WCER Working Paper No. 2010-6
April 2010

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> Hora, M. T. (2010). *Factors influencing change initiatives to improve K–20 STEM education at California State University, Dominguez Hills: Final case study of SCALE activities* (WCER Working Paper No. 2010-6). Retrieved from University of Wisconsin–Madison, Wisconsin Center for Education Research website: http://www.wcer.wisc.edu/publications/workingPapers/index.php

The research reported in this paper was supported by a grant from the National Science Foundation to the University of Wisconsin–Madison (EHR 0227016) for a Mathematics and Science Partnership project called System-wide Change for All Learners and Educators (SCALE), and by the Wisconsin Center for Education Research, School of Education, University of Wisconsin–Madison. Any opinions, findings, or conclusions expressed in this paper are those of the author and do not necessarily reflect the views of the funding agencies, WCER, or cooperating institutions.

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Matthew T. Hora

Executive Summary

Institutions of higher education (IHEs) play an important role in math and science education by providing undergraduate instruction, operating teacher training programs, and providing in-service training for K–12 teachers. The System-Wide Change for All Learners and Educators (SCALE) project—funded by a grant from the National Science Foundation (NSF) Mathematics and Science Partnership (MSP) program—sought to effect change in its partner IHEs by creating a "transformative culture" through the development of "cross-cultural teams" that worked at the intersecting nodes among K–12 districts, colleges of education, and colleges of mathematics, science, and engineering (SCALE, 2005). The SCALE theory of action regarding IHEs seeks to achieve the following goals: (a) improve science, technology, engineering, and mathematics (STEM) undergraduate education; (b) improve collaboration between STEM and education faculty regarding preservice programs; (c) improve collaboration between IHE faculty and K–12 districts regarding in-service training; and (d) improve institutional policies and practices that support these activities. As part of the SCALE IHE case studies line of work, this document provides findings on the effects of the SCALE project, along with the Department of Education (ED)–funded Quality Educator Development (QED) project, at California State University, Dominguez Hills (CSUDH) between May 2004 and May 2007. This case study includes two interrelated accounts of SCALE/QED activities: (a) evaluation findings for each of the SCALE/QED activities undertaken at CSUDH and (b) exploratory analysis of how specific aspects of the institutional context influenced SCALE/QED activities. This research was also undertaken at two other SCALE IHEs, the University of Wisconsin–Madison and CSU Northridge (CSUN).

CSUDH, a relatively new university founded in 1960 as part of the California State University (CSU) system, is located in a predominantly minority and working-class area of south Los Angeles. CSUDH is a comprehensive IHE with 44 undergraduate majors, 25 master's degree programs, and several credential programs including a K–12 teacher credential program in the College of Education (COE) that recommended 592 credentials to the state in 2005–2006.

This qualitative case study employs a repeated cross-sectional design and is based on 40 interviews with 29 individual faculty and administrators and documentation data. Respondents included SCALE/QED participants (*N* = 20) and non-SCALE/QED participants (*N* = 9) who were interviewed in mid-2005 and early 2007. Based on preliminary data that emphasized the importance of context and subjective interpretations of institutional life, and theoretical

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The author would like to thank faculty and administrators from California State University, Dominguez Hills, for participating in this case study. I extend special thanks to Susan Millar for her significant contributions to the analysis and final editing of this paper. I also wish to thank Matt Clifford, Joe Ferrare, Eric Osthoff, Laura DeLima, and members of the SCALE Research and Evaluation Team for their support and suggestions, especially Andrew Porter, William Clune, Natalie Tran, and Paula White.

approaches that corroborated and extended these findings (Argyris & Schön, 1978; Bourdieu, 1977; Van Maanen & Barley, 1985), I developed the *institutional context framework* (ICF). The ICF allowed me to organize a complex data set according to discrete categories of the institutional context that were grounded in the experiences of my respondents. The ICF includes the following categories: external influences; internal structure; task-based interactions; resources (i.e., material, social); shared meanings; individual disposition; and instructional practices. Using this classification system, I conducted a thematic analysis of the data using grounded theory and a causal network analysis of conceptually linked indicators, organized temporally with SCALE/QED activities as the mediating condition.

Evaluation Findings

Aspects of the institutional context that *supported* achievement of SCALE/QED goals include the following:

- administrative support for excellence in teaching and pedagogical reform;
- an institution type (comprehensive) that lends itself to a focus on teaching;
- a strong history of interactions with local K–12 districts;
- a cohort of faculty in the mathematics department committed to STEM pedagogy; and
- a population of STEM faculty interested in pedagogical improvement, based on a combination of personal interest and response to student underachievement.

Aspects of the institutional context that *inhibited* achievement of SCALE/QED goals include the following:

- a demanding faculty workload (4 courses a semester);
- state policy that divided responsibilities for teacher preparation between STEM (instruction in content) and COE (instruction in pedagogy) departments;
- STEM faculty’s historic and current lack of exposure to the learning sciences;
- fundamental differences in how COE and STEM faculty think about teaching;
- a local history of conflict between the STEM and COE departments;
- resistance to reform among science faculty, due to standards of scientific legitimacy and the associated primacy of research; and
- misalignment between institutional support for pedagogical reform and faculty resistance at the departmental level, as expressed in recruitment, tenure, and promotion (RTP) policies and prevailing attitudes toward STEM instruction.

Into this institutional context, SCALE/QED introduced a multifaceted intervention that was intended to have an impact on the teacher training and professional development process at multiple points. Attempts to change the *structure* of STEM undergraduate programs included two efforts: (a) revising "gateway" STEM courses and (b) creating new pathways for preservice candidates in mathematics and science. By May 2007, SCALE/QED had enacted changes in the curriculum and structure of Calculus I and II and General Physics I and II sections for a cohort of SCALE/QED students to create sections that modeled a more inquiry-based approach to instruction. The SCALE/QED project also developed applications for state-approved subject matter programs in four STEM departments: chemistry, physics, biology, and earth sciences. This change effort also included the creation of a new astronomy course and STEM course concentrations for liberal studies students. These programs would allow students to satisfy the subject matter proficiency requirement for obtaining a teaching credential. These structural changes would be "institutionalized" as part of the STEM department degree programs and would fill an important gap in the preservice pathways offered at CSUDH. Respondents, however, noted that the ultimate efficacy of these structural changes is contingent on ensuring that the faculty who teach the courses in the new pathways are experienced in inquiry-based pedagogies.

SCALE/QED also attempted to foster changes in the *instructional practice* of individual STEM faculty through one effort: offering professional development workshops for STEM faculty. In 2005, six science faculty, five COE faculty, five math faculty, and two curriculum consultants from the Los Angeles Unified School District (LAUSD) met 4 times. In the 2006–2007 period, five science faculty, two COE faculty, nine math faculty, and three El Camino Community College faculty met a total of 14 times (9 times for the science faculty and 5 times for the math faculty). The STEM faculty participants in these workshops generally represented a single cohort throughout this 3-year period.

Finally, SCALE/QED attempted to foster *interinstitutional collaborations* between CSUDH faculty and the K–12 sector through one effort: designing and facilitating K–12 professional development institutes in both science and mathematics. CSUDH faculty and SCALE/QED leaders organized and facilitated 23 one-week science institutes on three different CSU campuses. Of these, seven science institutes were held at CSUDH for 176 LAUSD science teachers. As part of the science institute activity, five science immersion units were collaboratively designed by CSUDH STEM and education faculty and LAUSD teachers and science experts. As for workshops in mathematics, five math institutes were held at CSUDH for 106 LAUSD middle school math teachers. As a result of participating in activities associated with these two efforts, five STEM faculty respondents reported changes in their instructional practices and attitudes toward the learning sciences and the K–12 sector. In addition, SCALE/QED fostered a new cohort of science faculty engaged in pedagogical issues, the science immersion unit process created new working relationships between CSUDH and LAUSD personnel, and the internal capacity of CSUDH to engage in K–12 related STEM educational activities was enhanced.

To better understand the specific mechanisms of change associated with SCALE/QED activities, I analyzed one of these interventions—the STEM faculty development workshops. Initially, the institutional context relevant to this effort included an institutional atmosphere amenable to change, structural and sociocultural divisions between the two colleges, and limited exposure of STEM faculty to the learning sciences (except for a small number of math faculty). SCALE/QED successfully addressed these conditions by creating a structure for intercollege interaction, providing funds to release faculty from their demanding workload, and engaging a skilled COE faculty member who designed and facilitated the sessions. A critical aspect of this success was the facilitator, who focused on ameliorating disciplinary stereotypes and divisions, making lessons relevant and applicable to STEM, being sensitive to STEM faculty's rate of change, and encouraging a degree of comfort with pedagogical topics. Also, by treating the STEM faculty not solely as content experts but also as professional educators, the facilitator allowed faculty's unconscious assumptions about teaching and learning to surface. Outcomes related to this activity include reported changes in STEM faculty's instructional practices and their views of teaching and learning, and the formation of a cohort of science educators. However, respondents cited factors—including RTP policies that generally do not reward pedagogical improvement, disciplinary standards that base legitimacy as a scientist exclusively on research accomplishments, and an uncertain future for the long-term viability of these workshops—that may compromise these outcomes.

Analysis of SCALE/QED Effects in Terms of Institutional Context Factors

The theory of change guiding SCALE/QED was to "create a transformative culture" at CSUDH. Determining whether SCALE/QED "changed the culture" of CSUDH, however, was not possible because "culture" was not defined and constructs to measure cultural change were not established in the research design. However, the focus on subjective interpretations of institutional life that inform this case study did allow for an *exploratory* analysis of the deeply held explanatory structures, known as cultural models (Shore, 1996; Strauss & Quinn, 1997), that individuals hold regarding specific domains.[1] In this case, the domain under consideration is that of STEM instruction. Analysis of respondents' espoused theories regarding STEM instruction made it possible to ascertain the broad outlines of the prevailing cultural model held by STEM respondents about STEM instruction. These outlines are composed of the following linked propositions, known as *schemata*:

- Science instruction is based on transmitting facts and emphasizes experiential learning through involvement with lab or field research.
- The learning sciences have value, but that value is unclear.
- COE faculty tend to be impatient and unfamiliar with the STEM disciplines.
- Improving STEM instruction will benefit the public.
- The limited academic abilities of students inhibit effective instruction.

Although this cultural model might be dominant among the STEM respondents, it is differentially expressed based on individual disposition and context and, in my analysis, coexists and interacts with other cultural models and is modified or reinforced through interaction with

[1] It is important to note that this is an exploratory analysis, and that further research employing methods developed specifically for schema identification should be pursued.

four distinct but intersecting "fields" of activity: the institution, the department, the subgroup, and the student body. By skillfully engaging STEM faculty in cross-disciplinary working groups and in problematizing and reconceptualizing their instructional practices, SCALE/QED actors enabled STEM faculty to make explicit and then change their cultural model for STEM instruction. At the individual level, this type of change may be considered an essential step towards reflective teaching; at the institutional level, in contrast, this change may be viewed as *double-loop learning*, whereby group members begin to question their basic assumptions about a topic. Although less visible than structural change, double-loop learning is considered a fundamental component of institutional change (Argyris & Schön, 1978). The relationship between individual cultural models and the social and technical context in which they are locally enacted will be investigated in greater detail in future research.

I postulate that the enacted theory of change for SCALE/QED was that to bring about improvement that is sustained over time, change must be pursued simultaneously on structural, social, and individual levels. This approach is consistent with research findings on institutional change processes in educational organizations (Gamoran et al., 2003; Seymour, 2001). Although the SCALE/QED program was fortuitously aided by preexisting conditions at CSUDH, such as administrative support for reform and an influx of new faculty due to faculty retirement, SCALE/QED successfully planted the seeds for future changes at each of these critical levels. As a result, elements for systemic reform supportive of the MSP goals appear to be in place at CSUDH. However, certain factors at CSUDH that remained unchanged might provide resistance to diffusing or incorporating these changes at the departmental level. The primary points of resistance are the demanding workload, which minimizes faculty engagement in programs such as SCALE/QED, and growing pressure on faculty to focus on research accomplishments. I postulate that this pressure is related to the prevailing cultural model of many STEM faculty and administrators regarding the primacy of research and its role in establishing and reinforcing the scientific credibility of individual faculty, departments, and the institution as a whole.

I consider the theory of change underlying SCALE/QED promising, and with regard to replicating elsewhere the successes of SCALE/QED at CSUDH, I bring attention to these additional observations from this case study:

- Faculty experiences and institutional change processes cannot adequately be understood using a unitary and homogenous understanding of "institutional culture" or climate.

- Any change effort should begin with an institutional needs assessment in order to identify the local contextual factors that might provide barriers and opportunities to reform, especially structural constraints for faculty practice (e.g., workload, lack of cross-college interactions).

- NSF should be aware of the potential for the design of the MSP program to exacerbate existing tensions between STEM and education faculty and should consider requirements that more directly involve COE in the achievement of its goals.

- Critical leveraging points in altering faculty members' cultural model of teaching and learning may rest in the surfacing of individual assumptions about teaching and encouraging individual faculty to "think like novices"—processes likely to be accomplished through skillfully facilitated professional development experiences.

- Further study of the history of the CSUDH mathematics department and analysis of other contexts and situations where a critical mass of reform-oriented faculty are working effectively alongside more traditional colleagues may yield better understanding of the formation of STEM education cohorts within STEM departments.

To help ensure the success of this theory of change as it unfolds at CSUDH, I propose the following recommendations to CSUDH and to NSF, the Department of Education, and other agencies interested in the MSP goals for IHEs. With regard to improvements at CSUDH, I recommend that (a) SCALE/QED leaders and CSUDH administrators ensure the continuation of the professional development workshops for STEM faculty by institutionalizing this activity, guaranteeing funding for faculty release time, and ensuring that a highly skilled facilitator is available to negotiate the sociocultural divisions between the STEM disciplines and the learning sciences; (b) SCALE/QED leaders target specific departments and clusters of faculty for participation in these workshops in order to achieve critical mass and minimize departmental resistance to pedagogical change; and (c) campus leaders consider the viability of policy levers (such as those afforded by the accountability movement) while simultaneously finding ways (such as the first and second recommendations above) to foster changes in the prevailing cultural model for STEM instruction so that faculty are amenable to such efforts.

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I. Introduction

Institutions of higher education (IHEs) play an important role in mathematics and science education by providing undergraduate instruction, operating teacher training programs, and providing in-service training for K–12 teachers. The System-Wide Change for All Learners and Educators (SCALE) project—funded by a grant from the National Science Foundation (NSF) Mathematics and Science Partnership (MSP) program—sought to effect change in its partner IHEs by creating a "transformative culture" through the development of "cross-cultural teams" that worked at the intersecting nodes among K–12 districts, colleges of education, and colleges of mathematics, science, and engineering (SCALE, 2005). The MSP program aims to improve the coordination among science, technology, engineering, and mathematics (STEM) undergraduate education, teacher preparation programs, and K–12 professional development by fostering mutually beneficial partnerships between IHEs and K–12. The SCALE theory of action focused on (a) improving STEM undergraduate education; (b) improving collaborations between STEM and education faculty regarding preservice programs; (c) improving collaborations between IHE faculty and K–12 districts regarding in-service training; and (d) improving the institutional policies and practices that support these activities. As part of the SCALE IHE case studies line of work, this document provides findings on the effects of the SCALE project, along with the Department of Education (ED)–funded Quality Educator Development (QED) project, at the California State University, Dominguez Hills (CSUDH) between May 2004 and May 2007. This case study includes two interrelated accounts of SCALE/QED activities: (a) presentation of evaluation findings for each of the SCALE/QED activities undertaken at CSUDH and (b) analysis of how specific aspects of the institutional context influenced SCALE/QED activities.

A. The Mathematics and Science Partnership Program

This section provides the background to the MSP program, a discussion of MSP goals and implementations, and a brief overview of the enactment of the SCALE MSP project.

The Problem: Declining Performance of U.S. Students in Mathematics and Science

The performance of U.S. students in mathematics and science has become an increasingly pressing problem, particularly in light of the implications for the future competitiveness and employability of U.S. citizens. As numerous studies and reports attest, the problem is systemic, with challenges including public policy, funding, and curricular strategies that span the educational continuum from higher education to K–12 (Committee on Science, Engineering, and Public Policy [COSEPUP], 2006; National Research Council [NRC], 2000; Project Kaleidoscope, 2006; U.S. Department of Education, 2006a; U.S. Office of Science and Technology Policy, 2006). Most recently, researchers and policymakers are focusing on the importance of a teacher workforce that is more highly trained in science and mathematics

(Levine, 2006; U.S. Department of Education, 2005). Indeed, the 2006 COSEPUP report suggested that an appropriate goal to address the eroding U.S. advantages in mathematics and science is to produce 10,000 qualified teachers annually. This goal addresses the "chronic and growing shortage of discipline-qualified K–12 teachers" that researchers have been warning policymakers about for several years (Seymour, 2001). This shortage is illustrated by the fact that in 2000, 93% of students in Grades 5–9 were taught physical science by an instructor who lacked a college major or certification in the physical sciences (National Center for Education Statistics [NCES], 2004). The Bush administration's No Child Left Behind (NCLB) mandate that all school districts must employ only "highly qualified teachers" provides further evidence that the issue of teacher workforce quality in science and mathematics is a critical national issue.

One of the many challenges in reforming teacher preparation and professional development practices in the United States is the complex nature of the preparation process. For example, in order to qualify for certification to teach at the K–12 level, most future mathematics and science teachers must navigate both teacher preparation programs in schools of education and disciplinary requirements in STEM departments at accredited IHEs. After employment, they then participate in professional development programs that are governed by state and/or district policies and offered by an array of providers including private vendors, district specialists, and IHE faculty. Thus, individual K–12 teachers obtain their mathematics and science content and pedagogical training from diverse institutions and stakeholders and in programs that are governed by diverse policies that operate in isolation and with little coordination (NRC, 2000). As a consequence, the quality of this training often is uneven, if not haphazard (Mundry, Spector, Stiles, & Loucks-Horsley, 1999). In 1998, the NRC addressed this multi-institutional problem by establishing a Committee on Science and Mathematics Teacher Preparation (CSMTP). The CSMTP report (NRC, 2000) stated that a significant restructuring of the relationship between K–12 schooling and higher education, including new partnerships to collaboratively design and implement high-quality professional development programs, is required to adequately prepare and train effective K–12 teachers.

Background to the MSP Program

The growing focus on improving the alignment of the teacher training continuum is among the reasons NSF has invested substantially in teaching improvement and organizational change in higher education—most recently through its MSP program. These concerns reflect development in some national policymakers' understanding of the role that higher education plays in preparing future teachers, expanding beyond long-held critiques of teacher preparation programs to include a closer examination of the role of disciplinary faculty in the STEM disciplines.

As noted, the MSP program aims to improve the coordination among STEM undergraduate education, teacher preparation programs, and K–12 professional development by fostering mutually beneficial partnerships between IHEs and K–12 districts. Specifically, it hopes to encourage partnerships between STEM disciplinary faculty, education faculty, and IHE administrators with the K–12 districts they serve in "efforts to effect deep, lasting improvement in K–12 mathematics and science education" (NSF, 2002). The MSPs are based on the premise that IHE/K–12 partnerships should draw on the disciplinary expertise of STEM faculty and graduate students as well as on undergraduate STEM (including preservice) students to develop strong mathematics and science content knowledge and pedagogical methods. Thus, the theory of change of the MSP initiative is predicated on increased involvement of faculty in the STEM disciplines in the teacher training continuum, in order to effect lasting improvements in K–12 student learning (Shapiro et al., 2006; NSF, 2002).

Specific Problems Addressed by the Mathematics and Science Partnership Program

The MSP program seeks specifically to address instructional quality in STEM undergraduate education, the rigor of teacher preparation programs, IHE participation in professional development programs, and current challenges to higher education reform.

STEM undergraduate instruction. Critiques of the quality of teaching in higher education began in the 1980s with *A Nation at Risk*, by the National Commission on Excellence in Education (NCEE, 1983). Since then, we have seen a cascade of criticisms of higher education, culminating in the U.S. Department of Education's *A Test of Leadership* (2006b). Critics noted that many STEM undergraduate majors graduate with substantial deficiencies in their content knowledge (e.g., Handelsman et al., 2004). Researchers have identified high rates of attrition among undergraduate science majors as one of the consequences of poor undergraduate instruction and academic assistance (Seymour & Hewitt, 1997). Because in most states, students seeking to earn secondary school teaching credentials are among these science majors and in all states students seeking to earn primary and secondary school teaching credentials take STEM courses, national policymakers are increasingly recognizing and scrutinizing the roles that STEM faculty play in the teacher training continuum by instructing preservice candidates in disciplinary content and modeling pedagogical methods. For example, the NSF report *Shaping the Future* (1996) recognized these roles when it urged STEM faculty to use active learning strategies in their undergraduate courses— not only to help students understand discipline content more deeply, but also to model effective pedagogy that future teachers can use in their own instruction.

Teacher preparation programs. The 2006 COSEPUP report suggested that an appropriate goal in addressing the eroding U.S. advantages in mathematics and science is to produce 10,000 qualified teachers annually. Achieving this goal will require addressing the long-standing critiques of teacher preparation programs and the colleges of education that operate them (Labaree, 2004). In particular, critics have charged that college curriculum for preservice candidates is poorly designed and insufficiently grounded in rigorous content courses and/or pedagogical instruction (Labaree, 2004; Mundry et al., 1999). In addition, policy bodies such as the CSMTP (NRC, 2000) and NSF-funded practitioner reformers have urged greater collaboration across departments and colleges within an IHE with respect to teacher preparation. In response to these critiques and recommendations, many initiatives both within and outside of IHEs are under way to improve teacher preparation and training (Robinson, 2006). Among these initiatives are several, including the NSF's Collaboratives for Excellence in Teacher Preparation program (CETP) and the MSP program, that focus on the role of STEM and education faculty in organizing and delivering a solid curriculum. However, critical gaps remain in our understanding of teacher education programs, including the effects of subject-matter coursework on teacher knowledge (Cochran-Smith & Zeichner, 2005), and the relative efficacy of different teacher education pathways (Darling-Hammond, Chung, & Frelow, 2002).

IHE participation in professional development programs. In-service training in disciplinary content and pedagogical methods, which authorities suggest should occur on a regular basis (U.S. Department of Education, 2005), is a key venue for enhancing K–12 teacher mathematics and science knowledge. There is a large body of research on the efficacy of professional development programs, and researchers are increasingly questioning the efficacy of the traditional model of professional development, in which IHE faculty or other "experts" deliver "knowledge" to K–12 teachers (Garet, Porter, Desimone, Birman, & Yoon, 2001). This approach is considered ineffectual because it is decontextualized, treats teaching as a routinized and technical activity, and stresses "additive rather than transformative change" (Carlone & Webb, 2006, p. 545). Possible solutions to this problem include paying closer attention to the context of professional development design (Ball & Wilcox, 1989), fusing content and pedagogy by involving both disciplinary and education IHE faculty (U.S. Department of Education, 2005), and explicitly building on novice teacher's prior experiences or knowledge (Mundry et al., 1999).

Challenges to higher education reform. The MSP program is facing the extremely difficult undertaking of fostering change in higher education, a sector known to be very resistant to change ("Teaching and Learning" [Cuban interview], 2000). Researchers cite the persistence and resilience of institutional tradition (Kezar & Eckel, 2002), the decentralized and "loosely coupled" nature of IHEs (Birnbaum, 1988), and the unique elements of organizational structures and autonomous cultures (Schroeder, 2001) as characteristics of IHEs that make them resistant to change efforts. Furthermore, historic divisions between STEM and education faculty, and between higher education and K–12 education, may inhibit collaborative activities between the two sectors (Gilroy, 2003; Labaree, 2004). These challenges are pertinent to the MSP program and may account for limited effects of this program on STEM faculty and institutional processes. For example, a 2006 review of institutional changes of 21 MSP higher education partners found that curricular changes were occurring at IHEs across the MSPs, but with the majority of the changes in preservice programs and in-service professional development and few in STEM departments. Furthermore, changes were at the individual level instead of the institutional level, with no department-wide initiatives or collaborative team efforts (Shapiro et al., 2006). An analysis of STEM faculty engagement in the MSP program similarly found little evidence of institutional change, but significant individual-level shifts in STEM faculty knowledge of and participation with K–12 education (Zhang et al., 2007). This study also found that the effect of STEM faculty engagement in the teacher training continuum is difficult to ascertain and that effects on student learning are even more elusive.

SCALE Theory of Change and Goals Regarding IHEs

SCALE sought to effect change in its partner IHEs by creating a "transformative culture" through the creation of "cross-cultural teams" that worked at the intersecting nodes among K–12 districts, colleges of education, and colleges of mathematics, science, and engineering (SCALE, 2005).

The SCALE theory of action regarding IHEs focused on the following goals:

1. Reform undergraduate STEM courses.

2. Promote collaboration between STEM and education departments regarding preservice teacher education.

3. Promote collaboration between IHEs and K–12 districts regarding in-service professional development.

4. Improve institutional policies and practices at the IHE level that support faculty engaged in pre- and in-service activities.

However, SCALE leaders neither defined nor made operational the construct of "organizational culture," nor did they articulate measurable objectives for the four goal areas of the IHE case studies. Thus, rather than measuring progress toward a set of clearly defined objectives or evaluating the program according to a set of established criteria, this evaluation design focused on describing program activities and assessing how well subsequently observed effects met stated goals.

B. Methodology of the IHE Case Studies

This section includes a description of the theoretical framework guiding the research, the research design, and the organization of the case study.

Research Design: Qualitative Case Study Using a Repeated Cross-Sectional Design

This research is a qualitative case study using a repeated cross-sectional design (Bernard, 2002). This study is both a *descriptive* analysis of the SCALE program and an *exploratory* analysis of how aspects of the institutional context influenced a STEM education reform effort. The research questions for the IHE case studies line of work were informed by the dual need to evaluate the SCALE MSP and to more deeply examine the reasons why SCALE did or did not achieve its goals and objectives. Hence, I posed these research questions—which mirror the SCALE theory of change—about each IHE studied:

1. How does the institutional context influence STEM instruction, STEM and education faculty collaborations on preservice programs, and IHE and K–12 collaborations on in-service programs?

2. Are SCALE activities contributing to changes in SCALE's primary goal areas? If so, how?

3. Under what conditions are change initiatives, including SCALE, accepted and incorporated at the institution?

Because the research questions focus on multidimensional change processes (i.e., individual instruction, group collaboration, institutional change) within a complex institutional environment, an embedded case study method was selected. This design was selected due to its utility in conducting empirical inquiry into a "contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 23). An embedded case study contains more than one subunit of analysis, in this case ranging from individual faculty to academic departments to the institution as a whole. Moreover, qualitative case study research is particularly appropriate for descriptive and exploratory studies that seek to grasp the "how" and "why" elements of project operations (Merriam, 1998). Because the how and why elements would presumably yield valuable information for funders and planners on contextual factors in MSP program implementation and outcomes (Owen & Lambert, 1998), this design seemed particularly appropriate for the SCALE/QED project.

The Theoretical Framework

The theoretical framework guiding the preliminary phases of this case study was that of ethnographic research, in which I attempted to describe the IHE context and the SCALE/QED implementation in a grounded and multidimensional fashion, based largely on the perspectives and experiences of local participants. Based on findings from the preliminary IHE case studies, I conducted a cursory literature review in higher education, sociology, anthropology, and management, in order to better understand my preliminary findings (Hora & Millar, 2007 Scholl, Millar, & Owusu-Yeboa, 2006).

The theoretical framework guiding this final case study is based on related traditions of research on the relationship between individual agency and institutional structures in the fields of sociology, education, and anthropology. Lave and Wenger's (1991) work on situated learning contributed to the notion that institutional behavior is best understood by viewing agency, structure, and the broader world as mutually constitutive. Bourdieu (1977), in his theory of social practice, posited that individual agency or practice can be viewed as the cumulative product of multiple, overlapping "fields" of social action, the capital obtained and expended by individuals, and personal disposition or habitus of individuals (Bourdieu, 1984). Finally, Geertz (1973) contributed a theory of culture that is not, as he put it, a "superorganic reality with forces and purposes of its own (p. 11)," but instead is a public and shared system of symbols that constitute "structures of signification" (p. 9). The long-standing conundrum in anthropology of where to locate cultural forms—in the individual or in the group—has been addressed by the work of cognitive anthropologists, who have asserted that individuals internalize these "structures," or models of cultural form that shape how individuals think and act (Shore, 1996; Strauss & Quinn, 1997). These perspectives highlight the importance of accounting for different elements of an institution in order to understand specific practice and have influenced the development of the institutional context analysis instrument used in this case study.

Data Collection

The types of data collected include *semistructured* interviews (N = 40) with 29 faculty and administrators, and relevant university documents. The interviews used a standardized interview protocol for different types of respondents (i.e., STEM faculty, education faculty, administrators). Respondents included both SCALE participants, selected based on their involvement with SCALE, and non-SCALE participants, selected randomly using department staff directories. *The nonparticipants were included to test and/or confirm findings from the SCALE participants, who might reflect a biased sample regarding their perceptions of the institutional context.* Documents related to the university were also collected and analyzed, including reports from the university's Office of Institutional Research, strategic plans, external evaluations of related programs, and recruitment, tenure, and promotion (RTP) policies.

The study was designed as a cross-sectional analysis of the IHE at two points in time: Time 1 (June–July 2005) and Time 2 (December 2006–January 2007). At Time 1 (T1), a total of 23 interviews were conducted: 17 with SCALE participants and 6 with non-SCALE participants. At Time 2 (T2), a total of 18 interviews were conducted: 10 with SCALE participants and 8 with non-SCALE participants. Due to respondent unavailability and faculty turnover (at both CSUDH and with SCALE), only 8 SCALE participants were interviewed at both T1 and T2. Documents were identified by both respondents and researchers and were analyzed at both T1 and T2.

Data Analysis

This research is both exploratory *and* explanatory. It is exploratory due to the lack of knowledge of the local contexts prior to data collection, which necessitated the identification of the local context for T1 through the inductive analysis of the interview and document-based data. This analysis led to the development of a new analytic tool, the *institutional context framework* (ICF). Once an informed understanding of the local context was achieved, the analytic strategy shifted to an explanatory mode in order to understand why certain phenomena were occurring. For the explanatory phase, I conducted a causal network analysis that integrated the ICF (Miles & Huberman, 1994). This section includes a description of the types of analysis used, issues in the data analysis, and the limitations of the design.

Inductive analysis of T1 qualitative data. I utilized a grounded theory approach to analyze the interview and document-based data from T1 in the tradition of Strauss and Corbin (1990), in which a structured coding system was used to analyze the data and identify discrete themes and patterns (Ryan & Bernard, 2003).

The institutional context framework. The broad categories of the ICF classification include indicators that could be used to track changes in institutional contexts. The semistructured interviews focused on eliciting respondent perspectives on each of these indicators and their interactions, if any. It is important to note that these categories were derived from analyses of complex institutional environments that were exclusively focused on STEM education, teacher preparation, and IHE/K–12 partnerships (Hora & Millar, 2007). Because this framework has not yet been applied to other IHEs using other research questions, it is possible that it adequately models only categories related to SCALE goals. The following categories were the basis of the SCALE ICF:

- *External influences.* Institution type, national and state education policy, academic training of faculty, economic forces affecting education, and local K–12 characteristics.

- *Internal structure.* Geographic location, organizational structure (i.e., governance, teacher education programs, STEM degree programs), student body composition, instructional workforce composition, personnel policies, leadership, and reform initiatives.

- *Task-based interactions.* Structure of interactions between STEM and education faculty, and between IHE and K–12 faculty.

- *Resources.* Material resources (i.e., time, funding) and social resources (i.e., community of practice).

- *Shared meanings.* Societal values and interpretations about the fields of STEM and education, institutional values and interpretations about the institution's mission and identity, and disciplinary values and interpretations about academic disciplines.

- *Individual disposition.* An individual's workload considerations, personality, background and training, views on instruction, and status.

- *Practices.* An individual's classroom instruction (planning and delivery) and collaborative activities.

Establishing the institutional context at T1 and T2. I coded the T1 and T2 interviews using NVivo qualitative analysis software and a coding scheme based on the classification system. This coding scheme included three different passes, the first focusing on components of the institutional context and SCALE activities, the second focusing on barriers and supports for SCALE activities as identified by respondents, and the third focusing on observed changes in the institutional context. Using codes from the first pass, I then constructed a preliminary map of the institutional context at T1; using codes from the third pass, I constructed a final map at T2. These maps are not intended to represent the "actual" operations of CSUDH, but instead are "mental maps" composed of respondents' perceptions and experiences.

Verifying respondent-identified causal links through causal network analysis. I then conducted coding and matrix queries in NVivo to identify links between the institutional context at T1, SCALE activities, and observed outcomes at T2 (see Figure 1). These respondent-identified links were then summarized and stored within "conceptually clustered matrices," which allowed for the verification and analysis of causal relationships between two factors (Miles & Huberman, 1994). Causally linked factors were only included after meeting three criteria: (a) reference by at least three respondents, (b) lack of counterfactuals after follow-up queries to the data, and (c) verification by brief follow-up interviews or e-mail inquiries with selected respondents. The finished causal network is a time-ordered display that organizes the data by time and sequence and posits mechanisms of change within the IHE context by linking the data points to a larger network of other variables, including SCALE program effects.

Constructing the case. Finally, I constructed a case composed of SCALE activities, a description of the institutional context, and an analysis of the network fragments. I further ensured validity of findings by using member checks (among respondents) and peer review (among SCALE research and evaluation team members). I also conducted an active search for disconfirming evidence by posing follow-up questions regarding preliminary findings (Bernard, 2002). Finally, respondent counts for findings are not provided in this case study, because most questions on the interview protocol were open-ended queries regarding the institutional context and subjective experiences with SCALE. As a result, respondents raised issues on their own volition and thus were not uniformly provided an opportunity to reflect on certain topics.

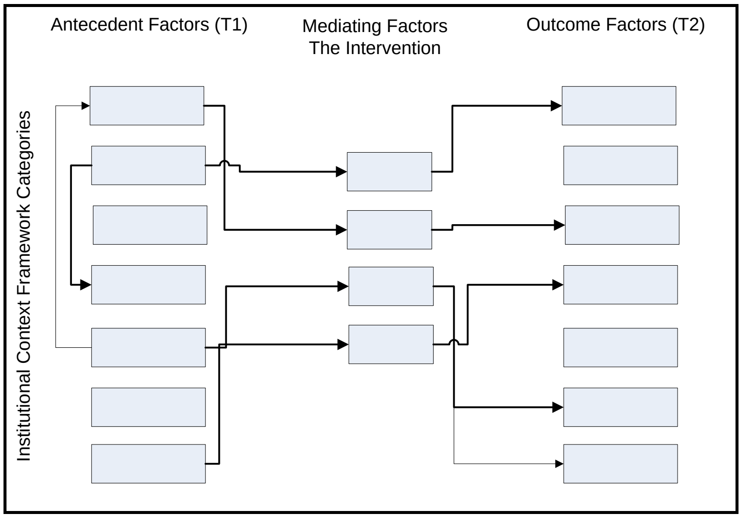

Figure 1. **How the causal network analysis linked indicators over time.**

Attributing effects. Evaluating complex programs that aspire to effect systemic change across a broad spectrum of individuals and organizations is challenging, particularly when it comes to attributing effects to specific activities. For some SCALE activities with (a) clearly stated goals and objectives and (b) unmistakable causative influences on an "effect," attributing an effect to SCALE is relatively easy. In other cases, however, where SCALE activities have more ambiguous goals or the nature of the change involves a complex set of factors for which the influences are not clear to the evaluator, attributing effects to SCALE is more difficult. Furthermore, the nature of the SCALE goals is such that many effects or outcomes might not be visible for several years or might work their way through the IHE bureaucracy and organizational culture to emerge in a form that is difficult to attribute only to SCALE. In this case study, the process for determining outcomes of SCALE/QED at CSUDH was based on classic procedures of analytic induction, as specified by Miles and Huberman (1994). These include enumerative induction, which involves gathering a number of instances that point in the same direction, and eliminative induction, which involves testing these instances against alternatives. I then used the following criteria to evaluate if a "finding" would be included in the final analysis:

1. Document-based evidence of policy or curricular change.

2. Respondent self-reporting of changes in behavior, attitude, and experiences with institutional factors.

    a. Single reports from individuals when individuals are used to identify phenomena and changes at the individual level.

    b. At least three reports from individuals when members of a group are used to identify phenomena and changes at the group level.

Identifying limitations. The sample of IHE faculty interviewed for this research does not constitute a random or representative sample of CSUDH overall, or of individual CSUDH colleges or academic departments, and thus cannot be generalized to larger populations.

Although this is a limitation, it is not a problem because this research is not intended to be generalizable to IHEs or even to IHE faculty. Rather, it is designed to explore faculty sentiments at one intervention site, to investigate the initial impact of SCALE activities at that site, and to generate a theoretical and practical approach for analyzing STEM education projects. This micro-level of analysis is precisely the strength of the ethnographic case study approach, and consequently the interpretations and claims in this case study reflect the nature of the methods used and the data collected. Because the preliminary IHE case studies were also intended to provide feedback for SCALE administrators and practitioners, it is possible that these case studies influenced the outcomes of SCALE and the findings reported here. Another limitation in this research is that two different researchers conducted data collection at T1 and T2, which potentially resulted in variations in the type and quality of data collected. However, a single researcher conducted that analysis, including coding the interview transcripts in NVivo. Finally, attrition of faculty and program participants at CSUDH resulted in different populations available for interviews at T1 and T2. As a result, reported changes were composed from data on a variety of respondents at both points in time and do not represent the observations or experiences of a single cohort over time.

II. A Snapshot of CSUDH: Characteristics Salient to the SCALE MSP

Certain characteristics of CSUDH are particularly salient to the goals of the SCALE project and constitute the “field” in which the intervention was enacted. Section II provides a snapshot of these. A more intensive analysis of how these characteristics interact to influence the SCALE program is the subject of Section III.

A. Characteristics “External” to CSUDH

Characteristics “external” to CSUDH include the background to the institution, the linkages to local school districts, and its position in the California college system.

History and Location

CSUDH, initially named South Bay State College, was founded in 1960 as part of the CSU system. Over the next several years, the college underwent a number of name and location changes. In 1965, following the riots in Watts, the university settled on its current location in Carson because the site offered the best accessibility to minorities. Now, the university serves a highly diverse population of students and defines its central mission to be responsive to the higher education needs of the surrounding local communities (CSUDH mission, n.d.).

Local K–12 Districts

CSUDH is surrounded by several school districts, including Long Beach Unified, Compton Unified, and Torrance Unified, but the largest by far is the Los Angeles Unified School District (LAUSD). LAUSD is the second largest school district in the United States. In 2004, the organizational structure of LAUSD changed from a centralized system to a decentralized system with a central office and 11 local districts. The local districts were restructured in 2005 from 11 into 8 local districts (Osthoff, 2004). LAUSD receives a significant amount of federal and state funding to conduct professional development, which was noted by several respondents as a reason why there are so many opportunities to partner with the district.

Institution Type

According to the Carnegie Classification of IHEs,[2] CSUDH is a Master's L (larger programs) university (The Carnegie Foundation, 2006). Within the state of California, there is a three-tier system, consisting of the top tier University of California (UC) System, the second tier California State University (CSU) system, and the third tier California Community College (CCC) system. Of the 23 campuses in the CSU System, CSUDH is the 12th largest, with 8,640 full-time-equivalent enrollment in fall 2006 (CSUDH enrollment, n.d.).

B. Characteristics "Internal" to CSUDH

Characteristics "internal" to CSUDH include the characteristics of the student population, the organizational structure, faculty obligations, and campus engagement in the provost's learner-centered university reform initiative.

Student Body

In the fall of 2006, CSUDH had a total enrollment of about 8,640 students. Of that number, 40% were Mexican American or other Hispanic, 31% were African American, 18% were White, and 10% were Asian/Filipino/Pacific Islander (CSUDH ethnicity, n.d.). Overall, the university has many more undergraduate transfer students than it does first-time freshman. In the fall of 2006, new freshman represented 37% of the undergraduates on campus whereas students transferring from other 2- and 4-year institutions or returning undergraduates represented nearly all of the remainder of the undergraduate population. CSUDH is a "commuter campus": Approximately 40% of undergraduates are part-time students who live and work in the South Bay area of Los Angeles. Many courses are held in the late afternoon and evening to accommodate their schedules.

Organizational Structure

The university is organized into six academic colleges: Business Administration and Public Policy, Education, Liberals Arts, Health and Human Services, Extended and International Education, and Natural and Behavioral Sciences. For the purposes of this evaluation, only two colleges and their programs are of interest: teacher education programs in the College of Education (COE), and STEM degree programs in the College of Natural and Behavioral Sciences (CNBS).

Faculty Workload

The workload for faculty in the CSU System generally comprises four courses a semester (12 credits), plus related administrative responsibilities, student advising, research and

[2] The Carnegie Classification system is an IHE taxonomy, initially developed in the 1970s and periodically updated by the Carnegie Foundation for the Advancement of Teaching. According to the foundation, the classifications "are not intended as a ranking system, and the different categories do not imply quality distinctions." A Master's L institution grants over 200 MA degrees a year but fewer than 20 doctorates. (http://classifications.carnegiefoundation.org/descriptions/2010allinclusive.php)

publishing, and service activities including departmental committees and recruiting. At CSUDH, with a few exceptions, there are no graduate students to assist faculty in teaching courses.

Reform Environment

At the time of the SCALE intervention, CSUDH was engaged in the learner-centered university reform effort. This initiative was intended to foster an institutional environment in which faculty valued teaching and learning and emphasized student engagement and pedagogical improvement and in which students could feel adequately supported in their college careers. This initiative was based out of the provost's office.

C. Characteristics of Relevant CSUDH Programs

Discussion of program characteristics in this section focuses on the teacher education programs and the STEM degree programs.

Teacher Education Programs

The College of Education (COE) has two teacher preparation programs: an undergraduate liberal studies program and a post-baccalaureate teacher education program. These programs are built around the state's teacher credentialing system as stipulated by the California Commission on Teacher Credentialing (CCTC). The number of teaching credentials that CSUDH recommends to the CCTC—students completing both of these programs—has declined in recent years from 1,622 in 2002–2003 to 592 in 2005–2006 (CCTC, 2004, 2006, 2007). These data include both multiple subject (M/S) and single subject (S/S) credentials and both preliminary and internship credentials. For credentials in the STEM disciplines, CSUDH recommended 73 mathematics and 51 science credentials in 2005, and 79 mathematics and 33 science credentials in 2006 (QED Project, 2007a, 2007b).

The COE's undergraduate liberal studies program is designed specifically for students intending to become elementary school teachers and requires a core sequence of courses and a more focused "option" area in the disciplines. Core requirements include two mathematics courses (mathematics for elementary teachers: real numbers and geometry) and three science courses (general biology, physical science for elementary teachers, and earth science for teachers). However, only students electing the "blended option," which includes a specific sequence of courses focused on pedagogy, actually graduate with a teaching credential in addition to a baccalaureate degree. All other graduates must take courses in a 5th-year post-baccalaureate program in order to obtain a credential. Currently, there is only one STEM-related option for liberal studies students, that of a concentration in mathematics. The post-baccalaureate teacher education program is a one-year program that includes a sequence of pedagogy courses taught exclusively in the COE and a student teaching component. Students may elect either the "university intern" option, designed for current K–12 teachers who need additional coursework for a credential, or the "student teaching" option, designed for students who are not currently employed by a K–12 district.

Both current and future K–12 teachers may take CSUDH courses outside of these designated programs. Included in the latter group are people who, already credentialed in one subject area, take courses needed to complete subject matter requirements in a new subject area and are recommended for a subject matter authorization by the COE. Also included are people who have been hired as classroom teachers by a district in the area, do not have teaching credentials, and are unable to meet California subject matter standards in their teaching area. These people take courses (primarily in mathematics and science) without enrolling in the COE teacher education division.

STEM Degree Programs and STEM Teacher Education Pathways

The core STEM departments are located within the CNBS and include the departments of mathematics, biology, chemistry, earth sciences, and physics. The university does not have an engineering program. The STEM departments participate in the teacher preparation process in three ways: (a) offering courses for liberal studies majors, (b) offering course sequences or majors that satisfy CCTC requirements for subject matter proficiency, and (c) offering courses that enable individuals to satisfy various credential requirements. Of particular note in California are subject matter programs, specialized 4-year programs that have been approved by the CCTC. At CSUDH, only the mathematics department offers a subject matter program. After receiving a baccalaureate degree in this program, students then must enroll in one of the graduate-level options for further COE coursework if they want to pursue a teaching career. Figure 2 presents data on enrollment and the number of STEM courses required for these teacher education pathways for fall 2006.

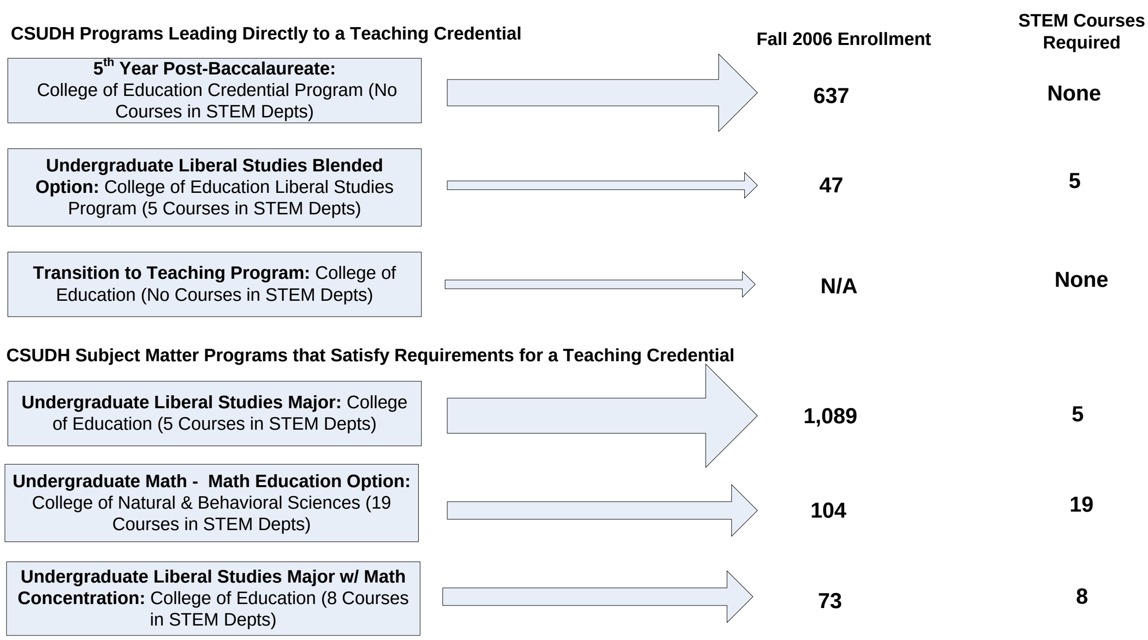

***Figure 2.* CSUDH teacher preparation programs showing required STEM courses, fall 2006.**

III. The Institutional Context of CSUDH Prior to SCALE

Based on the preliminary case study conducted at CSUDH, SCALE researchers were able to identify specific indicators to establish a baseline for the institutional context prior to implementation of SCALE/QED (Scholl, Millar, & Owusu-Yeboa, 2006). The indicators were based on a combination of interview and document-based data and were organized according to the categories of the institutional context framework. They were specifically designed to account for salient factors in the institutional environment that significantly influenced faculty life. This section includes an analysis of how the indicators interacted to either support or inhibit SCALE/QED activities.

In most cases, these indicators shaped the pre-SCALE context and exerted an influence on any outcomes that SCALE achieved (see Figure 3). These indicators, in turn, were influenced by a number of other factors that had less salient influence on faculty life, within and beyond the institutional boundaries. This analytic approach sought to situate any outcomes back into the institutional context, as opposed to presenting outcomes in isolation without attention to how the internal dynamics of the institution may support or inhibit the outcomes in the future.

A. Factors That Supported SCALE/QED Activities

The following section discusses key themes, as identified in the causal network analysis, that exerted a supportive influence on SCALE/QED activities and that were the primary features of CSUDH that "set the stage" for SCALE/QED and its eventual outcomes.

Leadership Supportive of Excellence in Teaching

Respondents were highly aware of their institution's mission to serve the local community and the high value CSUDH leadership placed on teaching excellence. These factors contributed to a sentiment that the espoused values and priorities of the institution were in accordance with projects such as SCALE/QED. One of the primary reasons respondents cited for their awareness of this support was a university-wide undertaking to become a learner-centered university, which involved increasing student engagement in the university and faculty adoption of active learning strategies. This initiative, based out of the provost's office, offered seminars to incoming faculty (designed to improve pedagogical skills) and to incoming freshmen (University 101, designed to enable a smoother transition for new students). The faculty professional development efforts were described as a central feature of the theory of change guiding this initiative: Individual faculty's skills and perceptions were considered a key linchpin in effecting change in the CSUDH culture. However, there is evidence of a misalignment between the support for reform at the upper administrative level and that at the departmental level, where disciplinary traditions and retention, tenure, and promotion (RTP) policies were viewed as inimical to pedagogical reform.

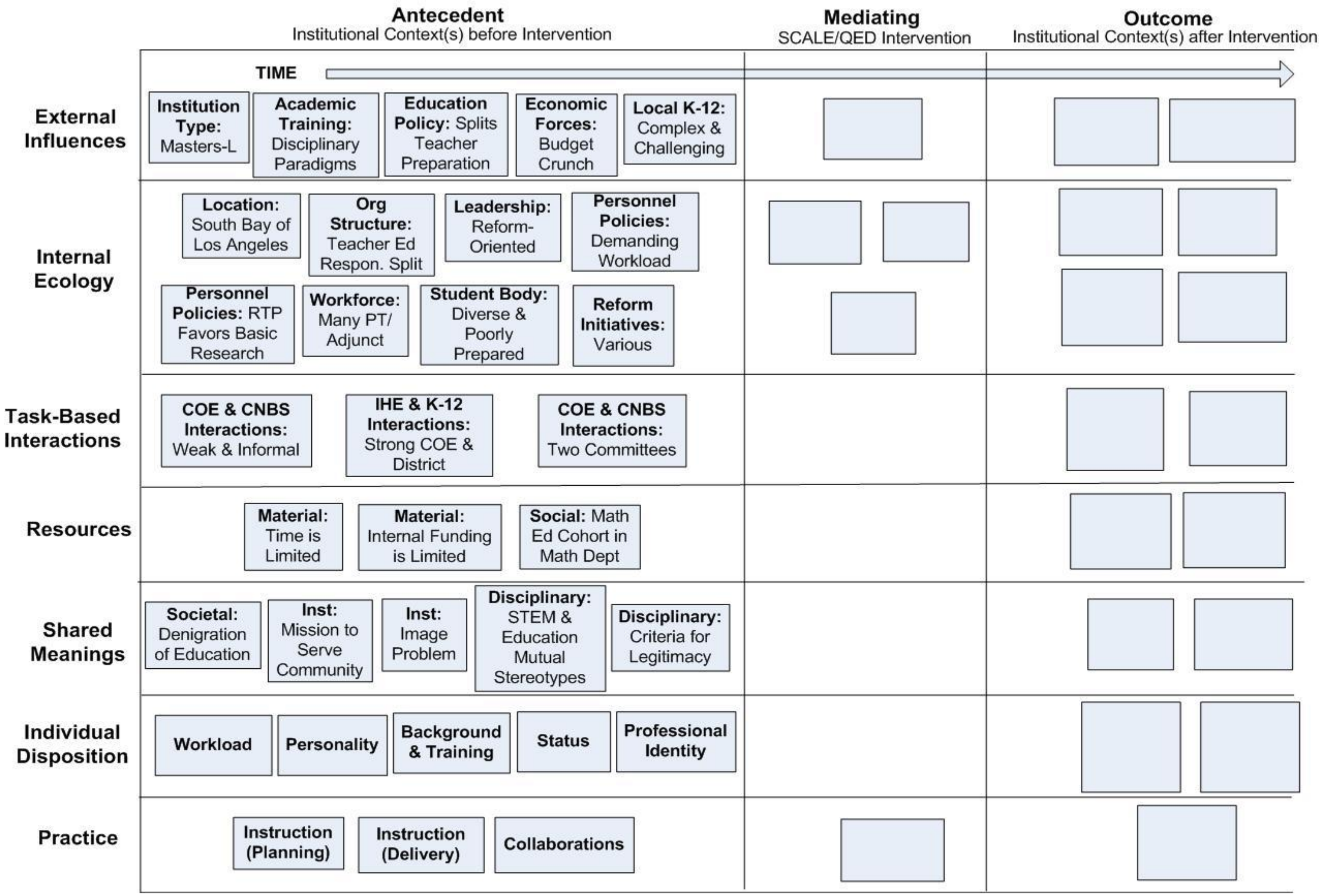

***Figure 3.* The institutional context at CSUDH prior to SCALE/QED.**

Institution Type Conducive to Focus on Teaching

In considering the influences on their professional lives at CSUDH, several respondents noted that the institution type influenced their professional identities and workload priorities. As a relatively small IHE, which some respondents called a "blue-collar" campus, CSUDH is a low-prestige institution in a second-tier system that has traditionally focused its limited resources on undergraduate education and teacher preparation instead of on research activities.

Several respondents exhibited a keen awareness of the interrelatedness of the local K–12 sector and CSUDH because many CSUDH students not only come from the schools and communities surrounding the university, but they also return to live and work in those communities. If these students further become teachers, they prepare the K–12 students who later go on to take courses at CSUDH. As one faculty member noted:

> In our niche, and the world of things, we are not a Research I.[3] We're not trying to compete with UCLA. We are a comprehensive university that prepares a lot of teachers, and we'd like to do it well. And in particular we've prepared teachers from underserved groups, and we'd like to do that particularly well, because those are students that come back to us too. (STEM faculty member, interview data)[4]

Also, several faculty respondents observed that the low status of CSUDH had a variety of effects, including how the administration made decisions and how they set workload priorities. Some respondents spoke of an "image problem" at CSUDH, which was confirmed by a recent report that noted that 75% of the faculty and staff affirmed a campus inferiority complex (The Napa Group, 2003). Some were cognizant of and even apologetic about their presence at this relatively low-status institution and observed that the recent decision to increase the importance of research and publications in the RTP process was an attempt by the administration to increase the status of CSUDH. This was corroborated by administrators, who noted the need to uphold a certain standard of academic excellence. Given the already demanding workload at CSUDH, this decision had a very real impact on faculty. Faculty responded to these issues by adapting and altering their workload priorities and negotiating the gap between their original disciplinary identity (obtained in doctoral work) and the one being developed in their current institutional setting. As one faculty member noted:

> So if I worked at University of Chicago in the [STEM field] group and taught one course every year—and if it were generally a graduate course—I don't think it [preparing K–12 teachers] would be such a big deal. [Then look at] STEM faculty at an institution like the one I'm at. I think it is a much bigger deal [here], and it deserves more preeminence in my personal ordering of what I'm going to do. (STEM faculty member, interview data)

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[3] *Research I* is a Carnegie classification formerly applied to universities that offered a full range of baccalaureate programs, were committed to graduate education through the doctorate, awarded more than 50 doctoral degrees annually in at least 15 disciplines, received $40 million or more in federal support, and gave high priority to research, engaging in extensive research activity (Carnegie Foundation, 2000, pp. 1–11).

[4] Quotations included in this document are drawn from both waves of data collection for this study.

A History of Interactions With Local K–12 Districts

Several respondents referred to existing COE and K–12 district activities, such as student teacher mentoring, professional development activities, and graduate placement, as examples of partnership between CSUDH and the K–12 sector. The COE works with over 20 districts. Respondents claimed that the university enjoys a strong reputation for working collaboratively with the districts and has close relationships with individual superintendents, LAUSD teacher recruitment programs, and career ladder programs.

One respondent observed that these close relationships mean that CSUDH can respond quickly to district and state initiatives, such as new curricula or standards, and prepare teachers accordingly. This leads also into a feedback mechanism between the district and the COE where graduating students convey to faculty mentors their views about the quality and applicability of their K–12 training. These activities were perceived as part of the normal professional work of COE faculty, and some respondents observed that they spent at least 4–5 days a month “in the field.” As a result, COE faculty perceived themselves as already in partnership with K–12 districts.

In contrast, STEM faculty had no disciplinary or institutional mandate to interact closely with the K–12 sector. When STEM faculty did interact with the K–12 sector, it was usually as parents or as content experts in summer professional development workshops, where they perceived themselves as participating in relationships that did not obviously fit into their professional obligations. Furthermore, there were no naturally existing feedback mechanisms between K–12 districts and STEM faculty. This might explain why several STEM respondents spoke about their local K–12 districts solely based on media accounts and personal experiences as parents, which led to admittedly incomplete and biased perspectives. This lack of experience with K–12 and the learning sciences was cited by some respondents as a problem that needed to be addressed before STEM faculty could become involved in K–12 issues. One math faculty member was particularly sensitive to the discrepancy in experience:

> Math professors probably have to read about math education. I mean, we have to be more humble and say we need to go and learn about the issues here. And so probably Step 0 is we need to clean house ourselves at the undergraduate level of instruction and until mathematicians can teach classes well, how can we go into K–12 classrooms and say, “Hey, you guys aren’t doing it right”? I mean, I don’t know, it seems sort of irresponsible and dishonest. So, before we get to the pie in the sky part, I would say let’s take care of our backyard. (STEM faculty member, interview data)

An exception to this lack of familiarity or direct involvement with the K–12 sector was the math education cohort in the mathematics department, which had been involved in professional development activities such as the California Mathematics Project, part of the California Subject Matter Project supported and coordinated through the University of California Office of the President.

A Cohort of Faculty in the Mathematics Department Committed to STEM Pedagogy

Several respondents observed the value of having a collegial network. Such networks commonly provide camaraderie, professional feedback, and resources at the departmental or research area level, but at CSUDH, the mathematics department was repeatedly cited as the site of a relatively unusual collegial network of STEM educators. In the science departments, there were individuals who had collaborated with the science education specialists in the COE in the past, but no science department included a coherent, supported group like the one in the mathematics department. Approximately half of the faculty in the mathematics department were either officially trained in math education, formerly K–12 teachers, or interested in the field. In fact, 5 of the 17 tenure-track faculty in the department were hired for their research and work in math education. Together with a COE faculty member with a mathematics specialization, they formed a math education group that was involved in preservice and in-service teacher preparation activities, including teaching courses for CSUDH students who planned on becoming secondary mathematics teachers. A key feature of this group was that content knowledge was viewed with both a pedagogical lens (how learning takes place) and a disciplinary lens (a focus on core content of the field). This group was referred to as an example of what was possible for STEM faculty interested in pedagogical issues and what might be the best point of entry into the STEM departments for education faculty. As one faculty member noted:

> So we've managed to be where we're considered completely part of the math department, but our field of interest is mathematics education—just like an algebraist would have their field of interest. So we are listened to in the sense of what our needs are, too. (STEM faculty member, interview data)

By functioning as a cohort, this group had the ability to partner with other groups and to tailor partnering efforts to the needs of the K–12 community. Through those activities, they believe they learned much about teachers' needs and how to more effectively provide professional development that had a tangible impact on teachers' classroom practice. However, some respondents noted that even within this cohort, there remained a disciplinary tendency to value research and publications in the "pure" math areas more highly than those in math education. Also, some noted a sensitivity to the relatively high profile of this group, which was based in good part on the high level of external funding. In this vein, a respondent cautioned that "it would not be well to think that the math education group dominates and that the others are sort of nothing." I propose that this observation is important because it highlighted the tensions between the values of the discipline and those of the institution.

A Population of STEM Faculty Interested in Pedagogical Improvement

One of the aspects of CSUDH most favorable for a reform initiative such as SCALE/QED was the presence of faculty who were already exploring ways to improve their instructional practice. These faculty were not limited to the group of mathematics educators in the mathematics department, but included individual faculty from different science departments who were generally uninvolved with any structured pedagogy-based activity prior to SCALE/QED. They had worked with individual COE faculty on small collaborative projects or were independently exploring ways to improve their lectures and labs. Some respondents observed that this interest in pedagogy was based on the realization that lecturing was not working for them or for their students. These respondents observed that because they were ultimately alone with a group of 25–30 CSUDH students in a classroom, students' abilities, attitudes, and reference points exerted a strong influence on their pedagogy in several different ways. Several respondents observed that this reaction to the student body was in stark contrast to the approach taken by mostly older, senior faculty, which was characterized by the sentiment that any learning difficulties students had were their own fault, not the instructor's. It was felt that younger faculty were not only more open to change and innovation, but that they might be more responsive to the challenges their students were experiencing.

One younger faculty member provided an example of this kind of sensitivity:

> In Los Angeles, most of my students have never seen a river bottom. They think a river bottom is concrete, you know. You give a whole lecture, a whole chapter on river bottoms, and they talk about meandering rivers and braided rivers and gravel and bars and chutes and all this stuff, but they don't get it. (STEM faculty member, interview data)

Although this respondent exhibited an unusual sensitivity to the impact that his students' background might have had on their ability to learn the earth sciences, his awareness of their struggles was widely shared by his colleagues. Most respondents mentioned the poor academic preparation levels of many students, particularly in mathematics and science, and noted the challenging learning environment of local K–12 schools, including untrained teachers, poor teacher retention, a challenging classroom environment, and other factors. A study by LAUSD to see how many students completed high school with all UC or CSU entrance requirements found that of 20,386 students who were enrolled in Grades 9–12, only 54% were enrolled in courses that would meet UC/CSU entrance requirements, and of these, only 28% passed with a grade of C or better (Rickles & White, 2005). One effect of this poor level of preparation was that a large number of CSU students required remediation, which could set back their graduation date by months or years, as indicated by the poor pass rate (87% unprepared) for the mathematics entrance exam for first-time freshmen in fall 2006 (CSUDH assessment, n.d.). Although this situation was typically viewed as a negative aspect of faculty life, it appeared to have also had the beneficial effect of sensitizing STEM faculty to the complexity of teaching and learning.

B. Factors That Inhibited SCALE/QED Activities

The following section includes key themes that exerted an inhibiting influence on SCALE/QED activities, as identified in the causal network analysis.

A Demanding Workload That Kept Faculty From Participating in Pedagogical Improvement and K–12 Activities

Almost every respondent noted that the primary factor influencing faculty professional life at CSUDH was the demanding instructional and administrative workload. A teaching load of four courses a semester, plus student advising, administrative responsibilities, research, and service activities translated into long hours for most faculty. At the time of the study, faculty were being asked to continue a high level of teaching while also increasing their research activity. The increased expectation for scholarship, however, created tensions because the faculty teaching load was not being reduced.

As one administrator noted:

> You can't teach four classes and do the kind of research that we want [them to do]. When I came here, I worked 6 and 7 days a week because I was doing research, but I don't have a family, I don't have [that] responsibility. And the cost of housing has skyrocketed and so when you come here now you can't afford a home, you're being asked to work on the weekends. If you're going to do this, believe me, this is not an 8-to-5 job, the way it's set up right now. So if we're going to ask this from these folks, we've got to give them something, and that's what we're going to have to work on. (STEM administrator, interview data)

One effect of this situation was that some respondents felt they had little to no time to participate in activities that were not central to their immediate job responsibilities. This included activities like SCALE/QED and professional development offerings on campus. One respondent explained:

> The Center for Teaching and Learning [at CSUDH] does an outstanding job. The biggest problem I would say there is finding the time to attend. It's that same old same old that we're pretty much fully booked when you look at the teaching schedules. And so when they're putting on these workshops, they're good workshops, and the people who attend them—and I've attended some—rave about them, but you've got to have the hours in the day to do them. (STEM faculty member, interview data)

State Policy That Bifurcated Responsibilities for Teacher Preparation

CSUDH teacher preparation programs are built around the state's teacher credentialing system, which requires a broad liberal arts education for elementary teachers and an undergraduate degree in a discipline for secondary teachers. The Division of Teacher Education is housed and administered by the COE, and includes the undergraduate liberal studies program, a post-baccalaureate teacher education program, and a graduate program. However, the state policies governing teacher training create a division of labor between the COE and CNBS regarding teacher preparation, such that pedagogy and content are addressed in separate degree programs. As one administrator noted:

> One very serious consequence was that [state policy] pretty much built a wall between colleges of education and the content areas, including STEM faculty. They offered no education classes. We offered no content classes. So structurally there were more disincentives for collaboration than there were incentives. And they [STEM faculty] often didn't see themselves as teacher preparers, so there wasn't much that happened in the content areas that enhanced teacher preparation, as an unintended consequence of the design. (COE administrator, interview data)

Moreover, this structural division, which that made collaboration between the two colleges unlikely, was reinforced by other factors, such as faculty training and disciplinary stereotypes. There were, however, some exceptions where interdisciplinary collaboration was required as part of teacher preparation programs. For example, the University Committee on Educator Preparation and the Liberal Studies Committee both included members from departments across campus. Some respondents cited these committees as providing members a unique vantage point on university happenings that was not available to other faculty.

STEM Faculty's Lack of Exposure to the Learning Sciences

In considering their own instructional practices, STEM respondents continually mentioned that they had had no training in pedagogy as part of their graduate education. The lack of training resulted in a reliance on teaching "the way I was taught," which was described as a practice that "was taken for granted":

> When you become a professor, interestingly, you have no teacher training whatsoever. I mean, I had a PhD in [STEM field] and never even really knew anything about pedagogy and that kind of stuff, and I was thrust, of course, into the classroom. They assume one can teach. (STEM faculty member, interview data)

The instructional method that STEM respondents relied on was generally a didactic, lecture-based approach, with little direct engagement with the students outside of labs. This approach to instruction was also characterized by a lack of planning that incorporated any focus on pedagogy. Instead, it was focused on conveying the content knowledge of the discipline, and "covering the canon" of the discipline. Several faculty in both STEM and education disciplines pointed out that incorporating pedagogy and content knowledge was a difficult endeavor that many STEM faculty did not feel was necessary. These respondents attributed poor student outcomes not to their own instructional practice, but to students' lack of "hard work" or native talent. Yet others said that efforts in STEM pedagogical reform must take into account the need to address the core content areas while also incorporating pedagogy. Some respondents stated that successfully integrating content with pedagogy was extremely difficult, and a lack of expertise with either the learning sciences or pedagogical techniques made some faculty reluctant to become involved in something that they "know nothing about."

STEM faculty with little teaching expertise found opportunities to gain experience primarily through their professional societies and interactions with their counterparts in the COE at CSUDH. Regarding the role of the disciplinary associations in improving the status of STEM pedagogy, a respondent expressed his excitement that the American Geophysical Union conference had a section on "novel instruction in the geosciences." Interactions between STEM and COE faculty, however, remained a "weak area" of the university, and there were no formal incentives or structures that encouraged people to collaborate. Although there were interdepartmental committees, a respondent emphasized the superficial and skeletal nature of those committees, mentioning their lack of "day-to-day collaboration" and consistent participation by certain departments. When interactions did occur, they were largely informal collaborations between individual faculty based on a grant and not based around a common interest in pedagogical approaches to content. However, a few one-on-one interactions did have some impact. For example, one STEM faculty member credited a collaborative K–12 professional development project with shaping his instruction.

Several respondents frequently referred to the influence that their disciplines and their graduate and postdoctoral training in these disciplines had on how they conceived of their professional identities and practices. Once students are granted entry to the "field" of a discipline, through the awarding of a PhD and subsequent measures of achievement, the discipline becomes the primary source of their new identity as a professional academic. Respondents noted that this professional identity is related not simply to the content of a discipline, but also to certain behavioral characteristics that serve to differentiate disciplines from one another. As one respondent noted:

> An acquaintance who was a writer for *Science* magazine was looking for quips about scientists living abroad, and I told him that the difference between physicists and normal people is bigger than the difference between American and Japanese people. Yeah, we're in a slightly unusual group, but I'm used to working within that group. (STEM faculty member, interview data)

Fundamental Differences in COE and STEM Faculty Thinking About Teaching

Several respondents observed that there were fundamental differences in how COE and STEM faculty conceived of the pedagogical process. As previously mentioned, the lack of exposure to the learning sciences shaped many STEM faculty's perception of pedagogy, and in the absence of guided instruction they reproduced the didactic lecture style of their mentors. Underlying the didactic lecture style is the pedagogical theory that learning entails the simple transfer of content from one person to another, which runs counter to many education faculty members' understanding of learning. As one faculty member explained:

> [The] priority is teaching for transfer, which requires being clear on exactly what concept, procedure, or principle should transfer. There is also a concern for viewing the course through the eyes of the novice learner versus the expert, and that if the instruction isn't meaningful to the learner, retention will be problematic. (COE faculty member, interview data)

Another indicator of how far apart STEM and education faculty might have been regarding teaching was the difference in their sets of discipline-based concepts, jargon, and practices. For example, an education faculty respondent described a misunderstanding with a STEM colleague over the meaning of the term *fieldwork*: the STEM faculty member (a geologist) construed the term to mean the collection of geological specimens, whereas the education faculty member took it to mean qualitative research in K–12 schools. Further exacerbating these disciplinary differences in language was the sentiment expressed by several STEM faculty that their COE counterparts did not think highly of the STEM faculty's abilities as instructors. Some respondents described previous encounters with COE faculty where STEM faculty had felt as if they were expected to rapidly adopt a new pedagogical method; others felt like they had been treated disrespectfully. In any case, the following quote from a COE respondent captures the essence of what some STEM faculty disliked about how they were viewed:

> We want to get the science faculty to begin to think like we think, to teach science the way science is supposed to be taught. So rather than the normal lecture and cookbook kind of stuff, we feel that they need the pedagogy, the current pedagogical practices that have proved to be effective, so that's why they are going through this professional development. (COE faculty member, interview data)

Several respondents observed that misunderstandings and stereotypes such as these have served to alienate STEM and education faculty further from one another than is normally the case between different fields.

A History of Conflict Between the CNBS and the COE

Several respondents referred to an extended series of active conflicts that had contributed to a rancorous institutional atmosphere and harmed intercollege collaboration. At the time of SCALE/QED's arrival at CSUDH, the COE had just had a dramatic switch in leadership. According to respondents, the previous COE leader had further heightened the structural and perceptual distance (as noted previously) between the two colleges by severing ties with STEM departments. Only with new leadership in 2004 was a rapprochement between the two colleges possible. Several respondents also referred to various personal conflicts between individuals in different colleges and departments. As one faculty member noted:

> I don't even remember how it began because when I came here, the relationship between education and the [STEM department] was in pretty bad shape. Personalities, misunderstandings, people making speculations about what intentions of the other people are. Someone got a grant, and they didn't call the other, maybe power, and who knows? (COE faculty member, interview data)

This phenomenon is relevant to reform initiatives such as SCALE/QED because preexisting tensions and conflicts effectively set the stage for the intervention. In the following case, the propensity for faculty to respond positively to their disciplinary, as opposed to other, colleagues influenced the choice to become involved with the project:

> [A COE faculty member] had talked to me about it a lot, and then I didn't get really involved until [a STEM faculty member] started doing QED, and she said she's in the math department, not in the College of Education. I probably knew [the COE faculty member] better than [the STEM faculty member], but wouldn't have been as apt to put my name on a—as senior personnel—on a proposal at that point with somebody from College of Education. (STEM faculty member, interview data)

Although it is not clear if this respondent's lack of responsiveness to his COE colleague was due to a lack of regard for the colleague's discipline, the respondent was clearly reluctant to attach his name and professional reputation to a project affiliated with the COE. Some respondents alluded to these conflicts in describing a COE-based program in which goals were closely aligned with those of SCALE. This program, Transition to Teaching, focused on recruiting midcareer professionals to become mathematics and science teachers in area high-needs high schools. At the inception of SCALE and QED, there was no collaboration between these efforts and SCALE/QED, and determining the precise reasons for this lack of coordination was not possible.

This conflict was not limited to intercollege relations, but also afflicted intracollege and departmental contexts. Some respondents reported persistent schisms within the COE and with individual STEM departments, citing strained or very weak collegial relationships. In particular, some faculty members could not identify the work that their departmental colleagues were doing and stated that, due to workload, the course schedule, and off-campus educational responsibilities, they rarely saw each other, even in passing. These conflicts highlight the fact that tension and misalignment may exist at multiple layers within an institution as complex as an IHE. For example, one respondent noted different commitment levels of faculty and remarked that the "culture" of the college was characterized by "ingrained communities" and fear. This atmosphere was in part attributed to a lack of stability and trust resulting from replacing the dean of the College of Education nine times in the previous 11 years.

Science Faculty Resistant to Reform Due to Traditions of Scientific Legitimacy as Instantiated in Retention, Tenure, and Promotion Policies

Several respondents noted that resistance to reform efforts such as SCALE/QED or the learner-centered university initiative was based on resilient traditions in the science disciplines. The strength of these traditions was attributed to the socialization processes that each faculty member undergoes in his or her graduate and postdoctoral training, during which time individuals are exposed not only to a scientific discipline, but also to a social group with unique social skills, managerial patterns, epistemological positions, engagement with the public, and methods for conveying legitimacy. How a discipline determines criteria for membership in its social world is largely based on demonstrated expertise in the field as legitimized by a course of study in the discipline through the doctoral level, publications in peer-reviewed journals, and involvement in an active research program. These criteria demarcate a significant and unavoidable boundary between the STEM faculty and the STEM specialists in the COE, as the latter are acutely aware that they lack legitimacy in the STEM field. As one STEM faculty member commented about a less than distinguished colleague:

> [The faculty member] did not have a strong enough [STEM field] background, so [the faculty member] was not acceptable to the [STEM] department. Because if you're going to be in a [STEM] department, you'd better be able to be tenured and promoted to full professor in [the STEM field]. (STEM faculty member, interview data)

The role of retention, tenure, and promotion (RTP) policies in reinforcing these criteria for legitimacy—and thus discouraging involvement in K–12 or pedagogical improvement activities—was widely cited by respondents. The three RTP criteria are teaching performance, scholarly and professional performance, and service (CSUDH RTP policies, n.d.). Despite the administration's stated acceptance of pedagogical research in considerations of RTP, several respondents expressed skepticism about the reliability of the support. This skepticism is based on three elements: (a) observations of colleagues who were denied tenure or promotion reportedly due to their publication record and/or their involvement with K–12 related initiatives or research; (b) increased demands for research and publications; and (c) the resiliency of the academic (and disciplinary) hierarchy that favors disciplinary research above all else. As one STEM faculty member put it, "I've served on tenure committees where people have only done education research, and the questions always come up, 'Well, what have they done as far as science?'" (interview data).

One respondent noted that these factors interrelate to form an unequivocal sentiment that discourages the scholarship of teaching. In particular, for junior faculty, who have not yet achieved the job security that comes with tenure, an administrator's actual acceptance of pedagogical research and related activities is critical to determining their future engagement with reform efforts. However, despite these disciplinary values at work, some respondents insisted that departmental or disciplinary dynamics did not necessarily reproduce themselves wholesale in each faculty member. Instead, they indicated a lack of coherence within departments and stressed the importance of individuality and academic freedom as defining features of their experiences within a department.

Misalignment Between Institutional Support for Pedagogical Reform and Departmental Resistance

Several respondents referred to an apparent lack of alignment between institutional support for pedagogical reform and resistance to such reform at the departmental level. One respondent succinctly described this tension:

> [Although] this university as a whole values "the scholarship of education," I think there's still a reluctance at the level of the department and the college—not a fatal flaw. Somebody who comes in and says "Look, I've been doing this research on how to teach science better" is not going to be turned down for tenure because they did that. It's just that I think it's probably natural to most of us [to publish] in the scientific field. That's by no means denigrating the pedagogical journals, it's just that if you're a scientist, that's your currency. (STEM faculty member, interview data)

That other respondents corroborated this respondent's honest assessment points to a significant challenge for reform efforts such as SCALE/QED.

IV. Findings on the SCALE/QED Intervention

This section presents a summative evaluation of SCALE/QED activities at CSUDH, consisting of descriptions of the activities from May 2004 to May 2007, observed outcomes of these activities, and analyses of the longer term consequences of each intervention. Because SCALE/QED is engaged in a wide range of activities,[5] I decided to include in this evaluation only activities (a) that respondents described and that directly involved CSUDH faculty in a substantive manner or (b) that were focused on changing internal policies and practices. As a result, some activities that can be considered SCALE/QED might not be included in this evaluation. The descriptions of SCALE/QED activities are based on interview and document-based evidence regarding program operations, whereas the analyses of outcomes and institutionalization are based on the causal network analyses (see Figure 4).

[5] Discussion in this section is based on findings and analysis as of 2008.

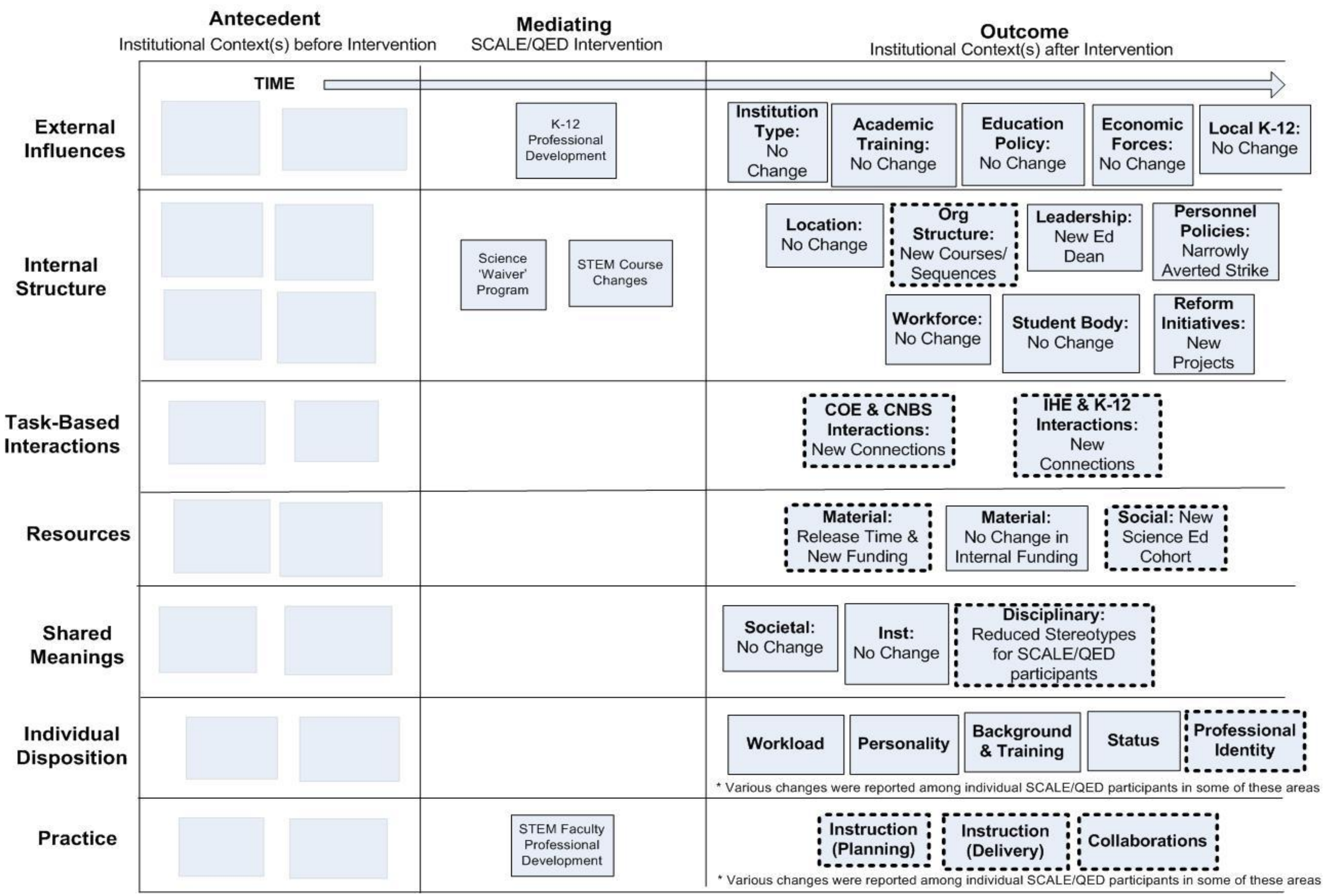

Figure 4. **The institutional context at CSUDH after SCALE/QED.**

The causal network analyses are based on identifying the relationships between the institutional context framework (ICF) indicators at two points in time (May 2005 and May 2007) and SCALE/QED activities. This analysis provides specific links between the pre–SCALE/QED institutional context, the intervention, and any observed outcomes. The changed ICF indicators were identified using the following criteria:

1. Document-based evidence of policy or curricular change.
2. Respondent self-reporting of changes in behavior, attitude, and experiences with institutional factors.
   a. Single reports from individuals as individuals are used to identify phenomena and changes at the individual-level.
   b. At least three reports from individuals as members of a group are used to identify phenomenon and changes at the group-level.

Interactions of ICF indicators with other contextual factors were analyzed in order to better understand genesis and longevity of the indicators.

A. SCALE/QED Intervention at CSUDH

CSUDH was formally involved with SCALE from its beginning in 2003 through an agreement between SCALE leaders and the (then) dean of the College of Education. Yet representatives from both the COE and the STEM departments at CSUDH did not actively participate in SCALE until the spring of 2004, when a member of the mathematics department, who also led that department's Center for Mathematics and Science Education, began working with the SCALE principal investigator (PI), at the University of Wisconsin–Madison (UW–Madison).

Development of the QED Project

Shortly after the working relationship between the CSUDH mathematics faculty member and the SCALE PI began, a group that included CSUDH faculty, SCALE research and evaluation team members, and an LAUSD administrator developed and submitted a proposal to the Department of Education's Title IIb Teacher Quality Enhancement grant program. This joint effort resulted in the Quality Educator Development (QED) project. The grant for the QED project was awarded to the associate dean of the CSUDH COE for 5 years (2004–2009) and was co-led by the CSUDH mathematician who was working with the SCALE PI and an LAUSD administrator.

The QED project proposal stated that individuals interested in teaching face three challenges: (a) finding sufficient social and organizational support to enable them to persist in the certification program; (b) learning sufficient disciplinary content and pedagogical content knowledge to implement reform-oriented curriculum with expertise; and (c) "learning the ropes," through apprenticeship with expert teachers who have bridged the gap between theory and practice in their own classrooms. In light of these challenges, QED's overarching goal was to "increase the pool of highly qualified mathematics and science teachers who are willing and able to serve the poor, minority, and limited English proficient students in LAUSD and other urban schools" (QED, 2004).

Consequently, the goals of both SCALE and QED were focused on improving mathematics and science education throughout the entire educational system (K–20) by working at multiple points in the teaching and learning continuum, with QED focusing on the local challenges associated with teacher preparation processes at CSUDH. In fact, a respondent noted that he viewed the QED project as the local instantiation of SCALE. As a result, most clusters of QED activity at CSUDH were joint SCALE/QED initiatives that were deliberately designed to reinforce each other. As one administrator commented:

> They're both fairly comprehensive projects, and QED is really the kind of the preservice local institution component of SCALE, [which is] building on the SCALE immersion units as our driving concept. [At CSUDH] we're implementing curriculum and instructional reforms in undergraduate teacher preparation in the content areas, professional preservice classes, and advanced master's programs for experienced teachers in order to match the reforms that are going on in the school district. (COE administrator, interview data)

Challenges in Evaluating Two Initiatives

Although a common challenge in evaluation, the conflation of two distinct programs, SCALE and QED, had implications for evaluation, particularly in determining where the effects of one program began and ended relative to its counterpart. SCALE and QED were supported by two different funding agencies and, as a result, had different goals and objectives, and different evaluators and evaluation criteria. But the two projects could not, in practice, be distinguished in most regards. Several respondents associated the K–12 professional development workshops in LAUSD primarily with SCALE, and all the other activities focused on internal processes at CSUDH primarily with QED. Many also observed that the lines separating the administration of the NSF and ED grants and the IHE personnel working on them became increasingly blurred over time. The case study reported here was organized solely around the goals of SCALE, but given the difficulty of distinguishing between the program effects of each grant on the institutional context of CSUDH, the activities and outcomes of both grants are treated collectively in reporting results of this case study, and the project is referred to as *SCALE/QED*.

B. SCALE/QED Activities: May 2004–May 2007

As previously noted, SCALE/QED was designed to be a systemic change initiative that would focus on improving mathematics and science education by working at multiple points in the teaching and learning continuum. During the period from May 2004 to May 2007, SCALE/QED implemented the following activities: (a) STEM course redesign, (b) preservice candidate recruitment and support, (c) new pathways for preservice candidates in mathematics and science, (d) STEM faculty professional development workshops, (e) K–12 science immersion unit design and implementation, and (f) K–12 mathematics institute implementation. Each of these projects is described in detail in the following section.

Structural Change: STEM Course Redesign

SCALE/QED leaders had found that many CSUDH students had either dropped or failed certain STEM "gateway" courses (e.g., calculus, introductory physics). Yet students needed to pass these courses in order to continue on a trajectory to becoming STEM majors and thus to becoming secondary school teachers in mathematics or science. According to the QED work plan, the original objective regarding this goal was to revise Calculus I, Calculus II, General Physics I, and General Physics II. These proposed changes were designed to reach specific audiences—the QED-selected cohorts in mathematics and physics courses—and intended to promote alignment of pedagogy in these STEM courses with math and science education methods in the COE, so that students would eventually receive a more consistent approach to teacher preparation. Several respondents noted that they hoped that this realignment would substantially improve the teacher preparation process at CSUDH.

Observed outcomes. Starting in 2005, SCALE/QED initiated efforts to revise introductory calculus and biology courses by convening meetings of STEM faculty to discuss the possible curricular changes and providing release time to faculty to do the preparatory work required to redesign a course. By May 2007, SCALE/QED had enacted changes in the curriculum and structure for sections of Calculus I and II and General Physics I and II. The changes in the curriculum and structure of these sections were intended to ensure that the revised courses would include a pedagogical approach that paid more attention to the mathematical learning process than previously and that addressed the needs of future K–12 teachers.

With these changes implemented, there was a greater likelihood that the revised courses would be taught in a way that modeled an engaged and inquiry-based pedagogy. For one respondent, the structural changes to the course were exciting because they reinforced his personal vision of how mathematics should be taught. Several respondents observed that these changes should result in a more aligned teacher preparation system at CSUDH, noting that students experienced a similar pedagogy in their COE and CNBS courses. One respondent stated:

> I think it's great that we're changing our calculus course so that [the preservice students won't] get to my methods course and say, "Ah, what's going on?" It should be reflected in your undergraduate work. (COE faculty member, interview data)

However, for these structural changes to actually translate into changes in instructional practices, the person teaching the course (whether regular or adjunct faculty) needed to be conversant with these pedagogical techniques. The faculty development workshops partially addressed this issue by including adjunct faculty as participants. This step, however, did not address the prospect of the "traditional" faculty rotating through these courses and modeling a pedagogy that ran counter to the goals of SCALE/QED. Also relevant is the course assignment system, which included, as a regular practice, a review of course curricula by course chairs, based on the opinions of faculty teaching the course. For the math education cohort in the mathematics department, this might not have been a problem because the changes in the calculus courses should have effectively matched the existing skill sets of the math education group. How a structural change to a course would translate to instructional changes by the science faculty, who had just recently been exposed to active learning strategies through SCALE/QED, was unclear. This lack of certainty that faculty teaching the courses would have the requisite skills or intent to teach the courses in the desired fashion drew into question the sustainability of this accomplishment. It is also important to note that *the revised courses were intended only for the SCALE/QED "cohort" of recruited students,* not for the entire CSUDH student body.

Institutionalization and sustainability. These structural changes, once integrated into each department's operations, might have had impacts on how mathematics and science teachers were trained at CSUDH, yet the unmistakable successes in changing structural aspects of this system could have been jeopardized by the practice of rotating faculty and lecturers among different courses. As one respondent noted:

> The math department is split. It's a small department, and there are five of us who are full time in math education [and] between four and six people who are full time outside of math education and not working on these kind of projects. Those people respect the work that the other four of us are doing to varying degrees, but they don't always have a deep understanding of all of the things that we're doing and all of the time that we put in, all of the things that are going on. So those students get very different experiences [depending on] the teachers that they have. (STEM faculty member, interview data)

This situation might have been even more acute in science, where faculty "on board" with STEM education were more outnumbered than in the mathematics department. Thus, the effects of the course revisions might have been minimized by course assignment practice. Such practices present both an opportunity and a challenge for initiatives like SCALE/QED.

Structural Change: Preservice Candidate Recruitment

The goal of the cohort recruitment effort was to identify graduating high school seniors as well as community college students who expressed an interest in becoming mathematics and science teachers, enroll them in CSUDH, and group them into cohorts to provide them with the social, academic, and advising supports necessary to enable them to persist throughout the teacher preparation continuum. This goal was viewed as a change in "how we do business" in that student support would be reinforced by the changes in the gateway STEM courses.

Activities. A respondent familiar with this effort described progress as "slow," in part due to the difficulty in getting students to commit to a career path early on in their time at CSUDH. The effort aimed at recruiting 60 students each year for entry into math and science teacher preparation cohorts. These students were to take courses together, have access to faculty mentors and advisors, attend social events with other members of the cohort, receive financial assistance, and have the opportunity to receive academic tutoring. Faculty involved in this effort noted that although many CSUDH students had shown an initial interest in teaching, they often left teacher preparation programs because they did not have an adequate support and mentoring system.

Observed outcomes. The available information related to this activity was insufficient to support analysis.

Structural Change: Preservice Pathways in Mathematics and Science

In order to earn a single-subject credential to teach in a secondary school in California, individuals must either complete a state exam in the content area (California Subject Examinations for Teachers) or get a waiver from the exam by completing coursework in a subject matter program approved by the state. These programs allow undergraduate students who want to become secondary school teachers to satisfy the state's subject matter proficiency requirement as they complete their 4-year degree. At the time of this study, CSUDH had a subject matter program in mathematics but none in science. Many years ago, the university also had a state-approved program in science, but then lost that approval when the state's program requirements shifted. Because of this change, CSUDH undergraduate students who wanted to become high school science teachers had to either prepare to take the state exams or complete coursework at another university that had an approved program in the sciences. In response, SCALE/QED leaders decided to develop subject matter programs in chemistry, biology, physics, and earth science. The potential loss of students due to the lack of such programs for a university with declining enrollment, and for science departments that were quite small, was a "selling point" for SCALE/QED leaders as they attempted to garner support for this initiative. Once these efforts were under way, SCALE/QED leaders identified additional opportunities for new preservice pathways, including options or program concentrations for the liberal studies program.

Activities. SCALE/QED leaders originally obtained release time for one science faculty member, who reportedly ran into a series of hurdles with the application process, not the least of which was a lack of familiarity with K–12 standards, California standards for approved subject matter programs, and educational jargon. A retired COE faculty member was then designated to spearhead the effort. This individual worked closely with representatives from chemistry, biology, physics, and earth science to identify existing STEM courses that would meet the subject matter proficiency criteria of the California Commission on Teacher Credentialing (CCTC) and to prepare the applications. As one respondent noted, some science faculty viewed this process not only as *not* essential but also as a "nuisance" because teacher preparation was not a core part of their departmental responsibilities. In addition, SCALE/QED leaders collaborated with COE faculty to create additional pathways for liberal studies, with concentrations in general science, earth science, biology, chemistry, and physics. This effort built on an existing mathematics option for liberal studies students.

Observed outcomes. As of May 2007, each of the subject matter applications was close to completion, and SCALE/QED leaders were hoping to submit them in summer or fall 2007. In addition, a new astronomy course that satisfied a precondition for the science waivers was created, as were planned courses with concentrations in the science fields for liberal studies students. SCALE/QED leaders expected that these programs would be institutionalized as part of the STEM department degree programs and would fill an important gap in the preservice pathways offered at CSUDH.

These efforts involved only structural changes and did not include revisions to the curriculum or demands for new pedagogical approaches in the courses, with the exception of the new astronomy course. Fifteen STEM faculty, however, did participate in 3 years of professional development workshops on interactive and developmental instructional strategies led by a COE faculty member (see the following subsection for details), and many of the STEM faculty who taught these courses participated in the summer institutes where teachers were trained in the SCALE immersion units. When students were enrolled in these course sequences, the pedagogical approach that they experienced might or might not have been in accordance with the goals of SCALE/QED regarding STEM instructional improvement, depending on whether the courses were taught by faculty members who had participated in the workshops. Expectations, however, were that those faculty who had participated in STEM workshops would be scheduled to teach the STEM classes for teacher candidates whenever possible.

Although the goal of these programs was to improve support for preservice students and increase enrollment, task implementation (which entailed meetings of STEM and education faculty to discuss the state requirements of the science waiver program) also created opportunities for cross-college interaction on specific, immediately relevant tasks. However, several respondents reported that the tasks were limited to “onerous and frustrating” administrative work. Despite the relatively superficial degree of task-based interactions required by this effort and the frustrations experienced mostly by STEM faculty, this activity did lead some STEM respondents to feel more ownership of the teacher preparation process than previously.

Institutionalization and sustainability. As noted, CCTC consideration of the subject matter programs is pending as of this writing. If approved by the CCTC, the subject matter programs will become an official part of each participating department’s course offerings. This is clearly a type of institutionalization of a reform effort. Further, expectations are that the team of education and STEM faculty that is focused on recruiting future mathematics and science teachers will collaborate with the outreach staff in the admissions office. The success of this effort will depend on whether new preservice teachers do, in fact, flock to the new waiver programs. The faculty in education and STEM areas will continue to meet on a regular basis under the auspices of the University Committee for Educator Preparation and will engage in the intensive program review and documentation process each time the CCTC changes its program standards.

Instructional Practice: STEM Faculty Professional Development Workshops

STEM faculty professional development workshops were not originally part of the QED proposal or work plan. Rather, they emerged as an initiative after the project began. Many of the findings described here can be linked to both the STEM faculty professional development workshops and the science immersion unit efforts. Because several respondents participated in both efforts, it is difficult to separate the relative influence of each activity. The observed outcomes related to changes in STEM faculty instructional practice, professional identity, and collaborations with their COE counterparts are discussed in this section due to the frequency with which respondents attributed changes to the STEM faculty professional development workshops. A detailed discussion of this activity is included in Section V.

Activities. In 2005, six science faculty, five COE faculty, five math faculty, and two LAUSD curriculum consultants met 4 times. In the 2006–2007 period, five science faculty, two COE faculty, nine math faculty, and three El Camino Community College faculty met a total of 14 times (9 times for the science faculty and 5 times for the math faculty)*. The STEM faculty* *participants in these workshops generally represented a single cohort throughout this 3-year period.* The 2006–2007 mathematics workshops were collaboratively facilitated by the COE faculty member and a math faculty member. Topics addressed included (a) classroom management, (b) active learning strategies, (c) teaching for transfer, and (d) cooperative learning. One notable feature of the workshops was that the facilitator included STEM content examples in the course activities and handouts. The facilitator intended the professional development workshops to influence the teaching practices that faculty members used as they participated in other SCALE/QED–initiated work.

More recently, a cohort of adjunct and community college faculty was recruited to participate in these professional development workshops. A respondent familiar with the administration of the workshops stated that this population was selected due to their strategic placement in the “pipeline” for teacher preparation. The community college faculty instruct a large percentage of students who then transfer into CSUDH degree programs, whereas adjunct faculty teach several introductory courses required in the liberal studies and other key degree programs.

Observed outcomes. Based on the causal network analysis of the STEM faculty development workshops, I identified the following outcomes: (a) shifts in STEM faculty views of the learning sciences and STEM instruction, (b) self-reported instructional changes, (c) formation of a cohort of science faculty, and (d) shifts in the facilitator’s views of STEM faculty and pedagogical issues. A detailed analysis of these outcomes is included in Section V.

Interinstitutional Collaboration in K–12 Professional Development: Science Immersion Unit Design and Implementation

The goals of the SCALE/QED science institutes were to develop and implement high-quality professional development for K–12 teachers using an inquiry-based methodology.[6] Teams of local IHE faculty, K–12 personnel, and UW–Madison staff collaborated in designing professional development sessions that were focused on topic-specific “immersion units.” An immersion unit is a carefully selected and designed learning opportunity in which students are engaged in the scientific inquiry process over an extended period of time (in this case, 4 weeks), focusing intensely on a particular concept or big idea in the content area (Lauffer, 2004). Each of the science immersion units provided a coherent series of lessons designed to guide students in developing deep conceptual understanding aligned both with key science concepts and with the essential features of classroom inquiry, as specified in the state standards of the district for which each unit was designed. In each unit, students learned academic content by working like scientists: making observations, asking questions, doing further investigations to explore and explain natural phenomena, and communicating results based on evidence.

Early in the SCALE project, a small team of immersion unit developers from UW–Madison began meeting with central office science staff at LAUSD. After much effort to define the scope of the immersion work, the district and SCALE staff agreed that a series of units would

[6] A secondary goal of the institutes was to expose STEM faculty to new pedagogical methods in the hope that they would transfer these methods to their undergraduate instruction. However, the ultimate focus of the institutes was on professional development for K–12 teachers.

be developed and written into the district's science instructional guides and that teachers then would be provided with professional development in the use of these units. SCALE and QED joined forces to coordinate the development of these units between January and June 2005, to offer science immersion institutes to LAUSD teachers during summer 2005, and to revise the units and the institutes during 2005–2006. SCALE's immersion unit design team from UW–Madison (consisting of curriculum writers and scientists with expertise in teacher professional development) headed up a joint collaboration involving the UW–Madison team, CSU faculty, and LAUSD science administrators and specialists. The science immersion institutes were 5-day professional development workshops for LAUSD science teachers. They were co-designed and co-facilitated by teams of LAUSD personnel (teachers, science experts, and administrators), CSUDH faculty, CSU Northridge (CSUN) faculty, and SCALE staff from UW–Madison. The institutes were designed (a) to introduce the concept of immersion to K–12 teachers by engaging them as learners in a scientific inquiry and (b) to model unit implementation as if the implementation were occurring in a K–12 classroom.

Activities. The activities pertaining to the science immersion units include the unit design process, the professional development design process, and the actual institute implementation. As a result of working on immersion units and modeling active learning pedagogies during 2004–2005, UW–Madison staff and other SCALE leaders realized that they could also use this immersion in-service project as an opportunity to help STEM and education faculty improve their approach to undergraduate teaching. Accordingly, they decided to bring STEM and education faculty together to collaboratively design a high-quality professional development plan, with the focus on K–12 teacher learning and instructional improvements.

In particular, the UW–Madison staff and other SCALE leaders began to more explicitly develop the design process to engage *all* participants, including IHE faculty, as learners and practitioners. One respondent noted the difficulties of the process:

> What happened was that as we were developing the immersion units, [one UW–Madison staff person] came up to me and said, "The most important aspect of this is not so much the product that we will prepare, the unit itself, but in the process of preparing it, the professional development that has occurred among the [IHE] faculty and the [K–12] teachers in working together to do this." We also realized that once we did the institutes, we needed [more] professional development for the professional developers. (SCALE leader, interview data)

This experience included learning core elements of subject-specific pedagogical content knowledge as well as "tricks" of education, including classroom management. Although relatively few personnel participated in this effort (three STEM faculty and four education faculty from CSUDH), the unit design work was very intensive, and they accomplished a great deal. For example, participants from the different institutions met together on the CSUDH campus every 2 weeks from January to June 2005 to define the scope of the units' learning objectives and to develop curriculum and instructional activities to support those objectives. During 2005–2006, a key mechanism for designing the professional development for the summer institutes (which focused on the immersion units) was the leadership study group, composed of representatives from UW–Madison, CSUN, CSUDH, and LAUSD. The goal of this group was to pool expertise and resources to design a high-quality professional development curriculum and to collectively learn how to implement the unit for the upcoming summer institutes. They enabled this more intentional professional development experience for the CSU faculty and LAUSD teachers by asking the leadership study group members to learn how to model the active-learning pedagogy embedded within the immersion units.

Between June 2005 and August 2006, CSUDH faculty and SCALE/QED leaders organized and facilitated 23 one-week science institutes (9 during summer 2005 and 14 during summer 2006 on three different CSU campuses). Of these, 7 were held at CSUDH for 176 LAUSD science teachers (QED, 2007a). As part of the science institute activity, five science immersion units were collaboratively designed by CSUDH STEM and education faculty together with LAUSD teachers and science experts. Each institute focused on the introduction and preparation for implementation of a science immersion unit in the participants' classrooms in Grades 4–8. As of May 2007, five immersion units had been designed: *Rot It Right* (Grade 4), *Weather* (Grade 5), *Plate Tectonics* (Grade 6), *Variation* (Grade 7), and *Density and Buoyancy* (Grade 8).

Observed outcomes. One of the most consistently reported aspects of SCALE/QED was the collaborative design and implementation process involved with the science immersion units. Teams of STEM and education faculty from CSUDH, LAUSD personnel, and UW–Madison SCALE staff worked over the course of several months to collaboratively design the units. Then during week-long professional development sessions, these interinstitutional teams facilitated the implementation of the units with groups of LAUSD K–12 teachers. For some of the STEM participants, this was the first time they had worked closely and collaboratively not only with K–12 personnel, but also with other IHE faculty.[7] As one respondent explained:

> I think the collaborations have been the most thorough of any project that I've been a participant in. I'd say they're very extensive, actually. There's always representation by active participants representing each of the institutions, and they're not token participants. They're very much bona fide members of the team. The idea is to bring the people there who potentially benefit from the same thing and to have them work together on the same kind of projects, bringing each party's side and perspective to it. And that's very much been the case. (STEM faculty member, interview data)

Respondents reported a variety of effects from this close collaborative process. First, many STEM faculty gained a better understanding of the K–12 sector, including knowledge of standards, classroom conditions, and the constraints facing K–12 teachers. For some faculty, there was also the opportunity to apply what they had learned from working on the immersion unit teams to their own coursework at CSUDH.

Second, the CSUDH participants generally reported that they felt part of an interinstitutional team in which each party's expertise was valued. Many considered this type of interinstitutional work highly unusual in education, noting that hierarchies between and among different sectors can be extremely divisive. As one respondent noted:

[7] See Clifford and Millar (2007) for a detailed discussion on IHE/K–12 partnerships.

> Before I worked on this project I knew more Nobel Prize winners than I knew middle school teachers. Now it's vastly the other way around, and [now] I'm on speaking terms with the head of secondary science. So I think in that way, collaborating a lot more when we do the professional developments, I do feel that I know them personally, and we work together as colleagues well, so in that sense I'm a lot more involved. [But] I haven't started my own formal collaborations. (STEM faculty member, interview data)

Finally, these collaborations led to a high-quality professional development product, including the immersion unit curricula as well as the instructional methods associated with their use. As of this writing, the immersion units are implemented by LAUSD science teachers and have been widely supported by district administrators and science experts.

Institutionalization and sustainability. As previously noted, the COE faculty and programs had particularly strong ties with local school districts. By contrast, science departments in particular had minimal ties associated with recruiting students or providing professional development, and no links to teacher preparation or activities involving substantial shared tasks. Once the resources provided by SCALE/QED have ended, the "buyout" that allowed CNBS faculty to collaborate with COE and LAUSD faculty to develop immersion units might disappear. One administrator sympathetic to SCALE/QED goals noted that without external funding, he would be unable to release faculty from other duties to participate in these kinds of collaborative activities. Therefore, the only way in which ongoing development of immersion units could be institutionalized at CSUDH would be through continued release time for faculty to work on such projects. This effort might also be sustained if science faculty used immersion units in their CSUDH courses. It is too soon to know if this will occur.

Inter-institutional Collaboration in K–12 Professional Development: Math Institutes

The mathematics department at CSUDH had provided professional development institutes for K–12 teachers for many years prior to the SCALE/QED project. These efforts were funded by external agencies, including the California Mathematics Project, which is part of the California Subject Matter Project. The CSUDH mathematics project has been engaged in improving pre-K–12 education through grants fostering institutional change and through partnerships with local agencies. As a result, respondents referred to the SCALE/QED math institutes as the current iteration of a long line of professional development activities in the department. The goals of the math institutes were (a) to increase student achievement in and understanding of the mathematics contained in the California state standards in Grades 6–9 through implementation of a professional development program and (b) to better equip teachers to facilitate their students' deeper understanding of mathematics.

Activities. A total of five math institutes from July 2005 through August 2006 were held at CSUDH for 106 LAUSD middle school math teachers (QED, 2007a). In addition, teachers in each institute worked with the faculty to co-develop two 3-week teaching units that conformed to the district's *Mathematical Instructional Guide* and the district's selected textbooks. The math institutes held at CSUDH were 3-week long sessions that were co-facilitated by a mathematics department faculty member and a COE faculty member.

The math institutes employed an inquiry-based methodology while focusing on the LAUSD mathematics curricula and instructional guides. According to official advertisements, these institutes included unit development and lesson planning, discussions of current research addressing English language development and mathematics issues, and explorations of assessment methods that could inform instructional practice. A typical institute day began with an introduction of the problem of the day, grounded in algebraic thinking. The teachers were then given time to solve the problem cooperatively, or they might be instructed to think about the problem and return to it later in the morning. The morning would then continue with a hands-on content lesson, based on the theme in the problem of the day and primarily geared for teachers, followed by a discussion of the mathematical content and further development of the mathematics of the lesson. In the afternoon, a discussion might deconstruct the morning lesson, singling out the mathematical task, the academic language, and the specific goals and subtasks, and then reconstitute the lesson with a scaffolding of English language development strategies.

Observed outcomes. The QED Year 3 annual report (QED, 2007b) presented findings from a pre- and posttest administered to 56 participants from the 2005 institutes. A perfect score of 51 points was possible; the average pretest score was 32.6 points, and the average posttest score was 37.3 points. Change from pre- to posttest, calculated based on the change of the sum over all participants, was found to be statistically significant, passing a t-test ($t = -6.11$, $p < .0001$). Measured in effect size, the change was .54, which indicated that the institutes had a moderate effect on teacher performance on the content portion of the assessment tool. These institutes had a much stronger effect on the first two problems in the exam, which emphasized algebraic reasoning, with effect sizes of .78 and .38, respectively. The problems emphasizing probability and mathematical justification saw effect sizes of only .04 and .08, respectively. This reflected the focus on algebraic reasoning throughout the institutes (QED, 2007b).

Institutionalization and sustainability. As previously mentioned, professional development programs had been offered through various funding vehicles in the mathematics department for many years. The continuation of these efforts depends on continued funding from external sources.

C. Direct SCALE/QED Impacts on Preservice Programs

SCALE/QED leaders sought to influence preservice teacher programs through multiple points: curricular change, cohort recruitment, and instructional changes. They reasoned that improvements in STEM faculty teaching practices would improve the learning of preservice candidates who took their courses. This section reviews SCALE/QED activities to make structural changes in the preservice pathways and to foster improvements in the instructional practices of STEM faculty participants who teach students in designated preservice pathways.

Preservice Candidate Pathways

One perspective on preservice pathways was that all students in all courses are potentially preservice teachers—and thus all faculty are engaged with preservice teachers. This perspective was based on the fact that California awards a range of credentials, and each one has different course and degree requirements. As a result, preservice students may audit a single STEM course to satisfy a subject matter requirement, or they may enroll in a designated preservice degree program like the liberal studies teaching option. Some respondents further felt that because many students decide to enter the teaching profession after their undergraduate work, *all* STEM students are potentially preservice teachers. Because an evaluation to determine if such an intervention had reached this audience would be almost impossible to conduct, this research pursued the outcomes of another perspective that was voiced by several respondents. This perspective was that designated preservice pathways at CSUDH are expressly designed either to provide a student with a teaching credential (5^{th}-year post-baccalaureate teacher education program, liberal studies blended option) or to offer courses that satisfy credential requirements established by the CCTC (e.g., liberal studies major, math education major). Looking at the list of the courses required in these pathways and the faculty assigned to teach them in a given semester made it possible to ascertain if SCALE/QED participants were directly involved in teaching a course designated as a preservice requirement.[8]

Students in the 5^{th}-year post-baccalaureate teacher education program take an additional year of COE courses. Required courses at the time of the study included some in STEM methods or general pedagogy that could be taught by SCALE/QED faculty participants from the COE. Students in this program are not required to take calculus or physics unless they need to satisfy subject matter requirements in addition to the credential coursework. Hence, the design of this program did not bring STEM faculty into contact with this cohort. Students in this pathway often end up teaching at the elementary or secondary level.

Students in the liberal studies program are required to take Mathematics for Elementary Teachers: Real Numbers and Geometry. Those liberal studies students who select the mathematics option are also required to take College Algebra and Trigonometry, and two of the following three courses: Elementary Statistics and Probability, Computers for Mathematics Teaching, and Problem Solving in Mathematics. Required science courses include General Biology, the General Biology lab, Physical Science for Teachers, and Earth Science for Teachers. Students in this pathway are preparing to teach at the elementary level, and those with additional concentrations in mathematics or science may teach at the middle school level.

Another cohort of preservice candidates includes the math department's math education majors, who are required to take 19 STEM courses, including both calculus and physics. The completion of this program of study allows the future teacher to teach the entire secondary mathematics curriculum upon finishing the credential process. Most of these students are preparing to teach at the secondary level, in contrast to students in the liberal studies pathway.

Effects on Preservice Candidates

In the period under study, SCALE/QED faculty participants were deeply engaged in some pathways and not engaged in others. The largest pathway at CSUDH that leads directly to a teaching credential, the 5^{th}-year post-baccalaureate program, does not require any STEM courses. Thus, STEM faculty had no direct instructional influence on the 637 students who enrolled in this option in fall 2006 (see Figure 5). The 1,089 students who enrolled in fall 2006 in the liberal studies programs (including the mathematics option) could take courses from up to four SCALE/QED faculty. Four SCALE/QED faculty taught courses required for the liberal

[8] The description of requirements is based on the course list from fall 2006.

studies concentration in mathematics and the math department's math education major and were most likely have come into contact with these cohorts of 104 students and 73 students, respectively.

This analysis shows that the designated preservice pathways at CSUDH at the time of the study included a select number of courses and by extension, were taught by only a select number of faculty. Thus, in order to reach a designated cohort of preservice candidates, it is necessary to either engage faculty who teach these courses and/or change the courses themselves. SCALE/QED successfully enacted changes to calculus and physics courses, but changes reached only the cohort of students in the mathematics department's math education major. Of course, these changes might ultimately have impacts on all STEM majors, regardless of career path. But as noted above, this more general goal was different from the SCALE/QED goal of improving designated preservice programs.

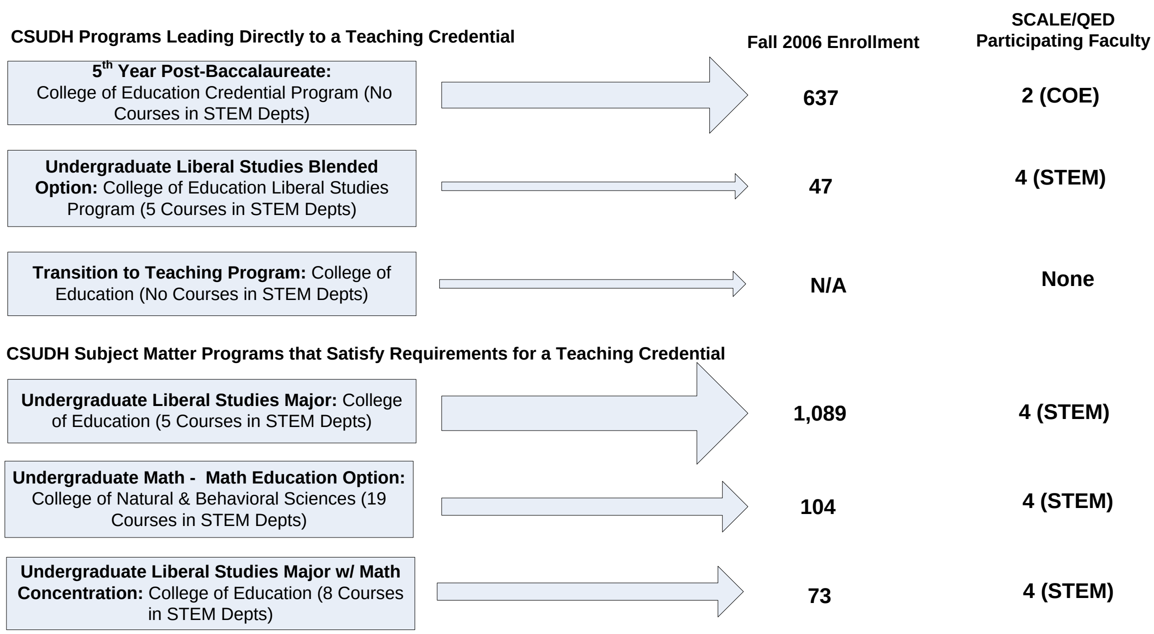

***Figure 5.* CSUDH teacher preparation programs showing numbers of participating COE and STEM faculty, 2006–2007.**

To my knowledge, no efforts were made to ensure that SCALE/QED faculty directly participated in any designated preservice pathways. However, one of SCALE/QED's major accomplishments was in expanding the number of preservice pathways available to future math and science teachers, including subject matter programs and the new liberal studies concentrations. As a result, it is highly likely that in the future more STEM faculty will directly interact with preservice candidates than at the time of this analysis.

D. Summary

This section provides a brief summary of the descriptive data available for each SCALE/QED activity, including IHE faculty participant data (see Table 1).

Table 1
Total CSUDH Faculty Involved in the SCALE/QED Project

Department	Science institutes	Math institutes	Preservice pathways	STEM courses	Preservice cohort	STEM faculty professional development
COE						
Teacher education	4	1			1	5
Administration					1	
Retired			1			
CNBS						
Physics	2		2	1		2
Earth science	1		1			1
Chemistry	2		1			2
Biology			1	3		
Mathematics		2		3	1	9[a]
Inter-disciplinary	1					
Administrative					1	
Total	**10**	**3**	**6**	**7**	**4**	**19**

[a]One mathematics faculty member also served as a co-facilitator of the professional development workshops for mathematics faculty.

Structural Change

SCALE/QED structural change activities focused on preservice pathways in two ways: course redesign and recruitment.

STEM course redesign. By May 2007, SCALE/QED had enacted changes in the curriculum and structure of sections for Calculus I and II and General Physics I and II. These sections were intended for the cohort of SCALE/QED students.

Preservice candidate recruitment and preservice pathways in math and science. The available information related to recruitment was insufficient to support analysis. For the preservice pathways, subject matter program applications for chemistry, physics, earth science, and biology were close to completion in May 2007, and SCALE/QED leaders submitted them that year. As of this writing, these applications are being reviewed by the CCTC. In addition, a new astronomy course was created to satisfy a precondition for the science waivers.

Instructional Practice

SCALE/QED activities relating to instructional practice focused on STEM faculty professional development workshops**.** In 2005, six science faculty, five COE faculty, five math faculty, and two LAUSD curriculum consultants met 4 times. In the 2006–2007 period, five science faculty, two COE faculty, nine math faculty, and three El Camino Community College faculty met a total of 14 times (9 times for the science faculty and 5 times for the math faculty). The STEM faculty participants in these workshops generally represented a single cohort throughout this 3-year period. Based on the causal network analysis of the STEM faculty development workshops, I identified the following outcomes: (a) shifts in STEM faculty views of the learning sciences and STEM instruction, (b) self-reported instructional changes, (c) formation of a cohort of science faculty, and (d) shifts in the workshop facilitator's views of STEM faculty and pedagogical issues.

Inter-institutional Collaboration in K–12 Professional Development

SCALE/QED activities relating to interinstitutional collaboration focused on the creation of science immersion units and on the math institutes.

Science immersion units. Between June 2005 and August 2006, CSUDH faculty and SCALE/QED leaders organized and facilitated 23 one-week science institutes (9 in summer 2005 and 14 in summer 2006 on three different CSU campuses). Of these, 7 workshops were held at CSUDH for 176 LAUSD science teachers (QED, 2007a, 2007b). As of May 2007, five immersion units that included CSUDH faculty involvement had been designed for LAUSD.

Math institutes. A total of five 3-week math institutes were held at CSUDH for 106 LAUSD middle school math teachers (QED, 2007a, 2007b). These institutes were co-facilitated by two CSUDH faculty (math and COE). LAUSD teachers in each institute worked with CSUDH faculty to co-develop two 3-week teaching units that conformed to the district's *Mathematical Instructional Guide* and the district's selected textbooks.

V. Discussion

Underlying this research and evaluation is a desire to conduct an empirical investigation into specific effects of the institutional context on mathematics and science education reforms. Because reform efforts, far from working in a vacuum, interact with various elements of the institution and coexist with extant reform initiatives, understanding of the context in which a reform effort unfolds is critical (Anderson & Helms, 2001; Katzenmeyer & Lawrenz, 2006; Patton, 2006). In the case under study, the MSP program explicitly sought to restructure an IHE in order to enhance the teaching of mathematics and science throughout the K–20 educational system (NSF, 2002). Accordingly, this evaluation was designed as an exploratory empirical analysis of the processes by which one IHE's constituent elements affected achievement of the goals pursued by an MSP project. This case study shows that institutional context factors that influence a reform effort include more than degree programs and governance structures: They also include material and human resources, group identities fostered by structured interactions, and individual dispositions and practices—all of which are influenced, in turn, by external factors. All of these factors may influence the acceptance, rejection, or effectiveness of a reform effort, often in a nonlinear and unpredictable manner. Illustrating this point, this section considers how contextual variables influenced STEM faculty professional development, and whether SCALE/QED changed the institutional culture of CSUDH. It then concludes with my recommendations for program improvement and replication.

A. Influence of Contextual Variables on STEM Faculty Professional Development

To understand how contextual factors influenced the outcomes of a SCALE/QED initiative, it is instructive to investigate a single effort closely. In this case study, the STEM faculty professional development workshops provide an excellent illustration of the intersection of institutional forces. Furthermore, the quality and quantity of data for this activity provide adequate opportunity for analysis. This is not to say that other activities, such as the science immersion units, were not of equal importance, but only that these workshops represented an opportunity to study a variety of factors at work in microcosm. This analysis is based on a causal network analysis (see Figure 6), where linked propositions related to the STEM faculty professional development workshops were situated in the ICF.

Preexisting Contextual Variables That Influenced the STEM Faculty Workshops

The antecedent conditions relevant to the STEM faculty professional development workshops included an institutional atmosphere amenable to change, structural and sociocultural divisions between the two colleges, and limited exposure of STEM faculty to the learning sciences, except for a small number of mathematics faculty.

CSUDH leadership and influx of resources created an atmosphere conducive to change. The presence of active pedagogical reform initiatives—such as the learner-centered university effort out of the provost’s office and the involvement with STEM pedagogy by the mathematics department—helped to ensure that a national effort such as the MSP had an audience and local support. In addition, the ability of both the provost’s office and mathematics faculty to secure significant amounts of external funding raised the profile of STEM education issues at CSUDH. These factors resulted in a campus-wide sentiment that reform was actively promoted and supported “from the top” and that trends in funding were beginning to favor pedagogy-related activities.

Structural boundaries limited opportunities or reasons for interaction. The structure of preservice programs and course sequences did not require interactions and/or collaborations between CNBS and COE faculty. Content and pedagogical preparation occurred separately in different degree and/or credential programs and were only co-located in the liberal studies program for future elementary teachers. The most logical venues for collaboration were campus-wide committees for the liberal studies program and teacher preparation in general, but these committees involved very few STEM faculty, and meetings were sparsely attended.

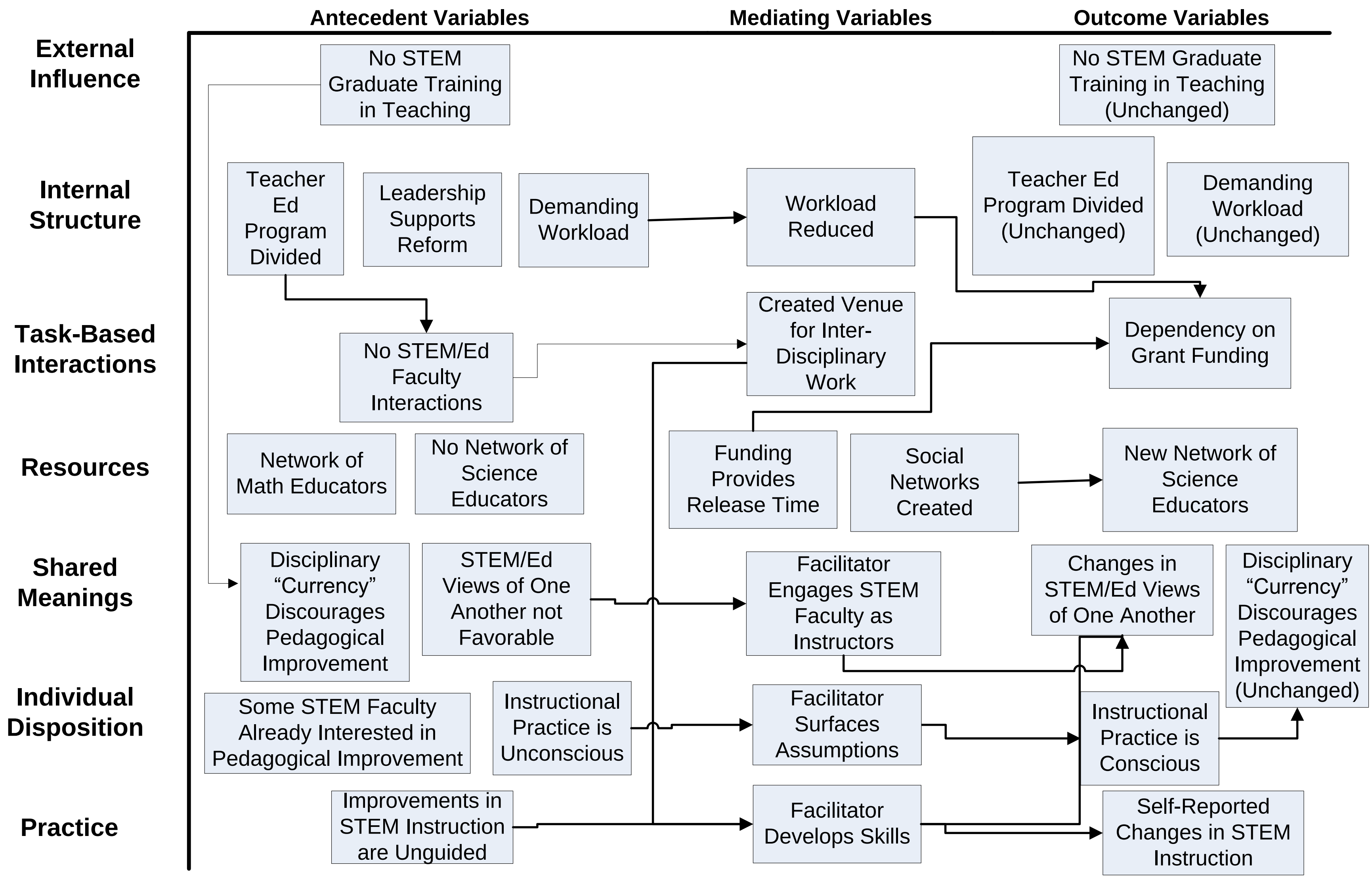

Figure 6. **Causal network analysis of STEM faculty professional development as mediating variable.**

Sociocultural boundaries existed between disciplines, and local conflict was evident. Although boundaries naturally demarcate different academic disciplines, project faculty exhibited strong social boundaries that were based on the division between the social (i.e., *soft* or *applied*) sciences and the natural sciences and mathematics (i.e., *hard* or *pure* sciences). Despite personal relationships with individual education faculty, most STEM faculty respondents exhibited a lack of understanding (and exposure) to the learning sciences—and sometimes skepticism of the academic rigor of social sciences as a whole, but especially education sciences. Conversely, some education faculty respondents stereotyped STEM faculty as completely reliant on lecture as an instructional method and felt that "they [STEM faculty] need to think and teach like us." Finally, relations between the two colleges had been strained by a history of personal conflict and an education dean who actively "cut off ties" between the colleges.

STEM faculty exposure to pedagogical instruction was limited by training and workload. Individual faculty interpreted the conceptual and practical divisions noted above in terms of their underlying conceptions and beliefs about teaching and learning. STEM faculty lacked exposure to pedagogical issues due to lack of training in graduate school, and this was exacerbated by the fact that getting training at CSUDH was inhibited by the constraining effect of the workload. As a result, their approach to STEM instruction was characterized by a lack of specific tools for instruction, a lack of self-awareness or reflection about pedagogy, and a reliance on the way they themselves had been taught (e.g., traditional lecture, bench research). However, some STEM faculty were interested in pedagogical improvement prior to SCALE/QED, which they attributed to a combination of personal interest and concern for the state of scientific literacy among the general public.

Design and Intent of the Workshops

In this context, SCALE/QED introduced the STEM faculty workshops, in which five to six science and nine math faculty participated over the course of 2 years. The design of these workshops effectively mitigated aspects of the institutional context that inhibited the goals of SCALE/QED by creating a structure for intercollege interaction, providing funds to release faculty from their demanding workload, and engaging a skilled COE faculty member who designed and facilitated the sessions. The efforts and performance of this COE faculty member were key to the success of these workshops.

The focus of the QED grant, as written, was on engaging CSU faculty in designing and implementing K–12 professional development workshops. After the grant was awarded, the workshop facilitator conjectured that the STEM faculty involved in the planned activities would benefit substantially from a structured professional development program. She thus proposed to provide professional development workshops, and the SCALE/QED leaders agreed to fund this activity. She then designed the workshops in a way that effectively addressed several features of the institutional context. These included alleviating the demanding workload by "buying out" faculty from one course, without which it is highly unlikely that faculty would have participated in any of the sessions. In fact, despite the university's offering professional development sessions as part of the learner-centered university initiative, some faculty cited lack of time as a reason for not taking advantage of these opportunities. Other important features of the workshops were that they created a structure for intercollege collaboration where none existed, they tapped into a preexisting cohort of STEM faculty who had some interest in pedagogical issues, and they served to negotiate the sociocultural divisions between STEM and education faculty.

It is important to note the fortuitous nature of this SCALE/QED activity. As previously mentioned, these workshops were not originally part of the SCALE or QED proposals and were suggested by the COE faculty member. This individual’s primary research interest was in IHE pedagogy, inspired in part by research that indicated that students’ perceptions of academic success were influenced by professor behavior. The facilitator had also been involved in a Title V grant where she had trained faculty members across campus to infuse skills such as writing into their course design and instruction without “destroying their syllabus.” This focus on providing professional development in a way that acknowledged and respected the participants’ syllabi and existing skill sets became a critical feature of the SCALE/QED workshops. Without the presence of this individual, who had the foresight and skills necessary to design such a professional development series and successfully negotiate the sociocultural barriers present between STEM and education faculty, it is unlikely that this activity would have taken place.

Drawing on her own experiences, the facilitator designed a series of four professional development workshops specifically for STEM faculty. The workshops addressed the following topics: (a) classroom management, (b) active learning strategies, (c) teaching for transfer, and (d) cooperative learning. The goal of these sessions was to improve the professional teaching practices of STEM faculty at CSUDH by helping them develop strategies for engaging students actively in their own learning. The facilitator also emphasized the idea of backward design where faculty, at the outset of a course, identify measurable outcomes for student learning and then design the course and plan their instruction to get students to those outcomes. The facilitator noted that because this process required clarity from instructors about what was expected and “clarity in designing curricular learning outcomes is not a natural skill” for many IHE faculty, she had decided that helping participants become aware of the pedagogical techniques that they implicitly used or relied on was an important task.

SCALE/QED and Facilitator Approach to the Workshops

The facilitator was very deliberate in designing these workshops and in interacting with the STEM faculty. As someone experienced in her own institution and knowledgeable about the aforementioned barriers, she was cognizant of the divisions in the university and among the disciplines and aware that boundary crossings needed to be negotiated. The facilitator focused on ameliorating disciplinary stereotypes and divisions by acknowledging them, being sensitive to individual rates of change, making lessons relevant to participants and applicable to STEM, and creating and developing individual comfort levels with pedagogical topics and issues.

Acknowledge disciplinary stereotypes and divisions. At the beginning of the workshops, the facilitator told the faculty, “I am not the expert in math and science, [you] are, and I have [expertise in] pedagogy, so we’ll meet in the middle.” By acknowledging the boundaries between the disciplines, the facilitator accomplished two things: (a) she staked the claim that the learning sciences are in fact a valid academic field, and (b) she assured the STEM faculty that their expertise would be respected, not challenged or disparaged. This was an important step in reducing the well-founded trepidation that some STEM faculty had about COE faculty telling them how to teach.

Be sensitive to individual rates of change. The facilitator also understood that change does not happen overnight, particularly among adult learners, and that faculty in the COE "need to be sensitive to people's rate of change." This was important because it was clear that when some faculty at CSUDH had experimented with methods such as small group work, the attempt had "exploded," leading them to avoid trying such techniques and to inform their colleagues that such techniques might not work. In fact, the facilitator conveyed to workshop participants that although an intensive inquiry approach might be desirable, there was a continuum of instructional styles and that "one size does not fit all." To facilitate acceptance, she provided practical tips that could be applied in a variety of ways, such as "getting them to look at where and how to intersperse an active thinking task in the lecture," and assigned faculty to conduct self-assessments and to set goals for how they might use new techniques in their lectures.

Ensure that the workshops are relevant and applicable. Next, the facilitator ensured that the content of the workshops was directly and immediately applicable to the STEM faculty's work at CSUDH, rather than providing materials replete with educational theory or methods that would not translate well to their courses. One of the stated reasons for this effort was to increase the likelihood that the participants would feel responsible and motivated to practice and apply the techniques they learned in the workshops. As the facilitator noted, "It's easy to say '[these techniques are] fascinating' and then not make a difference in their classrooms where future math and science teachers are." For example, the facilitator spent several hours searching for examples from physics for a lesson on graphic organizers, explaining later that it helped "when they saw content that they recognized."

Build a comfort level with pedagogical issues as a step toward continual learning. Another strategy that the facilitator used to increase the chances that the participants would apply what they were learning was to help create in participants an adequately high level of comfort and competency with pedagogical content knowledge. She felt that if participants developed a level of comfort with such knowledge, they would be more likely (a) to develop long-term interest in pedagogical improvement and (b) to begin to speak with their colleagues about pedagogy. She noted that this latter point was important because continued faculty involvement and interest in pedagogical improvement depended on working in an environment where, instead of feeling isolated or alienated, they felt supported. in their efforts. As one respondent noted:

> Some of the math faculty have taught methodology courses themselves. But [it is important] to have their comfort level to the point where they could actually have a dialogue with someone in their department and say, "This is how I might be designing my course with these end-outcomes in mind. Perhaps I could help you with your syllabus." Until they're very comfortable, we can't expect them to be partnering. (COE faculty member, interview data)

The facilitator also observed that this comfort level was developing across faculty in different departments. In making this point, she explained, "A chemist said to a geologist, '[T]hat sounds more like conceptual knowledge than factual knowledge.'" In her view, behaviors like this were small but important indicators that a sense of collegiality, grounded in a personal comfort and proficiency with STEM pedagogy, was developing at CSUDH among a small cohort of science faculty.

Short-Term Outcomes

Of the 15 STEM faculty in the workshops, 5 were interviewed for this case study. The respondents extensively described their experiences in the workshops, including their responses to the COE facilitator and changes in their views about the learning sciences and in their own instructional practices. Based on the causal network analysis (see again Figure 6) of the STEM faculty development workshops, I identified the following outcomes: (a) shifts in STEM faculty views of the learning sciences and STEM instruction, (b) self-reported instructional changes, (c) formation of a cohort of science faculty, and (d) shifts in the facilitator's views of STEM faculty and pedagogical issues.

Participants appreciated the respect they were given in workshops. Some participants expressed an appreciation for the way the facilitator treated them—noting a contrast with the condescension and pressure to immediately change instructional practices that they had previously experienced with other COE faculty.

Some of them explained that the facilitator's sensitivity to "people's rate of change" and her concomitant attention to presenting an array of pedagogical techniques and tools that could be used in a variety of circumstances eased the trepidation they had developed when other COE faculty had insisted on a single way of teaching STEM content. As one participant explained, "[It was] refreshing to hear from that corner of campus, since a lot of people tell us that this is the new way to do things, and everyone should do them that way."

Some respondents also noted that in previous encounters, COE faculty had a propensity to use disciplinary jargon and to cite well-known researchers or pedagogical theories, which served to alienate faculty who were not familiar with the field. Although these workshops included a fair amount of technical information, the respectful and STEM-focused delivery of this content seemed to minimize potentially off-putting effects. This finding is also corroborated by an evaluation of STEM faculty engagement in the MSP program, which emphasized the need to "be sensitive to the needs of STEM faculty" (Zhang et al., 2007, p. 55).

Being treated as an educator allowed STEM faculty's tacit models to surface. The STEM faculty also appreciated how the facilitator addressed and interacted with them as professional educators, not solely as STEM "content experts." For example, a chemist explained how, in a previous collaboration with a COE faculty member, the educator had viewed and utilized the chemist solely as the "content expert," leaving the chemist with little reason or opportunity to learn:

> She uses me strictly for my brain, for my chemistry, whereas with [the facilitator], it is also about the pedagogy, [and so] it's where I've been learning. First of all, [the facilitator pointed out] a number of [good pedagogical] things that I didn't know I did, because as a professor I never took education courses. We just do chemistry and then go into the classroom. So [now I've learned that] there are names for [pedagogical techniques that I unconsciously use]. (STEM faculty member, interview data)

By treating the workshop participants as *educators* of STEM content, the facilitator helped STEM faculty bring to the surface their unconscious pedagogical techniques, which is a critical step in problematizing one's own instructional practice (Cochran-Smith & Lytle, 1999; Schön, 1983). By viewing participating STEM faculty as educators, the facilitator laid the groundwork for the participants to become self-reflective about their own pedagogical techniques. Once these unconscious practices surfaced, the facilitator then helped the faculty reexamine these approaches to teaching and presented a variety of techniques and tools that could be used in their courses. By contrast, many education reform projects engage STEM faculty primarily in their capacity as content experts, as many noted. Although this approach may feel comfortable and natural to STEM faculty, who are indisputably experts in a specialized field of mathematics or science, it may also result in STEM faculty not being treated as "learners" or as skilled enough in teaching to speak intelligently about pedagogical issues. However, if pursued too aggressively, the strategy of surfacing tacit assumptions or "cognitive maps" of teaching and learning can backfire, as Argyris (1985) found when groups of business executives with whom he was working felt that the process challenged their sense of competency and confidence. This finding underscores the need for a facilitator to balance the need to challenge, and thus surface these assumptions, with the need to acknowledge and value a group's core competencies.

In effect, the facilitator succeeded in credibly establishing herself as an expert in the learning sciences with her STEM faculty "students." This relationship became more explicit when the facilitator mentored individual faculty by critiquing the lesson plans that they developed for their own courses. According to one respondent, this approach worked due to a combination of the facilitator's personal style and the attention she paid to ensuring the applicability of the content to the STEM faculty's actual courses.

Workshops were relevant to their coursework. Some respondents appreciated the facilitator's respect for and understanding of the individualistic nature of instruction in an IHE classroom, which was expressed by her stating that the tools and methods discussed in the workshops were not intended as a "one-size-fits-all" for each of the participants. As one STEM faculty member put it:

> One of the things that I respected most about her, early on in that series, was that she told us up-front, "Not all of these techniques are going to be important for every one of you, depending on your style, and how you can deal with things in your classroom." (STEM faculty member, interview data)

This acknowledgment enabled the faculty to learn that the unique conditions for a particular course, including the content, number, and proficiency of students and the instructor's background and disposition, combined to create unique conditions that demanded certain instructional techniques. They explained that they had not learned this from other COE faculty, who had presented instructional tools and methods in a proscriptive fashion, with little attention to the nuances of a STEM classroom.

Working in interdisciplinary teams proved to be a valuable learning experience. Finally, respondents noted that the collaborative nature of the workshops, where they worked closely with two or three other STEM faculty, was a valuable learning experience because they rarely had the opportunity to work so closely with other faculty, especially faculty from other departments. Several respondents also noted that they rarely interacted with any other faculty, which inhibited opportunities for developing collegial relations or sharing ideas. At these workshops, in contrast, groups of faculty were asked to work together, to explain why a pedagogical technique worked or did not work, and then to collectively argue, reflect, and share with the larger group certain decisions they had made. This process is important because faculty who become accustomed to working in such a collaborative manner may begin to foster a collegial community in which they may share notes about classroom experiences and ideas about why different techniques succeed or fail (Knight & Trowler, 2000). The sharing of information among peers is important in diffusing and reinforcing innovations such as instructional practices: Innovations are more likely to be positively received if presented by a near peer—in this case, a fellow STEM faculty member (Rogers, 2003).

STEM faculty increased self-awareness of instruction and changed their perspectives of the learning sciences. As noted above, some faculty described changes in how they perceived their own instructional practice. This involved bringing to the surface the implicit techniques that they had unconsciously utilized in the classroom and acknowledging that there were some shortcomings in their previous approaches to teaching and learning. One participant made this point as follows, "I do see some very real change in a few of the specific overt things I do, and I think I see some subtle shift in style about my expectations for what I do and my expectations for the way students react to it." When these types of new awareness emerged, the facilitator skillfully worked with the STEM faculty to help them understand and practice a more informed and deliberate approach to course design and classroom instruction. This interaction with an expert in the learning sciences also instilled in some STEM faculty a newfound or deeper respect for the field of education, as they discovered its value, rigor, and applicability to their own work. As one respondent noted:

> I think that most scientists piddle in cognitive science for themselves in the sense that we really are a bunch who thinks about how we think. But we're not professionals, have no guidance, and don't bother to follow up most of the time, and we tend to do it more with ourselves than we do it with other people. Starting to do it with other people more is something I [had] from my own teaching before, but I think I picked up a lot more and a lot better from looking at what the cognitive scientists involved in this project are doing. Professionally, I think it has helped my teaching, partly because of this cognitive aspect of it, and partly because of some very explicit things as far as techniques I've learned from the professional developments we've been doing—both the professional development for the STEM faculty and the professional development that we're doing with the middle school teachers. (STEM faculty member, interview data)

Faculty self-reported changes in STEM instruction. Five faculty reported changes in how they designed and taught CSUDH courses based primarily on their participation in the faculty professional development workshops and secondarily, for three, on their participation in the science immersion unit activities. Respondents cited using new tools for understanding how to structure lessons and for incorporating specific techniques into their lessons that required deliberate attention to pedagogy. One faculty member noted:

> I've actually completely revised my coursework based on things that I've learned about cooperative learning and team learning and things like Think/Pair/Share [an instructional technique], which is language, of course, I didn't even know prior to becoming involved

> with QED and SCALE. And I now use it pretty much constantly in my organic and biochemistry courses. (STEM faculty member, interview data)

Others reported that the workshops provided specific pedagogical techniques that improved their already in-place learner-centered approach. Some faculty reported changes in how they interacted with their students, such as a newfound patience in asking questions and avoiding the temptation to fill the silence with their own expert answers. One respondent explained:

> I do find that I've learned on my own that I need to stop often enough and ask some questions. I think that the professional development that we've been doing has gotten me even better at that, and even better at directing those questions in a more fruitful way—for example, by turning it into a real quiz-like activity, but one that you won't grade or collect anything from, as opposed to just asking the question: "How many people think this? How many people think that? And then, let's go through it." That's a good example of how the professional developments have influenced what I do. (STEM faculty member, interview data)

Interestingly, this finding was reported almost exclusively by the science faculty. For some math faculty, the approaches to STEM instruction promoted in the workshops were not new. For example, one math faculty member said, "Not to say anything about [the workshop facilitator], she does great work, but I had already been working on this for many years [and so this] was not anything that I had to adjust to." This comment suggests not only that some math faculty already had the requisite skills and techniques for teaching in a more engaged manner, but that they were already "sensitized" to their own pedagogical approach. Additional workshops for math faculty were under way at the time data for this report were gathered, so this topic cannot be explored in greater detail.

Cohort of science faculty engaged in pedagogy formed. One of the outcomes of the SCALE/QED intervention most widely mentioned by respondents was the cultivation of a group of pedagogy-minded science faculty. Prior to SCALE/QED, there was no such cohort of science faculty. As previously discussed, the formation of such a collegial network can serve important functions for continued innovation, feedback, and support.

Mutual respect for respective fields of expertise contributed to creating a productive learning environment. Finally, the facilitator noted that working with STEM faculty gave her the opportunity to approach the learning sciences "through the eyes of the novice." Conversely, she also noted that the fact that she was not a STEM expert may have been an advantage because it enabled her to more effectively anticipate students' reactions to the STEM faculty. In short, the facilitator learned that it was important that her "students" come to understand that her expertise was different from theirs and that mutual respect for one another's field could contribute to a productive learning environment. As one COE respondent noted:

> I also learned that I could make valuable contributions to science faculty even though I was not an expert in their subject matter. That credibility on the part of the education professional development person needs to be established over time in order to create a climate for STEM faculty to feel comfortable in expressing the need for more

> pedagogical knowledge related to the teaching of their disciplines. (COE faculty member, interview data)

Longer-Term Outlook

Although the SCALE/QED program was fortuitously aided by preexisting conditions at CSUDH, such as administrative support for reform and an influx of new faculty due to retirements, SCALE/QED did successfully plant the seeds for future changes at the structural, sociocultural, and individual levels of the institution. As a result, it appeared at the end of this study that elements for systemic reform supportive of the MSP goals were in place at CSUDH. However, I claim that situating these outcomes within the broader and more complex institutional context permits a more nuanced perspective on the potential supports and barriers to the long-term effects of these outcomes. For example, taking this broader view leads me to suggest that in order to sustain into the future the instructional improvements that SCALE/QED effected, ongoing professional development and/or further development of a cohort of STEM faculty engaged in pedagogical improvement will be needed. Without these structural and social supports, the long-term viability of the SCALE/QED–induced changes will depend on individual faculty motivations to continue improving their instructional practices and mere faith in their own ability to retain the skills gained through their SCALE/QED experience. This said, the following two interrelated factors suggest that this latter scenario will prevail.

First, maintenance of instructional innovations may depend on ongoing engagement with professional development opportunities and/or a social network that is engaged in such activities (Gamoran et al., 2003). But ongoing engagement is not likely unless faculty consider education a priority in their careers. In this case, faculty participating in these workshops viewed their involvement in STEM pedagogy as only an intermittent activity secondary to their research endeavors. As one respondent explained:

> [One question is] how much I see myself as a leader in any of this work, since I don’t consider it my only scholarly activity—and probably still not my major one, although it may take as much time as anything else. I don’t really see myself as a leader in this. Maybe I could be a leader in it at some point, I don’t know. I don’t see myself on a career path toward that, because I think it would be as likely that I take that kind of leadership in some of the fundamental [disciplinary] research. I think most of us [at CSUDH] don’t see ourselves as leading it, but there are a few who I can see developing in that way like [a STEM faculty member at CSUN who is a leader in science education]. But most of us may not have even thought about where it takes our scholarly activity other than “I’m going to get 3 units of release time if I do this job next spring.” (STEM faculty member, interview data)

The question of leadership raised by this respondent is an important factor because it is central to concerns about the future of STEM education at CSUDH. One of the faculty, who has championed STEM education for decades and is the co-PI of the QED grant, is, at the time of this writing, semi-retired, leaving many wondering about the ultimate longevity and sustainability of the reforms enacted at CSUDH.

The second, and perhaps strongest, factor that influenced whether STEM faculty engaged more deeply in STEM education was the strong, persistent emphasis on research accomplishments within their departments and in the CNBS. This emphasis was codified in RTP policies that favored research accomplishments over pedagogical improvements and was also evident in faculty opinions about colleagues who became deeply involved in pedagogical activities. Although several respondents noted that scholarly activity in STEM pedagogy was sanctioned by the upper level administration at CSUDH, others indicated that this approval might not be filtering down to departmental decisions regarding RTP and to individual perceptions about the validity of pedagogical research. That a STEM faculty's decision to become engaged in pedagogical activities was viewed negatively can be inferred from the following remarks:

> I mean, they're sort of making a career choice, you know, that they're really putting a stake down in that. And we have our folks in math education that have made that career choice. And so this becomes part of their ongoing activity. They're making a commitment. I mean they're setting a trajectory for themselves. (STEM faculty member, interview data)

Maintaining a sense of departmental collegiality and feeling esteemed by one's disciplinary colleagues, although not always possible or needed, are important factors in the sustaining of STEM education reforms. This is particularly true for junior faculty who, because they are seeking tenure or promotion, are more susceptible to the opinions of their colleagues. In these cases, being considered as a faculty member on a "trajectory" toward STEM education might actually harm professional advancement, despite the avowed support of the institution.

B. Impact of SCALE/QED on the Culture of CSUDH

Because of the recurrent use of the "culture" concept among respondents and the value that both SCALE/QED and NSF MSP administrators placed on effecting "cultural changes" in higher education, we now turn to the question: Did SCALE/QED change the institutional culture of CSUDH? Given the lack of an operative definition of culture and the absence in the research design of constructs to measure cultural change, determining if SCALE/QED "changed the culture" of CSUDH is not possible. However, the focus on subjective interpretations of institutional life that informed this case study did allow for an analysis of how individual respondents made sense of the intervention in light of certain contextual elements of their institution. These contextual elements are composed of the main categories in the ICF, which was developed to focus the study on specific and observable processes of institutional change.

To understand how individuals experience institutional life, I turn to a psychological explanation of behavior that posits that individuals employ deeply held explanatory structures, known as cultural models, to make sense of and act in any given situation (Shore, 1996; Strauss & Quinn, 1997). Using data only from STEM faculty ($N = 15$) in three categories—*shared meanings, instructional practice*, and *individual disposition*—and noting interactions between these and other categories in the ICF framework, it was possible to infer, in broad strokes, the cultural models that individual faculty employed regarding STEM education. This section includes a brief review of the role of cultural models in STEM education and the ways SCALE/QED influenced these cultural models.

Cultural Models

The focus on subjective interpretations of institutional life that informed this case study supported an analysis of how individual faculty interpreted certain situations and acted in response.

The idea that an individual's cognitive processes shape how information (e.g., visual stimuli, aural stimuli) is processed and interpreted is an old concept in psychology and the cognitive sciences, and the fields of neuroscience and cognitive psychology are currently undergoing a particularly fertile period investigating the biological processes underlying memory and perception (Kandel, 2006). Fully cognizant of the danger in borrowing concepts from fields with which one is barely familiar (as seen in the widespread use of the construct *culture* outside of anthropology), I nonetheless agree, particularly in light of recent applications of the construct to institutional behaviors (Lakomski, 2001), that it is important to invoke the heuristic of a mental or cultural model to explain how an individual interprets information within an institutional environment.

One of the ways that theorists in organizational studies have explained how an individual makes decisions in an institutional context is through the mental model metaphor. In this tradition, mental models are "deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action" (Senge, 1994, p. 7). Mostly applied in the business world as a way to help managers improve organizational learning (Argyris, 1985) and to align individual workers' mental models with those of the company (Senge, 1994), this line of inquiry represents a cognitive iteration of the managerial approach to culture theory. An important contribution from organizational studies to the current case study is a theory regarding change processes in institutions. Argyris and Schön (1978) argued that all human behavior is based on theories of action, which are either espoused theories of action or theories-in-use inferred from how people actually behave and act. In their analysis, change initiatives based solely on new action strategies that do not address implicit theories-in-use entail *single-loop learning* and are rarely effective. In contrast, change efforts whereby individuals begin to question their basic assumptions about a topic entail *double-loop learning*, which Argyris and Schön consider a fundamental component of institutional change and learning.

Another body of research that addresses the relationship between individual cognition and its sociocultural origins can be found in cognitive anthropology. Recent work in this field has focused on cultural models, which are composed of topic-specific *schemata*. Schemata, in turn, are units of culturally shared knowledge that are hypothesized to be encoded in neural networks in the brain (D'Andrade, 1995; Strauss & Quinn, 1997). Schema theory can be traced to the work of Piaget (1955) and is a core idea to the constructivist position.[9] This interpretation process may involve the omission or transformation of certain stimuli to conform to the expectations of the observer (Strauss & Quinn, 1997). Cultural models differ from personal or idiosyncratic models in that they are acquired through exposure to socially sanctioned and reified activities. This approach is similar to the influential theory of mental models in organizational theory (Argyris & Schön, 1978), but cultural models avoid the contention that organizations

[9] Constructivism holds that individuals do not simply reproduce information received from their environments, but instead restructure and interpret stimuli in an idiosyncratic fashion (McVee, Gavelek, & Dunsmore, 2007).

"learn" or "cognize," which is an untested and controversial assumption (Lähteenmäki, Toivonen, & Mattila, 2001). Instead, individuals within a group may share a particular model that may be more or less operational within a given environment, and multiple individuals with similar mental models can over time alter institutional structures and traditions.

STEM Faculty's Cultural Model of STEM Instruction

For this case study, respondents' espoused theories regarding STEM instruction were analyzed for evidence of tacit assumptions pertaining to lesson planning and instructional practice. *I cannot emphasize enough, however, that this analysis is an exploratory effort at understanding the role of cultural models in STEM education and is based on the interpretive tradition of Strauss and Quinn (1997), which uses natural discourse to identify cultural models.* Future research may involve the additional use of methods developed specifically for schema identification (e.g., free-listing, cultural consensus analysis) and should build on this exploratory effort.

Prevailing STEM faculty cultural model regarding STEM instruction. Based on the data collected for this study, the cultural model that STEM faculty held for STEM instruction was implicit. That is, the faculty actively used this model to guide their interpretations and decision making about STEM education, but were not aware of it as such. Similar to Argyris and Schön's (1978) theories-in-use, where an individual is unaware of his or her own tacit assumptions about a topic, the faculty cultural model for teaching is a "taken-for-granted" approach with origins that can be traced back to graduate training. The data suggest that the cultural model regarding STEM instruction is strongly shaped by personal experiences with graduate training at a research university, but is rarely articulated within academic departments. By contrast, the cultural model for research accomplishments and excellence is articulated in terms of specific disciplinary criteria.

Specific components of this taken-for-granted cultural model of STEM instruction included the following schemata:

- Instruction in a STEM field is based on transmission of facts and direct involvement with lab- or field-based experiences (*STEM instruction as transmission*).

- The learning sciences have some value, but that value is unclear (*learning science value*).

- COE faculty have the tendency to be impatient, arrogant, and/or unfamiliar with STEM disciplines (*COE faculty impatience*).

- Improving instructional practice would greatly benefit the public, specifically future K–12 teachers (*instructional practice value*).

- The poor preparation of students in STEM disciplines limits the effectiveness of college-level STEM instruction (*student preparation*).

These schemata were differentially enacted by different STEM faculty and might or might not have surfaced in their actual work at CSUDH. Yet they constituted a shared set of tacit assumptions about STEM education that was widely agreed upon.

The effect of the institutional context on this cultural model. I theorize that this STEM faculty cultural model regarding STEM instruction was refined and/or reinforced through interaction with four distinct but intersecting "fields" of activity: the institution, the department, the subgroup, and the student body. The *STEM instruction as transmission* schema was derived from faculty's graduate training, during which they were given no training in teaching or pedagogical principles. Their reliance on the lecture model of instruction was locally reinforced at the departmental level by a resistance to reform among faculty due to inertia and to prevailing attitudes regarding standards for scientific legitimacy, which asserted the primacy of research over teaching excellence. These standards were made particularly influential in their instantiation into departmental RTP policies. Despite these barriers, there was a group of STEM faculty who exhibited the schema *instructional practice value*, which was based on personal conviction regarding the value of improved teaching and the mission and identity of the IHE (i.e., being at a comprehensive IHE increased the importance of teaching). As a result, a pool of faculty was predisposed to the goals of SCALE prior to the intervention.

The *learning science value* schema was derived from faculty's familiarity with scientific inquiry based on their experiences doing field and lab work, which had led to a sentiment that there was some inherent value in understanding the processes of scientific inquiry from a cognitive perspective. However, it was unclear how the learning sciences were directly applicable to their own instructional practices. This was due to a widespread notion that COE faculty thought that STEM faculty could not teach effectively at all and thus tended to treat STEM faculty with impatience and arrogance (*COE faculty impatience*). This schema was exacerbated by a lack of structured opportunities for cross-college interactions and a local history of conflict between colleges. Finally, the faculty's interaction with the student body in the STEM classroom was an important field of activity. Here, faculty were confronted with students who were not as well prepared in STEM disciplines as the faculty had expected (*student preparation*), which forced them to adjust their instructional practice and/or expectations accordingly. Many students lacked experience with the natural world: This was another effect that the student body might have had on the STEM faculty cultural model for STEM education and one that might have forced faculty to consider the implications of students' urban upbringing on their instruction.

Changes to the cultural model via SCALE/QED. For science faculty at CSUDH, SCALE/QED helped make explicit, and then helped to change, different aspects of their cultural model for STEM instruction. Fortunately, CSUDH had a group of science faculty who already exhibited the schema *instructional practice value*, and who were thus interested in participating in the professional development workshops. Additionally, the venue in which these workshops took place effectively used cross-disciplinary working groups in which science faculty worked closely with one another and with a COE facilitator. By acknowledging and confronting the boundaries between disciplines, the facilitator created an effective learning environment. Another factor that might have led the science faculty to be receptive to such change in their fundamental beliefs was the COE facilitator's treatment of STEM faculty as professional educators, not simply STEM content experts. On being perceived and treated as professional educators, STEM faculty began to see themselves and their instructional practice in terms of the pedagogical principles, which resulted in the reinforcement and enlargement of the schema *learning sciences value*. In addition, the facilitator skillfully negotiated existing tensions and fears that the STEM faculty might have had regarding professional development, thus addressing the schema *COE faculty impatience*.

The COE facilitator was then successful in illuminating previously unconscious assumptions about teaching and learning, which proved an important step in beginning to effect change in the tacit assumptions, or schemata, that reflexively informed an individual's practice. As noted above, this method of surfacing assumptions is also used in the business world (Senge, 1994) and in efforts to shift the mental models of IHE faculty and staff regarding racial inequality (Bensimon, 2005). This process brought into bold relief the presence of the schema *STEM instruction as transmission*. Then, by introducing and modeling a more inquiry-based approach to STEM instruction, the facilitator demonstrated a pedagogical method that was remarkably similar to lab- or field-based instruction, which activated a new schema for STEM instruction. Finally, the formation of a community of science faculty who supported one another was cited as an important factor in the social environment that contributed to these changes.

Points of resistance and support in the institutional context. The types of changes to a cultural model observed in this case study can be understood as double-loop learning, a fundamental component of institutional change whereby individuals begin to question their basic assumptions about a topic (Argyris & Schön, 1978). In this case, double-loop learning enabled faculty to at least acknowledge the existence of their unconscious instructional practices and provided them an alternative way of undertaking lesson planning and instruction. Respondents, however, also cited several factors that might compromise these outcomes and the potential for widespread or long-term change at this IHE. These included RTP policies that generally did not reward pedagogical improvement, disciplinary standards that based legitimacy as a scientist exclusively on research accomplishments, and professional development workshops that had an uncertain future. Given that these factors remained unchanged, resistance to incorporating changes in the prevailing cultural model at the departmental level seemed likely. A particularly important point of support was the formation of a cohort of science faculty who became interested in STEM education, which was an important social component that could reinforce the observed changes in the cultural model.

C. Recommendations

This case study reveals mechanisms of change initiated by a STEM education reform effort at an IHE and, in the process, illuminates an enacted theory of change that appears to have achieved at least some of the intended outcomes. The following recommendations are based on this theory of change and include a set of core concepts that may help (a) CSUDH leaders to continually improve their efforts and (b) NSF, ED, and other national agencies design policies that more effectively foster achievement of MSP goals for IHEs. The recommendations that follow are organized into a set for each of these two audiences.

Overall, I postulate that the enacted theory of change for SCALE/QED was that *to bring about improvement sustained over time, change must be pursued simultaneously on structural, social, and individual levels.* This approach is consistent with research findings on institutional change processes in educational organizations (Gamoran et al., 2003; Seymour, 2001). Translated into a theory of action for achieving the MSP goals for IHEs, the approach suggests that change-makers should (a) address structural constraints for faculty practice (e.g., workload, lack of cross-college interactions), (b) foster collegiality and community, and (c) change cultural models (taken-for-granted theories in use) for STEM instruction that individual faculty hold by engaging faculty in well-defined, relevant problems that must be pursued jointly with their disciplinary colleagues in order to help the faculty make these cultural models explicit and thus subject to change. Regarding this third element, the kind of attention paid to the cognitive processes underlying learning for K–12 students in mathematics and science should also be applied to learning processes and identity formation for IHE faculty. I consider this theory of change promising, *with the caveat that* effective implementation of the theory requires a sophisticated understanding of the multifaceted nature of the barriers and supports within an IHE.

Recommendations for Program Improvement at CSUDH

CSUDH is in a unique situation with a relatively high rate of faculty turnover (due to an increase in retirements and the subsequent hiring of new, younger faculty) and an institutional environment that is already supportive of STEM education reform. However, as this case study demonstrated, there is a misalignment between this supportive institutional environment and the ability of departments to actually enact and support these changes. As a result, future efforts should continue to use the multifaceted theory of change of the SCALE/QED program in order to better align department policy and practice with institutional policy, and thereby harness the supportive aspects of the institutional context while mitigating the inhibiting aspects. I suggest the following specific strategies for enacting this multifaceted theory.

Sustain the professional development model for STEM faculty. Based on the participants' recurrent descriptions of the professional development workshops as influential, continuation of the workshops appears to be critical to the longevity of the observed outcomes in STEM instructional changes. CSUDH should ensure the continuation of the professional development workshops for STEM faculty by institutionalizing them, guaranteeing funding for faculty release time, and ensuring that a highly skilled facilitator is available to negotiate the sociocultural divisions between the STEM disciplines and the learning sciences. The facilitator should:

- View participants as STEM *educators*, not solely as STEM *content expert*s;
- Ensure that the materials are relevant to the coursework of STEM faculty;
- Create a venue for interdisciplinary work;
- Be sensitive to participants' rate of change; and
- Strive to change the cultural models of STEM faculty by being aware of the primary features of their models for STEM education and working carefully to change the schemata that compose the model.

Build a cohort for change by targeting clusters of STEM faculty. A recent review of the different strategies that MSP projects have used to engage STEM faculty includes a focus on faculty conversant in K–12 issues, midcareer or senior faculty without tenure pressures, and faculty with "friendly personalities" (Zhang et al., 2007, p. 54). I recommend that targeted recruitment of faculty who exhibit interest in and a propensity for pedagogical improvement continue, with the caveat that clusters of faculty in specific departments be recruited for participation in the professional development workshops in order to achieve critical mass and minimize departmental resistance to pedagogical change. Although the presence of individuals with a newly revised cultural model of STEM instruction does not guarantee changes in departmental policy or practice, it could enable faculty to inquire more effectively into the instructional systems, strategies, and policies used within their departments (Argryis, 1985).

Consider the viability of external pressure. Campus leaders should consider the viability of policy levers, such as those afforded by the accountability movement, as a way to carefully nurture change while finding ways to foster among STEM faculty mental models amenable to such efforts.

Recommendations for Program Replication

Replicating the success of any program requires careful analysis. In my analysis and review of the findings of SCALE/QED at CSUDH, I bring attention to five key observations related to the diversity of culture of the IHE, the necessity for preliminary needs assessment, the involvement of the COE faculty, the examination of the STEM cultural model in place, and further study of STEM departments with pedagogy-minded faculty cohorts.

Avoid using unitary and homogenous explanations of IHE contexts. Institutional change processes cannot adequately be understood through a unitary and homogenous understanding of institutional culture or climate. This perspective of institutional change necessitates an approach to reform that accepts that there are no single "magic bullets" and, instead, adopts a multifaceted approach to effecting change at different points of the institution.

Conduct institutional needs assessments prior to program planning and implementation. Any change effort should begin with an institutional needs assessment in order to identify the local contextual factors that may provide barriers and opportunities to reform (Tobias, 1992). Treisman (2007) suggested that this is important so that change leaders obtain a "clear sense of the idiosyncratic features of the environment" (Treisman, 2007, p. 2).

Consider requiring the involvement of COE faculty in the MSP. Several COE faculty at CSUDH as well as at CSUN and UW–Madison (the other SCALE IHE sites) observed that the MSP program as designed did not require their participation in this new iteration of NSF-supported reform. Some respondents felt that this led to the further marginalization of their colleges on each campus and that a more inclusive and collaborative effort would accurately reflect the notion that teacher preparation was the responsibility of the entire campus. As a result, I recommend that NSF take into account that the current design of the MSP program may exacerbate existing tensions between STEM and education faculty and that NSF consider requirements that more directly involve COE in the achievements of its goals.

Focus change efforts on the cultural model for STEM instruction of individual faculty. Critical leverage points in altering faculty members' cultural models of teaching and learning may be the surfacing of their assumptions about teaching and their being encouraged to "think like novices"—processes likely to be accomplished through skillfully facilitated professional development experiences.

Examine other cases of STEM departments with pedagogy-minded cohorts. Finally, in order to better understand the formation of STEM education cohorts within STEM departments, it would be instructive to further study the history of the CSUDH mathematics department and other examples where a critical mass of reform-oriented faculty were able to thrive alongside more traditional colleagues.

Next Steps

This research will be replicated at UW–Madison and CSUN and will be followed by a cross-case analysis. The ICF and the findings from this analysis regarding cultural models of STEM education will be utilized in these studies. Based on findings in this case study, which underscored the shortcomings of commonly used theoretical constructs such as organizational learning and which lacked operationalized measures or adequate explications regarding the relationship between individual learning and collective action (Lähteenmäki et al., 2001), the following questions will be pursued in detail:

1. How do specific indicators within the ICF influence an individual's cultural model of STEM instruction?
2. Can a change process that includes the dynamic interaction of institutional-, sociocultural-, and individual-level features be described?
3. Can individual behaviors within organizational units be adequately analyzed using theories of collective action (i.e., distributed cognition, shared mental models)?
4. How can multiple and competing cultural models of STEM instruction be harnessed and framed in order to achieve the goals of the MSP program?

References

Anderson, R. D., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching, 38*(1), 3–16.

Argyris, C. (1985). *Strategy, change, and defensive routines.* Boston, MA: Pitman.

Argyris, C., & Schön, D. (1978). *Organizational learning: A theory of action perspective.* Reading, MA: Addison-Wesley.

Ball, D. L., & Wilcox, S. K. (1989, March). *In-service teacher education in mathematics: Examining the interaction of context and content.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Bensimon, E. (2005, Fall). Closing the achievement gap in higher education: An organizational learning perspective. *New Directions for Higher Education, 131*, 99–111.

Bernard, H. R. (2002). *Research methods in anthropology: Qualitative and quantitative approaches* (3rd ed.). Lanham, MD: Altamira Press.

Birnbaum, R. (1988). *How colleges work: The cybernetics of academic organization and leadership.* San Francisco, CA: Jossey-Bass.

Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge, England: Cambridge University Press.

California Commission on Teacher Credentialing (CCTC). (2004). *Teacher supply in California: A report to the legislature*, annual report 2002–2003. Retrieved from http://www.ctc.ca.gov/reports/TS_2002_2003.pdf

California Commission on Teacher Credentialing (CCTC). (2005). *Teacher supply in California: A report to the legislature*, annual report 2003–2004. Retrieved from http://www.ctc.ca.gov/reports/TS_2003_2004.pdf

California Commission on Teacher Credentialing (CCTC). (2006). *Teacher supply in California: A report to the legislature*, annual report 2004–2005 (Rep. No. 06-01). Retrieved from http://www.ctc.ca.gov/reports/TS_2004_2005.pdf

California Commission on Teacher Credentialing (CCTC). (2007). *Teacher supply in California: A report to the legislature*, annual report 2005–2006. Retrieved from http://www.ctc.ca.gov/reports/TS_2005_2006.pdf

California State University, Dominguez Hills. (n.d.). *Assessment* (First-time freshmen). Retrieved from http://www.csudh.edu/oir/Assessment/Default.shtml

California State University, Dominguez Hills. (n.d.). *Enrollment history*. Retrieved from http://www.csudh.edu/oir/Enrollment/History.shtml

California State University, Dominguez Hills. (n.d.). *Mission statement*. Retrieved from http://www.csudh.edu/abouttheuniversity/mission.shtml

California State University, Dominguez Hills. (n.d.). *RTP policies*. Retrieved from http://www.csudh.edu/FacultyAffairs/RTP.htm

California State University, Dominguez Hills. (n.d.). *Student enrollment by ethnicity*. Retrieved from http://www.csudh.edu/oir/Enrollment/EnrollmentEthnicity.shtml

Carlone, H. B., & Webb. S. M. (2006). On (not) overcoming our history of hierarchy: Complexities of university/school collaboration. *Science Education*, *90* (3), 544–568.

The Carnegie Foundation for the Advancement of Teaching. (2000). *The Carnegie classification of institutions of higher education* (2000 ed.). Retrieved from http://classifications.carnegiefoundation.org/resources/

The Carnegie Foundation for the Advancement of Teaching. (2006). *The Carnegie classification of institutions of higher education*. Retrieved from http://www.carnegiefoundation.org/classifications/

Cochran-Smith, M., & Lytle, S. (1999). Relationships of knowledge and practice: Teacher learning in communities. *Review of Research in Education*, *24*, 249–305.

Cochran-Smith, M., & Zeichner, K. (2005). *Studying teacher education: The report of the AERA panel on research and teacher education*. Mahwah, NJ: Erlbaum and the American Educational Research Association.

Committee on Science, Engineering, and Public Policy (COSEPUP). (2006). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

D'Andrade, R. (1995). *The development of cognitive anthropology.* Cambridge, England: Cambridge University Press.

Darling-Hammond, L, Chung, R., & Frelow, F. (2002). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education, 53*(4), 286–302.

Gamoran, A., Anderson, C. W., Quiroz, P., Secada, W., Williams, T., & Ashmann, S. (2003). *Transforming teaching in math and science: How schools and districts can support change* (Sociology of Education Series). New York, NY: Teachers College Press.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915–945.

Geertz, C. (1973). *The interpretation of cultures*. New York, NY: Basic Books.

Gilroy, M. (2003). Articulating the K–16 dream. *The Hispanic Outlook in Higher Education, 13,* 26–28.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R. L., . . . Wood, W. B. (2004). Scientific teaching. *Science*, *304*, 521–522.

Hora, M. T., & Millar, S. B. (2007). *A preliminary case study of SCALE activities at the University of Wisconsin–Madison: Factors influencing change initiatives in STEM undergraduate education, teacher training, and partnerships with K–12 districts* (WCER Working Paper No. 2007-2). Retrieved from University of Wisconsin–Madison, Wisconsin Center for Education Research website: http://www.wcer.wisc.edu/publications/workingPapers/index.php.

Kandel, E. (2006). *In search of memory: The emergence of a new science of mind*. New York, NY: Norton.

Katzenmeyer, C., & Lawrenz, F. (2006). National Science Foundation perspectives on the nature of STEM program evaluation [Special issue: Critical issues in STEM evaluation, Huffman, D., & Lawrenz, F. (Eds.)]. *New Directions for Evaluation*, *109*, 7–18.

Kezar, A., & Eckel, P. (2002). The effect of institutional culture on change strategies in higher education: Universal principles or culturally responsive concepts? *The Journal of Higher Education*, *73*(4), 435–460.

Knight, P., & Trowler, P. (2000). Department level cultures and the improvement of learning and teaching. *Studies in Higher Education*, *25*(1), 69–83.

Labaree, D. F. (2004). *The trouble with ed schools*. New Haven, CT: Yale University Press.

Lähteenmäki, S., Toivonen, J., & Mattila, M. (2001). Critical aspects of organizational learning research and proposals for its measurement. *British Journal of Management*, *12*(2), 113–129.

Lakomski, G. (2001). Organizational change, leadership, and learning: Culture as cognitive process. *The International Journal of Educational Management*, *15*(2), 68–77.

Lauffer, D. (2004). *Immersion units description* [Madison Metropolitan School District Grade 8, Physics Immersion Unit Planning]. Madison, WI: University of Wisconsin–Madison, Wisconsin Center for Education Research, SCALE project.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, England: University of Cambridge Press.

Levine, A. (2006). *Educating teachers report* [Rep. No. 2]. Washington, DC: The Education Schools project. Retrieved from http://www.edschools.org/teacher_report.htm

McVee, B. B., Gavelek, J. R., & Dunsmore, K. L. (2007). Considerations of the social, individual, and embodied: A response to comments on "Schema theory revisited." *Review of Educational Research*, *77*(2), 245–248.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage.

Mundry, S., Spector, B., Stiles, K., & Loucks-Horsley, S. (1999). *Working toward a continuum of professional learning experiences for teachers of science and mathematics.* (Research Monograph No. 17). Madison, WI: University of Wisconsin–Madison, National Institute for Science Education.

The Napa Group. (2003). California State University, Dominguez Hills (CSUDH) *SWOT Survey and Town Hall Summary Report.* Unpublished report.

National Center for Education Statistics. (2004). *Qualifications of the public school teacher workforce: Prevalence of out-of-field teaching, 1987–1988 to 1999–2000* (NCES 2002-603, revised by M. M. Seastrom, K. Gruber, R. Henke, D. McGrath, & B. Cohen). Washington, DC: U.S. Government Printing Office.

National Commission on Excellence in Education (NCEE). (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Government Printing Office.

National Research Council & Committee on Science and Mathematics Teacher Preparation. (2000). *Educating teachers of science, mathematics, and technology: New practices for the new millennium*. Washington, DC: U.S. Government Printing Office.

National Science Foundation. (2002). *Math and science partnership (MSP) program solicitation*. Retrieved from www.nsf.gov/pubs/2002/nsf02190/nsf02190.htm

National Science Foundation. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology* (NSF 96-139). Retrieved from http://www.ehr.nsf.gov/ehr/due/documents/review/96139/start.htm

No Child Left Behind (NCLB) Act of 2001, Pub. L. No. 107-110, § 115 Stat. 1425 (2002).

Osthoff, E. (2004). SCALE *research and evaluation team case study: Los Angeles Unified School District*. Madison: Wisconsin Center for Education Research.

Owen, J. M., & Lambert, F .C. (1998). Evaluation and the information needs of organizational leaders. *American Journal of Evaluation, 19*(3), 355–365.

Patton, M. Q. (2006, October). *Evidence-based evaluation findings using systems change and complexity science frameworks and ways of thinking.* Paper presented at the NSF MSP Evaluation Summit II, Minneapolis, MN.

Piaget, J. (1955). *The child's construction of reality*. London, England: Routledge and Kegan Paul.

Project Kaleidoscope. (2006). *Report on reports II: Recommendations for urgent action, 2006. Transforming America's scientific and technological infrastructure.* Washington, DC: Author.

Quality Educator Development (QED) Project. (2004). *Grant proposal.* Unpublished document, California State University, Dominguez Hills.

Quality Educator Development (QED) Project. (2007a). *Year 2 QED annual report.* Unpublished documents, California State University, Dominguez Hills.

Quality Educator Development (QED) Project. (2007b). *Year 3 QED annual report.* Unpublished documents, California State University, Dominguez Hills.

Rickles, J., & White, J. (2005). *How many high school students satisfy the UC/CSU eligibility requirements after four years?* (Planning, assessment, and research division publication No. 280). Los Angeles, CA: Los Angeles Unified School District, Program Evaluation and Research Branch. Retrieved from http://notebook.lausd.net/portal/page?_pageid=33,102413&_dad=ptl&_schema=PTL_EP

Robinson, S. P. (2006). Response to "Educating school teachers" by Dr. Arthur Levine. *American Association of Colleges for Teacher Education*. Retrieved from http://hub.mspnet.org/index.cfm/13429

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: Free Press.

Ryan, G. W., & Bernard, R. (2003). Techniques to identify themes. *Field methods*, *15*(1), 85–109.

SCALE (2005). *Introduction to SCALE project.* Presentation at first national advisory board meeting, Madison, WI.

Scholl, L., Millar, S. B., & Owusu-Yeboa, L. (2006). *Organizational change in an institution of higher education: Improving K–20 math and science education through a university–school partnership.* Madison: University of Wisconsin–Madison, Wisconsin Center for Education Research.

Schön, D. A. (1983). *The reflective practitioner.* New York, NY: Basic Books.

Schroeder, C. M. (2001). *Faculty change agents: The individual and organizational factors that enable or impede faculty development participants' involvement in organizational change*. Unpublished dissertation, University of Wisconsin–Madison.

Senge, P. (1994). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Currency Doubleday.

Seymour, E. (2001). Tracking the processes of change in U.S. undergraduate education in science, mathematics, engineering, and technology. *Science Education, 86*, 79–105.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview.

Shapiro, N., Benson, S., Maloney, P., Frank, J., Dezfooli, N. A., Susskind, D., & Munoz, M. (2006). *Report on course and curriculum changes in math and science partnership (MSP) programs* (Change and Sustainability in Higher Education [CASHE] report). Retrieved from http://hub.mspnet.org/index.cfm/13463

Shore, B. (1996). *Culture in mind: Cognition, culture, and the problem of meaning.* New York, NY: Oxford University Press.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Strauss, C., & Quinn, N. (1997). *A cognitive theory of cultural meaning*. Cambridge, England: Cambridge University Press.

"Teaching and learning at the research university." (2000, Summer). [Interview with L. Cuban]. *Association of American Colleges and Universities Peer Review*, *2*(4), 19.

Tobias, S. (1992). *Revitalizing undergraduate science. Why some things work and most don't*. Tucson, AZ: Research Corporation.

Treisman, U. (2007). *On leadership in STEM. Volume IV: What works, what matters, what lasts*. Washington, DC: Project Kaleidoscope.

U.S. Department of Education. (2005). *The Secretary's fourth annual report on teacher quality: A highly qualified teacher in every classroom*. Washington, DC: U.S. Government Printing Office. Retrieved from http://www.ed.gov/about/reports/annual/otherplanrpts.html

U.S. Department of Education. (2006a). *Meeting the challenge of a changing world: Strengthening education for the 21st century*. Washington, DC: U.S. Government Printing Office. Retrieved from http://hub.mspnet.org/index.cfm/12675

U.S. Department of Education, Commission on the Future of Higher Education. (2006b). *A test of leadership: Charting the future of U.S. higher education*. Washington, DC: U.S. Government Printing Office. Retrieved from http://hub.mspnet.org/index.cfm/13445

U.S. Office of Science and Technology Policy. (2006). *American competitiveness initiative: Leading the world in innovation* (Rep. No. A910864). Washington, DC: U.S. Government Printing Office.

Van Maanen, J., & Barley, S. (1985). Cultural organization: Fragments of a theory. In P. J. Frost, L. F. Moore, M. R. Louis, C. C. Lundberg, & J. Martin, *Organizational culture* (pp. 31–53). Beverly Hills, CA: Sage.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Newbury Park, CA: Sage.

Zhang, X. McInerney, J., Frechtling, J., Nyre, G., Michie, J., Miyaoka, A., . . . Hershey-Arista, M. (2007). *A Year 3 RETA report for effect of STEM faculty engagement in MSP—A longitudinal perspective*. Prepared by Westat for the National Science Foundation. Retrieved from http://hub.mspnet.org/index.cfm/14375