SYSTEMIC REFORM
OF SECONDARY SCHOOL SCIENCE

A Review of an Urban U.S. School District:
San Diego City Schools

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INTRODUCTION

All countries have the continuing challenge of improving the student learning of science. Although specific, system, policies, curricula, instruction, and student achievement may vary, their common goals include maintaining adequate numbers of individuals selecting careers in science, technology, engineering, and mathematics and very importantly, achieving high levels of scientific literacy for all citizens. For these two goals, the United States is no different from educational systems in other countries.

Like many educational systems around the world, in the late 1990's San Diego faced the challenges of limited budget, large numbers of poor and minority children, inappropriate instructional materials, and inadequate professional development programs for teachers and administrators. In many respects San Diego, the focus of this discussion, resembles large cities in countries throughout the world. The changing demographics due to increased immigration and the development of one of the world's leading biotechnology and information technology centers brought new demands on the education system and has accelerated the changes needed, increased the urgency and suggested new direction for the reform. The need for systemic reform of school science was pressing. This presentation describes one aspect of reform in San Diego, that of secondary school science.

THE CONTEXT AND ORIGINS OF REFORM

San Diego City Schools is the second largest school district in California; with approximately 143,000 students who are ethnically diverse (with over 60 languages spoken in the home.) 56% of the district's students are considered economically disadvantaged and 29.4% are English language learners. Sixty-three different languages are reported as the language spoken at home. The student demographics are: 39.7% Hispanic, 26.6% Caucasian, 16.4% Asian, and 15.65% American Indian or Pacific Islanders. There are 9,000 teachers staffing the 187 schools in the district. There are 18 comprehensive high schools and 6 non-traditional schools that offer high school coursework. The district is one of the largest employers in the area with over 17,000 employees. The annual district budget is 1.2 billion dollars.

Initiating Systemic Reform
The systemic reform initiative began in 1999 when the school board selected a new superintendent to lead the district in what was described as a "need for change." The new superintendent immediately hired as chancellor an educational reform expert with successful experience in leading large-scale urban district reform. The chancellor assembled a skilled team who began to overhaul, centralize, and standardize teaching in San Diego City Schools. Crucial to this discussion are the central pillars of the plan: identifying and reallocating resources to support student achievement in literacy, mathematics and science, development of instructional leadership, on-going assessment of student progress and reform efforts, and the expectation that all stakeholders are accountable for results.

Richard Elmore's theme: "Improving instruction as the key to improving student achievement" became the district leadership mantra (Elmore, 2000). All classroom teachers and school administrators were expected to attend professional development that supported improved instruction and achievement. Central office administrators, coaches, and consultants worked with the teachers and administrators to that end. Professional learning communities of superintendents, directors, mentors, coaches, and teachers were challenged to improve their practice. These groups met regularly with nationally recognized educational reformers.

The ensuing two years were highly charged as people were moved to accept the changes. The superintendent demoted principals and vice-principals resistant to the changes. The superintendent communicated a sense of urgency that resulted in different consequences for different groups within the district. Two members of the school board became the champions of the teacher's union who decried nearly every reform effort undertaken. Parent groups lined up either for or against the changes taking place. The San Diego business community embraced the new direction of the school district and added financial support to the district. Although many mistakes were made, the focus remained on providing interventions or strategies that improved student achievement. If the strategy or innovation didn't work or contribute to improved student learning, it was abandoned.

The era of accountability also entered the educational arena in California in the late 1990's. The State Board of Education produced academic content standards in science in 1998. The science and education community were divided over the quality of the state's science standards, many describing them as "less than world class." Further confusion existed around the expectation for all high school students to meet standards in physics, chemistry, biology, and earth science while the state's high school graduation requirement is only two years of high school science. Recently the state began to test all students in grades 9-11 using a standards-aligned examination.

In 2000, the administration in San Diego City Schools began a review of high school coursework to determine how well prepared students were to move into the workforce or into a university setting. The district reviewed its student records, convened discussion groups with students, parents, and educators at each high school to discuss the coursework and programs offered to the district's 30,000 high school students. Faculty from the University of California San Diego (UCSD) led the research.

The results of the research revealed several interesting and troubling findings:

- The district had over 2000 courses available for high school students.
- Only 32% of the recently graduated seniors had taken the appropriate courses to allow them to apply for admission to the state's university system.
- Students found most of their coursework to be boring, unchallenging, and unrelated to what they perceived as "relevant to the real world."
- Most teachers felt they did a good job, and student failure was due to factors for which they had no control (student attitude and effort, parental support and supervision, materials, and resources).
- The district's guidance counselors held strong convictions about what courses students should take and were responsible for guiding large numbers of students away from science.
- The achievement gap for certain ethnic groups was widening.
- Review of the science records indicated that about 50% of freshman failed biology and less that 20% of students took chemistry or physics.

Based on these data, the district began to eliminate courses that were not tied to academic rigor that could lead to admission to the University of California or the California State University system. It was the superintendent's stated goal that two-thirds of the graduates in the class of 2006 would meet the state's university admission requirements. This announcement, made in the fall of 2001, charted a new course for the district's secondary education programs including the sciences.

AN INNOVATIVE SEQUENCE OF SCIENCE COURSES

Physics as a Foundation

With a focus on freshmen entering in the fall of 2002, the need to add an additional year of science to the high school schedule was acknowledged. The biology teachers urged a change in the sequence of the science course of study noting that some prerequisite physics and chemistry understanding is needed before the study of contemporary biology can be undertaken. A number of national experts opined that the proper sequence for 21st century high school science instruction should be physics, chemistry, and then biology (Lederman, 2001). In April of 2002, the board of trustees approved the adoption of *Active Physics*, a conceptual physics curriculum for a ninth grade physics courses and increased the graduation requirements for all students to three years of science to include physics, chemistry, and biology in that order. The new requirements would apply to the graduating class of 2006, which meant that the new program would have to be in place in 2003.

Almost everyone supported the idea of three years of science but opposition to physics first for all students emerged from four key groups:

(1) Many physics teachers who taught the eleventh and twelfth grade students were unhappy about the prospect of working with ninth grade students.
(2) Many science teachers were angered that the physics curriculum was selected with little teacher input while others did not understand its instructional design.
(3) Some parents espoused concern that not all students should be enrolled in physics. (Traditionally 10% of students each year took physics at mostly the higher socio-economic schools.)
(4) A national e-mail based organization, Mathematically Correct, which targets programs that use inquiry-based learning instead of text/worksheet instruction, weighed in with their objections.

In response to some of these concerns the course description for physics was submitted to the University of California for approval as a college preparatory course that would meet admission requirements. The approval was granted and the district was commended for selecting an inquiry-based conceptual physics curriculum, *Active Physics*. The reviewer stated, "the curriculum helps students to develop a deeper conceptual understanding of physics, as opposed to the traditional approach to physics instruction, which emphasizes solving numerical problems." (University of California, Office of the President, 2002)

Teacher practice has been the focus of much of the professional development. The science department added three physics teachers to its staff to develop and deliver professional development and support. A teacher support-guide was developed to scaffold instructional practice. Classroom visits, modeling, and peer review became common components of the reform. The department's resource teachers designed an honors physics course for advanced ninth grade students. Piloting teachers received an extra period each day for professional development and collaboration. Physics teachers were released monthly to meet as a professional learning community to review physics concepts (and misconceptions), review student work and assessments, and improve their instructional delivery skills (pedagogy). Currently, six of the district's lowest performing high schools have science administrators (vice-principals), four of whom were physics teachers and members of the district's high school science leadership team. They provide intense coaching and modeling for the physics teachers at the site level. The physics teachers have begun to develop as a professional learning community. They continue to review student work and assessments, discuss content, especially as it relates to misconceptions, and pedagogical practice that supports the needs of the learners.

Chemistry as a Building Block

The groundwork begun in physics, both in curriculum selection and professional development support, made the process of chemistry reform less thorny. The chemistry teachers expected change. They were not, however, prepared to embrace an inquiry-oriented curriculum. Professional development supports were used to help the chemistry teachers become more comfortable with an instructional model that uses an inquiry approach.

In the fall of 2002, a search for a curriculum that would support tenth grade chemistry students led to a National Science Foundation (NSF) supported curriculum that was developed at the University of California Berkeley and the Lawrence Hall of Science, *Living By Chemistry*. Eighteen chemistry teachers in the district volunteered to field test the curriculum and their success led to a decision by the district's chemistry teachers to recommend the program to the board for adoption. Teachers felt they were contributing to the reform and expressed their support to the school board. The board unanimously adopted the curriculum in May of 2003. Summer professional development, monthly professional development meetings, strong support from a university partner, San Diego State University, and strong teacher support are early indicators of a successful start at chemistry reform. Approximately 65 teachers are using the new instructional materials and most report satisfaction with the materials and student interactions. A teacher support guide and an end-of-course assessment will be developed in the summer of 2004.

Biology as a Capstone

Beginning in January of 2003, the district engaged biology teachers in the areas of inquiry and instructional design through a series of meetings led or supported by the Biological Sciences Curriculum Study (BSCS) staff. The science department recognized that a reform-designed curriculum was not enough to ensure student success in a program. Teachers have long been left on their own to piece together lessons, demonstrations, and discussions with the students that often do not lead to conceptual understanding. Most teachers continue to think about a course as the coverage of a certain number of topics in a discipline. The topic is delivered and then the class moves forward. Retraining teachers to check for conceptual understanding, re-teach when necessary, and let students construct their own meaning is a daunting task that is further complicated by teacher mobility. As many as 25% of a science faculty may be new or teaching a new course each year. Therefore professional development must be on-going and differentiated.

Many educators have given a great deal of thought about a curriculum for biology that could be taught to students who have taken physics and chemistry. Science colleagues from the district's high school leadership shared their thoughts, which are synthesized in these remarks in italics. High school students also shared their perspective on this topic.

An excellent summary of many of their remarks about the current state of high school biology is as follows:

> ***The traditional biology course has been an introduction to high school science, typically in ninth or tenth grade, through the understanding of life science topics. It is often dubbed a "second language" course because of the heavy emphasis on memorization of vocabulary words meant to represent concepts rather than by developing true conceptual understanding and application of biological principles***.

The respondents' collective vision for a new course can be summed up with the following:

> ***Students should leave the course with an understanding of the capacity of man to incrementally make sense of the biological world using the process of scientific investigation. This is a valid and necessary endeavor accessible to all students and required of all people to effectively participate in society.***

Taking this ideal to heart, the district's biology teachers gained the opportunity to take the high school biology program in a new direction.

The task of providing a capstone experience in biology for students who've completed both physics and chemistry became the next challenge. The selection committee included representatives from each high school, who worked together for a year. After a thorough review, analysis, and field review, biology teachers in San Diego City Schools recommended *BSCS Biology: A Human Approach* for adoption. In March 2004, the Board of Trustees approved the teachers' recommendation with a unanimous vote. The new curriculum will be implemented in the fall of 2004. A two-week summer institute will help support teachers with the implementation. Seven additional professional development days are scheduled throughout the school year.

CHALLENGES OF SYSTEMIC REFORM

Leadership

Systemic reform in a large urban school district is a considerable task. Relying on the constituents to come to consensus on what improvements need to be made, gathering support, creating a model that represents the views of all is a formidable task. (That approach was deemed inappropriate for the identified needs.) For this initiative the leadership model was quite direct and geared to making immediate changes. The superintendent attended to the political ramifications of making system changes. The chancellor charged the appropriate district level leaders to outline the strategies and identify the human resources necessary to expand the district's capacity to lead the reforms. The instructional leaders (assistant superintendents) were responsible for monitoring and supporting site level leadership. They worked with the principals to increase their knowledge of instruction. The content directors developed the professional development plan for the district's principals and teachers. The teachers were expected to follow prescribed daily agendas using curriculum materials selected to meet the needs of their students.

Curriculum Implementation

Early in the process of reform the district realized the magnitude of and central role curriculum implementation would play. The science department leadership decided to use a curriculum implementation model developed by BSCS with National Science Foundation (NSF) support. The model consists of four stages: *awareness, selection, adoption, and sustainability*.

Curriculum implementation begins with teachers and administrators developing an *awareness* of inquiry-oriented instructional materials. Based on this awareness, the district can build a case for examining the current programs and identifying programs appropriate for teachers and students. In the second stage, *selection*, the district uses a process of Analyzing Instructional Materials (AIM) to determine how well instructional materials align with content, teaching, and assessment standards. In the *adoption* stage, the district science leadership focused on designing and implementing an infrastructure for professional development to support teachers' use of the inquiry-oriented program. Finally, in the fourth stage, district leadership had to analyze the impact of the implementation and establish the district's capacity to *sustain* the reform initiatives.

Several critical elements form the systemic structure of this implementation model. Curriculum materials are central to the reform and establish the basis for the second element, professional development. Professional development is the vehicle by which the reform spreads through the system, first by deepening and broadening teachers' and administrators' understanding of the new program and second by developing support for the reform by all components of the educational system. (Further discussion will be devoted to this critically important element in the next section.) The third element focuses on data-driven decisions, which provided on-going evaluation of the reform efforts. The final two components are development of advocates for curriculum reform and the establishment of policies to sustain the new program and practices.

Although the use of this BSCS implementation model had variations due to unique circumstances in San Diego, in general the district has used the model and found it productive and beneficial.

Professional Development

Leadership development and professional development became critical to supporting, maintaining, and expanding the reform efforts in high school science. To that end the district formed two strong partnerships, one with the National Science Foundation in the form of an Urban Systemic Reform grant (USP) to support K-12 professional development efforts and the second with the SCI Center at BSCS to develop leadership to support secondary science reform initiatives.

The second partnership has helped us develop strong middle and high school leadership teams. The instructional materials review process developed at BSCS, the AIM (Analyzing Instructional Materials) process, has led to the selection and implementation of standards-based and inquiry-oriented instructional materials for grades 6-8, as well as physics, chemistry, and biology. The professional development provided by BSCS staff has greatly helped shape and support the direction of the reform efforts. The teachers' respect for and acceptance of the BSCS instructional model is widespread. Such esteem however has not been easily translated into practice.

Teacher practice has been the focus of much of the professional development. The science department has several secondary resource teachers who develop and deliver professional development and implementation support. Classroom visits, modeling, lesson study and peer review are tools that support the reform efforts. Physics, chemistry, and biology teachers are released regularly to meet as a professional learning community.

Appropriate credentialing is a continuing issue in the district, as it is throughout the country. Although all of the teachers in San Diego were certified in a science discipline (mostly biology), the district prepared to provide coursework for teachers not holding a degree or certification in physics and chemistry. San Diego State University's Center for Research in Mathematics and Science Education (CRMSE) partnered with the district to develop a two-year program for out-of–discipline teachers. A San Diego State "teacher in residence" and a graduate student taught the four-semester upper division physics courses begun in 2002. All teachers not physics certified were enrolled at the district's expense. In year one, the course was designed as a conceptual physics course and focused on the physics content found in the student program. The second year focused on more abstract physics problems along with test preparation for the California Subject Examination for Teachers (CSET) physics exam.

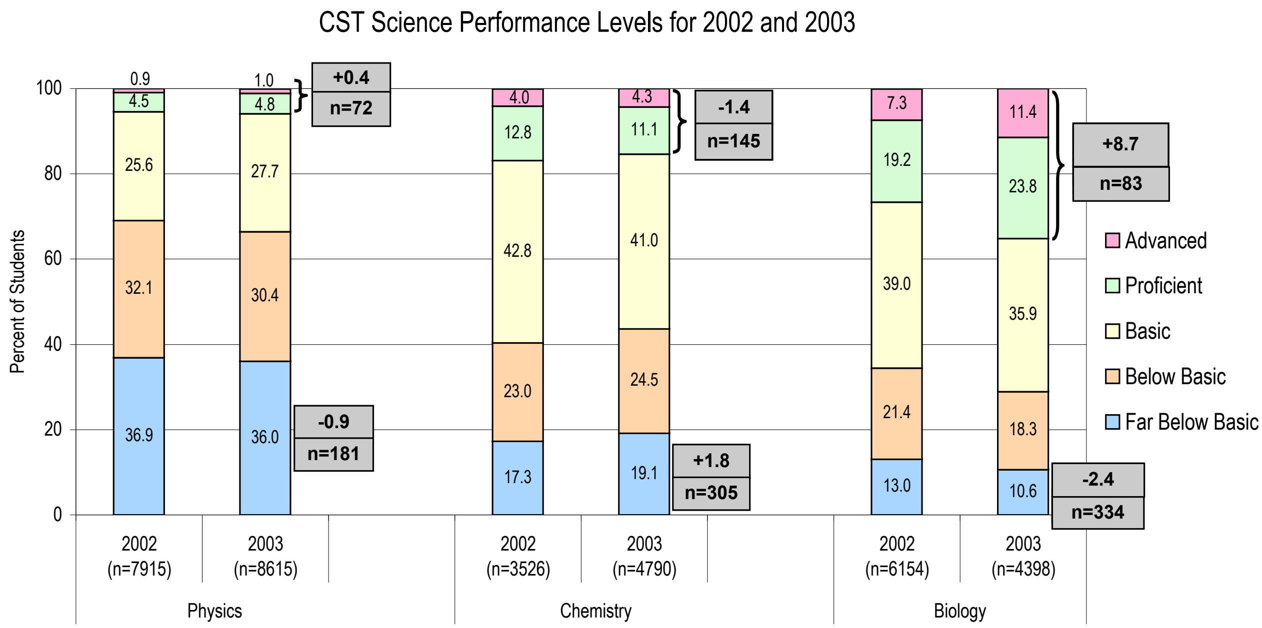
Curriculum and credentialing aside, most teachers were unprepared to support an inquiry-based curriculum. Few had any concrete grasp of a sound instruction model. The management of the instructional materials and equipment for use by all students to develop conceptual understanding overwhelmed many teachers. Many teachers hold deep-seated doubt about the capabilities of their students. They are challenged in evaluating conceptual understanding. The use of multiple measures for evaluation is limited. The assessment system is built around "right" and "wrong" which can serve as a deterrent to assessing concept mastery.

Evaluation

In the last two years, evaluation data has come in the form of teacher-reported information and standards test scores. Course grades lack specific enough criteria to be reliable. The teachers provide regular feedback at the professional development sessions. Using tools such as the Concerns Based Adoption Model (CBAM) and Stages of Concern (SOC), teachers report that they struggle with classroom and materials management, questioning strategies, assessment tools (other than multiple choice), and supporting English learners. The standards test score data show some improvement on moving students to higher performance bands and some success in moving students from the lowest performance band into to the basic level performance band. There is, however, a great deal of room for improvement.

The district has begun to create and administer both end-of-unit and end-of-course assessments. These formative and summative assessments will help identify areas of weakness in student conceptual understanding, which in turn will drive the content of professional development. Creating authentic assessments and performance assessments is a priority. San Diego State University, University of California Berkeley, and BSCS are helping the district with its evaluation efforts.

The following chart compares the performance of high school students on the California Standards Test (CST) in 2002 and 2003. A major element of the reform effort is to focus on the students in the lowest two performance bands to identify strategies that will help improve performance. It is not surprising that a large number of the students in these two bands are identified as English Learners.



IMPLICATIONS FOR AN INTERNATIONAL RESEARCH AGENDA

The international science education community would benefit from a well-established knowledge base about various aspects of systemic reform. Such knowledge has, to some degree, been established by international assessments such as Trends in Math and Science Study (TIMSS) and Program for International Student Assessment (PISA). Although TIMSS and PISA provide some knowledge about curriculum, instruction, teacher preparation, as well as other demographic information, they are assessments of students' knowledge, competencies, and attitudes, not investigations of systemic reform of science. Policy makers, educational leaders, curriculum developers, professional development providers, and those directly responsible for classroom instruction would all benefit from a strong empirical base of curriculum reform. The following suggestions emerge from the reform of secondary school science in San Diego City Schools.

1) Science as Inquiry

Teaching science as inquiry has emerged as a theme with international interest and support. This said, inquiry is usually associated with instructional strategies and the opportunities for students to learn through their own questions and investigations. Note that both of these perspectives have the aim of students' learning science knowledge. These views of science as inquiry have been criticized for their lack of thoroughness and effectiveness.

San Diego City Schools used the United States *National Science Education Standards* (NRC, 1996) as the basis for implementing science as inquiry. In addition to the aforementioned perspective on inquiry, the national standards provide two other perspectives. First, teaching science as inquiry implies providing students the opportunities to develop cognitive abilities associated with inquiry; that is, critical thinking and logical reasoning. Second, teaching science as inquiry means that students learn something about scientific inquiry. An international research for science as inquiry might include:

- Synthesis of students' understandings and abilities of science as inquiry
- Different models of scientific inquiry in instructional materials
- Cross-country comparisons of teachers' perceptions and understanding of science as inquiry
- Different models of professional development vis-a-vis science as inquiry

2) Leadership in Reform

Many believe that reforms such as those experienced in San Diego require extraordinary leaders. What are the common factors in the leadership of the superintendent, top instructional leaders, central office and site administrators that provide the fertile ground for reform to grow in? A thoughtful review of such leaders and their leadership practices could be of benefit to science education professionals.

- Synthesize the qualities of key leaders in successful educational systems
- How do leaders resolve the conflicts over changes in policies, programs, and practices

3) Fidelity of Implementation and Levels of Use

Studying the variations of teacher practice in the implementation of inquiry-oriented curricula raises the question of fidelity of implementation. Certainly in San Diego, as elsewhere, the professional development, whether centrally or site disseminated, results in classroom practice and student performance that are inconsistent with the developer's intent.

- Analyze the differences in student achievement for educational systems that have focused on fidelity of implementation of inquiry-oriented programs
- Analyze the differences in student achievement for educational systems that have focused on levels of use of implementation of inquiry-oriented programs

Relative to the aim of establishing a knowledge base about systemic reform, the identification of an agenda for research is an essential first step. The critical factor, however, is doing the research and reporting the results in a manner that engages the international community of science educators and facilitates the use of that knowledge in future reforms.

In many respects the central recommendation is to do something to demonstrate that international collaboration on investigating some component of systemic reform is achievable. An international effort should begin with a simple study to which all agree and work towards more complex studies as the capacity to conduct international research in science education reform is developed and refined.

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