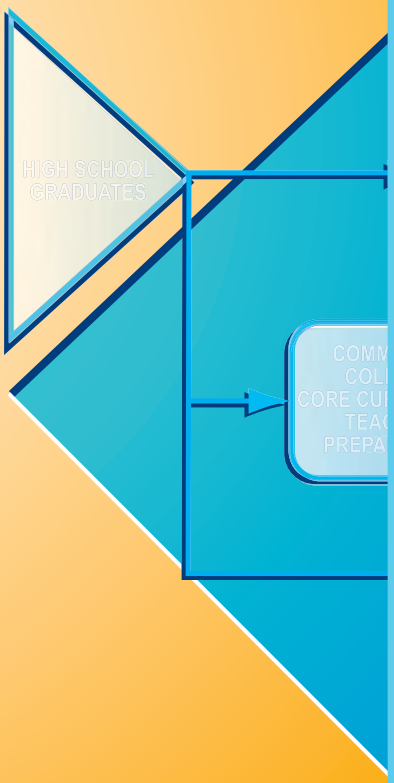

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