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A Final Case Study of SCALE Activities at California State University, Northridge: How Institutional Context Influenced a K–20 STEM Education Change Initiative

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A Final Case Study of SCALE Activities at California State University, Northridge: How Institutional Context Influenced a K–20 STEM Education Change Initiative

Matthew T. Hora and Susan B. Millar

Executive Summary

Institutions of higher education (IHE) play an important role in math and science education by providing undergraduate instruction, teacher training programs, and in-service training for K–12 teachers. The National Science Foundation (NSF)-funded System-wide Change for All Learners and Educators (SCALE) project sought to effect change in its partner IHEs by creating a transformative culture through cross-cultural working teams that operated at the intersections among K–12 districts, colleges of education, and colleges of mathematics, science, and engineering (SCALE, 2005). The SCALE goals for IHEs are as follows:

1. To improve science, technology, engineering, and mathematics (STEM) *undergraduate* education;

2. To improve collaboration between STEM and education faculty regarding *preservice* programs;

3. To improve collaboration between IHE faculty and K–12 districts regarding *in-service* training; and

4. To improve institutional *policies and practices* that support these activities.

As part of the SCALE IHE case studies line of work, this paper provides findings on the effects of the SCALE project at the California State University, Northridge (CSUN) between March 2005 and August 2007. Case studies of SCALE's partner IHEs—the California State University, Dominguez Hills (CSUDH), and the University of Wisconsin–Madison (UW-Madison)—have been produced (Hora & Millar, 2007; Hora & Millar, 2008). A cross-case analysis of the three IHE case studies will present a diagnostic approach to evaluating STEM education interventions in complex organizations.

Methodology

This qualitative case study addresses two interrelated challenges with studying and evaluating change processes in complex institutional environments. First, because reform efforts such as SCALE coexist with and seek to change diverse levels and elements of an institution, it is critical to understand the context in which a reform effort unfolds (Patton, 2006; Katzenmeyer & Lawrenz, 2006; Anderson & Helms, 2001). Second, research on reform implementation in both higher education and K–12 finds that when faced with policy directives, individuals frequently adapt them in the process of making sense of and applying them in local environments (Birnbaum, 1988; Spillane, Reiser, & Reimer, 2002). These research challenges are interrelated because local contextual factors shape the sense-making process, as individuals are inclined —if

not required—to attend to contextual features of their organizations, especially the cultural norms of administrative units such as academic departments (Gamoran et al., 2003; Coburn, 2001). However, research in this area is complicated by a paucity of theories and methods that adequately address the multilevel and recursive nature of these relationships among context, culture, and individual cognition. This lack is also very apparent in program evaluations. In response to these concerns, this study of SCALE at CSUN focuses on contextual factors by identifying which are salient to STEM education reform, their relationship to group- and individual-level cultural phenomenon (i.e., mental models), and their collective influence on the SCALE intervention.

This study used a repeated cross-sectional design, with in-depth interview data collected at Time 1 (T1; June 2006) and Time 2 (T2; June 2007). Other data collected for this research included official university and SCALE documents, and observations of SCALE meetings. Non-random sampling procedures were used to identify interview respondents, which included 18 at T1 and 16 at T2, for a total of 34 interviews with 25 unique individuals. Interviews were coded using a structured approach to grounded theory (Strauss & Corbin, 1990) based on a coding scheme we call the *institutional context framework* (ICF) (Hora & Millar, 2006). The ICF is comprised of the following code families: external environment, internal structure, resources (fiscal and social), pervasive values, individual sense-making, and practices. Interview data were coded, reduced, and inductively analyzed for recurring patterns and themes in the data in order to identify contextual factors salient to SCALE, group- and individual- level cultural norms, and individual sense-making processes. Additional analytic procedures included (a) a causal network analysis that allows for the graphic representation of the relationships among these multi-level phenomenon and (b) an exploratory analysis of mental models and their constituent cultural schema as situated within the institutional context of CSUN.

A Snapshot of the Intervention Site: California State University, Northridge

CSUN is located in the San Fernando Valley of Los Angeles County. Its location in a large, ethnically diverse urban area exerts a major influence on the institution's identity, mission, and academic programs. CSUN is part of the 23-campus California State University (CSU) system and shares with its sister CSU campuses a focus on undergraduate education and providing affordable opportunities for a broad cross-section of California's population. The fall 2007 enrollment at CSUN was approximately 35,000, making it one of the largest in the CSU system. CSUN is comprised of 9 colleges, including the Eisner College of Education (COE), and the College of Science & Mathematics. These two colleges include 56 departments that offer 60 baccalaureate degrees, 45 master's degrees and 28 types of teaching credentials. In 2006-2007, the CSU system recommended 53% of the state's teaching credentials (10,840), of which CSUN recommended 8% (844), the most of any CSU campus.

The Institutional Context Salient to the SCALE Math and Science Partnership

The factors listed below were identified as especially salient to the SCALE intervention, and then organized by the ICF categories. A plus or minus valence was assigned to each factor indicating whether, based on respondent views or our own interpretation of the relationship, it supported or inhibited achievement of SCALE goals. These factors are not static elements but interact with one another in a variety of ways.

- *External environment*: Trends in educational reform take root at CSUN (+); budget crises frustrate faculty yet make external funding attractive (+/-); lack of pedagogical training in STEM doctoral programs (-); demand for STEM teachers in local K–12 districts (+); institution type (comprehensive) closely aligned with the Math and Science Partnership (MSP) goals (+); state credentialing policies discourage inter-disciplinary collaboration (-); lack of policies governing type and quality of professional development for K–12 teachers (-); and tense dynamics between IHE and K–12 educators (-).

- *Internal structure*: Governance system emphasizes faculty autonomy (+/-); mission supports undergraduate education and teacher preparation (+); multi-tiered leadership generally favors pedagogical reform (+/-); limited pipeline of preservice science majors (-); some preservice programs require interdepartmental collaboration (+); large part-time workforce complicates efforts to reform instruction (+/-); recruitment, tenure, and promotion policies discourage teaching innovation (-); workload is heavy and not amenable to service (-); math department is strongly divided on pedagogical reform (+/-) existing reforms foster both support and skepticism (+/-).

- *Resources*: Active and historic reforms fostered social network of STEM educators (+); extant K–12 professional development services (+); funding pressures limit resources (-); student body requires more remediation (-); status and social capital influence ability of faculty to participate in reforms (+/-).

- *Pervasive values*: Tension between teaching mission and disciplinary traditions (+/-); scientific legitimacy and credibility equated with basic research (-); distinction between hard and soft science fuels inter-disciplinary tension (-); conflicting beliefs about the role of content and pedagogy in preservice STEM courses (+/-).

- *Individual sense-making*: Funding pressures and workload exert pressure on faculty time (+/-); faculty status influences time management (+/-); various personal reasons to participate in reforms (+); intellectual curiosity and willingness to take risks (+).

- *Practices*: Some faculty maintain didactic approach to STEM instruction (-); some faculty experiment with inquiry-based approach (+); participation in interdisciplinary activities (+); participation in K–12/IHE collaborations (+).

As the evaluation findings (below) indicate, these factors influenced how SCALE was implemented.

Evaluation Findings About SCALE Activities and Outcomes

CSUN's active involvement in SCALE began in spring 2005 as faculty began designing professional development (PD) institutes for K–12 teachers. Once introduced to CSUN, SCALE leaders from UW-Madison and CSUDH began interacting with a community of CSUN STEM and education faculty who were already active in the other reform initiatives. These faculty became part of a larger cohort who were led by SCALE faculty and staff from UW-Madison and CSUDH. Apart from the CSUN Provost, who had an advisory role in SCALE, no local CSUN staff participated in the SCALE leadership group. SCALE leaders primarily engaged CSUN STEM faculty and academic staff in science immersion institutes and math institutes, all of which were undertaken in collaboration with local K–12 districts.

The science immersion institutes are a learning opportunity in which students are engaged in the scientific inquiry process over an extended period of time (4 weeks). Although described in some detail in the original SCALE proposal as science immersion experiences, no measurable objectives for IHEs were assigned to this activity, which makes it challenging to assess if and how SCALE achieved its goals in this area.

Two factors within the institutional context of CSUN influenced the science immersion institute activity in different ways. A first factor was the demanding workload, which resulted in a limited pool of potential participants in the SCALE initiative. A key aspect of the workload is the high value placed on research productivity, which brings in valuable external funding in a time of budgetary crisis, elevates the prestige of individual faculty, their departments, and the entire university, and is an explicit goal of some CSUN administrators. As a result of this factor, some faculty indicated that it was not feasible or desirable to commit to an entire week of SCALE activities. A second factor that affected SCALE—and that somewhat mitigated the first—was the presence of a cohort of STEM and education faculty who were already engaged in K–12 PD activities. This cohort provided a ready-made pool of potential facilitators for the science institutes.

The science immersion institutes were preceded by a design process that involved interinstitutional teams who collaboratively developed grade-specific science immersion units designed to address Los Angeles Unified School District (LAUSD) science standards. UW-Madison staff, CSUDH and CSUN STEM and education faculty, and LAUSD science experts and teachers collaborated to develop immersion units for fourth, sixth, seventh, and eighth grades. These cross-institutional teams then co-facilitated 5-day science institutes (five in 2006, eight in 2007) for a total of 270 LAUSD teacher participants. Anticipated (i.e., first-order) outcomes include providing professional development workshops for the LAUSD science teacher participants, engaging STEM faculty as learners and not solely as content experts, and providing pedagogical tools that STEM faculty (N=3) later used in their undergraduate courses. Unanticipated (i.e., second-order) outcomes include the diffusion of SCALE pedagogical techniques to other reform initiatives, expanding and training the STEM education cohort, and developing an intensive interaction with K–12 personnel.

A series of math institutes (professional development workshops) for LAUSD middle and high school math teachers was the second primary SCALE activity at CSUN. These institutes were a joint effort of a CSUDH project funded by the Department of Education (QED) and SCALE. The leadership and materials for these institutes primarily came from CSUDH's mathematics department's Center for Math and Science Education (CMSE). The goals of the math institutes were to increase student achievement in and understanding of the mathematics contained in the California state standards in Grades 6–9, and to better equip teachers to lead their students to a deeper understanding of mathematics.

The QED/SCALE math institute activity was influenced by various factors in the institutional context of CSUN. One is the ideological schism that has long prevailed in the CSUN math department, which served as an important backdrop to the SCALE math institutes, and effectively limited the pool of potential facilitators. The department is generally split into two camps with divergent perspectives on math education, one of which is, and one of which is not sympathetic towards a constructivist approach to math education. Indeed, one CSUN respondent noted that most education faculty only pay attention to members of the sympathetic group. The split in the math department played a direct role in the 2006 math institutes, as one of the facilitators proved to be somewhat antagonistic to the intent of math education reform in general, and the design of the math institutes in particular. Another factor influencing the math institutes was the Teachers for a New Era (TNE) initiative in which some math department faculty were already engaged prior to SCALE, which led to information and ideas from one influencing the other.

The math institutes were preceded by a design process that involved inter-institutional teams who collaboratively developed grade-specific math units designed to address LAUSD math standards. CSUDH and CSUN STEM faculty collaborated to develop math units for middle school (pre-algebra) and high school (algebra). Cross-institutional teams including CSUN STEM faculty, Madison Metropolitan School District (MMSD) personnel, and LAUSD personnel then co-facilitated 15-day math institutes (two in 2006, two in 2007) for a total of 83 LAUSD teacher participants. Anticipated (first-order) outcomes for this SCALE activity include professional development workshops for the LAUSD teachers. Unanticipated outcomes (second-order) include complementing efforts of other reform initiatives (e.g., TNE), expanding and training the cohort of math educators, and becoming involved in the math department schism through a series of competing letters to the editor in the *American Journal of Physics*.

Exploring How Cultural Phenomena Mediate and Influence STEM Education Reform

Some pervasive values at CSUN posed a significant challenge to implementing the types of institutional and pedagogical changes envisioned by the SCALE project. To elucidate these challenges, we conducted a detailed, albeit exploratory, analysis of how cultural factors mediate and influence STEM education reform. Our reason for taking this fine-grained approach to studying culture is to articulate specific content and processes inside the black box called "CSUN cultural dynamics." For this analysis, we employed a distributed theory of culture developed by cognitive anthropologists that is based on *schema* theory in cognitive science. Schemas are unconscious mental structures that distill information into generic units that are encoded into the neural networks of the brain through repetition (Brewer, 1987; D'Andrade, 1995). Researchers theorize that different schema combine to comprise *mental models*, which in turn collectively comprise the explanatory structures that actors use in a filtering process to omit or transform environmental stimuli (Johnson-Laird, 1983; D'Andrade, 1995; Strauss & Quinn, 1998). Some schema can be considered more cultural than others since they are internalized from instantiated cultural forms that are "part of the stock of shared cognitive resources of a community" (Shore, 1996, p. 47). However, individuals differentially internalize these shared beliefs, values, and norms, and thus, communities are always "internally differentiated and cultural models are characterized by different degrees of sharing" (Shore, 1998, p. 1). An individual's mental model is then activated in response to environmental stimuli, which are largely composed of the unique context of the organization.

Working within the interpretive tradition of Strauss & Quinn that uses natural discourse to identify cultural models (1998), we analyzed the mental model for STEM education reform of one faculty member as a way to explore the relationships (for this person) among institutional context, culture, individual cognition, and STEM education reform. This respondent's mental model was largely comprised of four cultural schema pertaining to STEM education reform that we found to be common across social groups and administrative units at CSUN. These cultural schema include:

- Scientific legitimacy and credibility equated with basic research accomplishments;
- Distinction between hard and soft sciences;
- Tension between institutional support for reform and the disciplines; and
- Divergent beliefs about the relative importance of content and pedagogy in pre-service STEM courses.

It is important to note that we do not claim that all faculty, administrators, and staff at CSUN exhibit these values or beliefs. Instead, while these values were expressed by several respondents across different social groups and administrative units, individuals may differentially internalize and exhibit these cultural schema depending on their personal backgrounds, personality, social position, discipline, and many other situational or demographic variables. In addition, these cultural schema are related to specific policies, institutional structures, and other contextual factors. Anthropologists sometimes describe clusters of similar practices (e.g., rituals, tool-making, languages) in a bounded geographic area as "cultural complexes." Following this usage, we consider these schema pertaining to STEM education reform and their related contextual determinants to be a *cultural complex for scientific legitimacy and credibility*. We believe that this STEM education reform cultural complex is particularly resilient for individuals, in part because it is developed through years of intense training and socialization in communities of practice whose membership is carefully screened (Lave & Wenger, 1991).

This particular respondent did not participate in SCALE, and was hired relatively recently at CSUN—the respondent's first academic appointment. The primary contextual factor that shaped the respondent's mental model for STEM education reform was that of workload and attendant reward, tenure, and promotion considerations. As is common for junior faculty, this respondent was singularly focused on conducting research, publishing research articles, raising external research funds, and teaching the obligatory 12 units per semester. These immediate and practical concerns about workload were related to the cultural schema about scientific legitimacy and credibility. Since participating in a reform effort would likely impede progress towards tenure and promotion, this person turned down offers from SCALE. Concern about tenure also made approval from departmental peers particularly important, which led this person to place high value on social factors in the college and department. Of note, the cultural schema comprising this person's mental model were expressed as taken-for-granted aspects of academic life in a STEM discipline. As a doctoral student in a major research university, the respondent had never been in an institutional environment where the prioritization of research over teaching and service activities was not the case. Furthermore, these schema were reinforced locally at CSUN by the department's reward, tenure, and promotion (RTP) policies and CSUN leadership. Indeed, some CSUN leaders had conveyed explicit messages regarding the expectations for faculty research productivity, including the statement at a public meeting that junior STEM faculty "should be living in the lab."

Since participating in a reform effort would likely impede progress towards tenure and promotion, this person did not participate in any reform efforts, including SCALE. However, since the TNE effort did engage the department in an attempt to hire a pedagogy specialist, this respondent's deep-seated cultural schema related to STEM education was engaged. Through this process, this respondent's (and colleagues') deep-seated cultural schema related to STEM education was engaged. Since research was considered the top priority in the department, the respondent felt that while the TNE position "would be nice," it would essentially be useless since, "(I)nvesting time in becoming a good teacher is not rewarded and we are not really incentivized to spend inordinate amounts of time developing new teaching tools." Thus, the cultural schema that equates scientific credibility and legitimacy with basic research, and its reinforcement in RTP policy, rendered this reform attempt superfluous and actively at odds with the prevailing value system of the department. Ultimately, this faculty's mental model did not change as a result of the SCALE project and other reform efforts. In fact, the failure of the TNE effort to hire a pedagogy specialist may have reinforced their mental model by demonstrating that a research-centered perspective is truly the dominant one in the department, in spite of the allure of a fully funded tenure-track appointment.

Conclusions

Without measurable objectives with which to evaluate the SCALE project's activities and progress, it is difficult to make a definitive statement about the relative success or failure of the project. However, it is fair to say that in light of the original goal to affect changes to undergraduate STEM instruction, interdisciplinary collaboration on preservice programs, interinstitutional collaborations on in-service programs, and the underlying institutional culture that informs these activities, the effects of the SCALE project must be considered modest. Of note, SCALE focused its efforts on a relatively small and discrete point within the CSUN context—engaging faculty to support K–12 teacher professional development. It is also fair to say that the SCALE project resulted in outcomes pertaining to the institutional context of CSUN that directly and indirectly relate to the four goals of the project. This was possible largely because the SCALE initiative dovetailed with other extant reform initiatives that collectively created a very favorable environment for STEM education reform.

We conclude that there was an inconsistency between the goals SCALE leaders stated and the implementation of these goals. Since no SCALE leaders were present at CSUN, there was no explicit theory of institutional change for CSUN, in contrast to SCALE activities at both UW-Madison and CSUDH. Instead, SCALE engaged CSUN as primarily a site for its already existing math and science institutes, and largely ceded the effort at institutional transformation to chance and the extant reforms at CSUN. Since the SCALE leaders at UW-Madison and CSUDH did not have local expert knowledge, the campaign approach to change used at the other SCALE

IHEs was not evident at CSUN. Instead, SCALE in effect planted its interventions at CSUN and relied on local experts to conduct the project. An enduring lesson from SCALE at CSUN is that multi-institutional reform efforts should focus on recruiting local leaders who can be sufficiently informed about and active at each partner institution. One possible effect of this approach was a lost opportunity to coordinate SCALE with other extant STEM education reform initiatives.

Other core findings are derived from the analysis of the situated mental model of the CSUN faculty, and of the pervasive values and beliefs at CSUN pertaining to STEM education reform.

1. There is a cultural complex of scientific legitimacy and credibility.

2. Mental models are hard to change.

3. Contextual factors shape mental models.

4. Professional communities are critical in culture formation.

5. A comprehensive approach to culture change and culture-brokers is important,

Taken as a whole, this analysis suggests that shaping the culture of an organization may require comprehensive efforts to change the structural, social, and symbolic milieu in which individuals operate, in addition to efforts to change the cognitive processes that constitute individuals' habits of mind. Such efforts may require leaders to employ a flexible and multifaceted toolkit of frames through which to analyze their organizations (see, for example, Bolman & Deal, 2003). In addition, such an effort would require campus and other reform leaders to take a deliberate and strategic approach, as opposed to pursuing an intervention that unfolds according to chance. It is especially important that a local figure play a leadership role, as mental models within an organization may operate according to a logic that is inaccessible to external leaders and change agents. In cases where interinstitutional or interdisciplinary collaborations are taking place, it may also be important for a local individual to play the role of a culture broker. Our case studies of UW-Madison and CSUDH indicate the importance of such individuals, who understand the cultural schema that operate within different groups, and can carefully negotiate the divisions or tensions that may exist between the groups and their pervasive values and beliefs.

We also suggest that, of the many contextual factors identified in this study, the following stand out as especially important for leveraging the types of change sought by the MSP program:

1. Points of contact with the external environment;

2. Leadership at all levels;

3. Decision-making bodies and interdepartmental forums;

4. Networks of STEM educators;

5. Other reforms;

6. Cultural complex regarding disciplinary legitimacy and credibility; and
7. Individual faculty workloads

We suggest that the above factors deserve particular attention by campus leaders and STEM education reformers because they have the potential to affect a cascade of impacts in a variety of points in the institutional context of an IHE. In so saying, we caution that these seven, as well as other leverage points should not be viewed as isolated magic bullets that can produce fast and enduring reform across the entire university. Rather, they must be understood as operating in dynamic interaction, such that a change in one may yield unpredictable and even imperceptible movement in others.

We also recommend that future STEM education reformers at research universities, and policy makers at funding agencies such as the NSF and the Department of Education may benefit if they:

- Conduct assessments of the institutional context prior to program planning and implementation;
- Ensure that recruitment efforts pay attention to workload and cultural factors;
- Design neutral spaces in which different groups may interact;
- Recruit a skilled culture-broker when working with interdisciplinary groups;
- Marshal existing resources and reform projects to collectively target key leverage points;
- Focus on developing cohorts of STEM educators in specific departments; and
- Carefully design top-down structural reforms with attention to the moving parts of the institution

Potential benefits of this research to the STEM education community are twofold: (a) this approach may enable evaluators to systematically assess if and how an institution’s context and culture act as mediating variables that influence reform, and as outcome measures for programs aiming to affect institutional transformation or cultural change; and (b) given the widespread interest in changing the culture of schools and IHEs, such insights would give program planners and policy makers the tools to better understand their institutions and the ultimate effects of investments in reform.

A Final Case Study of SCALE Activities at California State University, Northridge: How Institutional Context Influenced a K–20 STEM Education Change Initiative

Matthew T. Hora and Susan B. Millar[1]

Institutions of higher education (IHE) 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 National Science Foundation (NSF)-funded System-Wide Change for All Learners (SCALE) project sought to effect change in its partner IHEs by: (a) improving science, technology, engineering, and mathematics (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, at the California State University, Northridge (CSUN) between March 2005 and August 2007. This case study includes two interrelated accounts of SCALE activities: (a) presentation of evaluation findings for each of the SCALE activities undertaken at CSUN, and (b) analysis of how specific aspects of the institutional context influenced SCALE activities. This case study is part of a larger effort to develop and field test an evaluation design that strives to measure how an educational organization's unique contextual features interact with an intervention. This larger effort includes case studies of the University of Wisconsin–Madison (UW-Madison) and California State University, Dominguez Hills (CSUDH) (Hora & Millar, 2007; Hora & Millar, 2008).

The NSF Mathematics and Science Partnerships Program

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. residents. 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 Committee on Science and Mathematics Teacher Preparation [CSMTP], 2000; Project Kaleidoscope, 2006; U.S. Department of Education, 2006b; 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 suggests that an appropriate goal to address the eroding U.S. advantages in mathematics and science is to produce 10,000 qualified teachers

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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, 2004). The mandate of the No Child Left Behind Act (NCLB; 2002) that all school districts must employ only "highly qualified teachers" further indicates 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 U.S. 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. Then, they 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 whose programs are governed by diverse policies that operate in isolation and with little coordination. 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) states 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 teachers.

The NSF's Math and Science Partnership Program

Growing concerns about improving the alignment of the teacher training continuum are among the reasons the 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 policy makers' understanding of the role that higher education plays in preparing future teachers, moving beyond long-held critiques of teacher preparation programs to a closer examination of the role of disciplinary faculty in the STEM disciplines.

The NSF 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. 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, and undergraduate STEM (including preservice) students to develop strong math and science content knowledge and pedagogical methods. That is, the MSP program's theory of change includes the idea that increased involvement of STEM faculty in the teacher training continuum will result in lasting improvements in K–12 student learning (CASHE, 2006; NSF, 2002).

Specific Problems Addressed by the MSP Program

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 (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* (2006). Critics note that many STEM undergraduate majors graduate with substantial deficiencies in their content knowledge (e.g., Handelsman et al., 2006). 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 policy makers 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 *Shaping the Future* report by the NSF (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 for future teachers.

Teacher preparation programs. Teacher preparation programs and the colleges of education that operate them have been subject to criticism for years. In particular, critics charge that college of education curricula for preservice candidates is poorly designed and insufficiently grounded in rigorous content courses and/or pedagogical instruction (Labaree, 2006; Mundry et al., 1999). Policy bodies such as the CSMTP (NRC, 2000) and NSF-funded practitioner reformers (Millar & Alexander, 1996) urge 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 IHEs are underway to improve how teachers are prepared and trained (Robinson, 2006). Among these initiatives are several—including the NSF's Collaboratives for Excellence in Teacher Preparation program 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 program effectiveness, 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 another 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, where 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 more explicitly building on novice teacher's prior experiences or knowledge (Mundry et al., 1999).

Challenges to higher education reform and institutional change. The MSP program is facing the extremely difficult undertaking of fostering change in higher education, a sector known to be very resistant to change (Cuban, 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 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 (Labaree, 2006; Gilroy, 2003). 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 are occurring at IHEs across the MSPs, but with a majority of the changes in preservice programs and in-service professional development, and not in STEM departments. Furthermore, changes were at the individual level instead of the institutional level, with no department-wide initiatives or collaborative team efforts (CASHE, 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). The Zhang et al. 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

The MSP project featured here, SCALE, sought to effect change in its partner IHEs by creating a transformative culture in IHEs through the creation of cross-cultural working teams who operated at the intersections among K–12 districts, colleges of education, and colleges of mathematics, science, and engineering (SCALE, 2005). Upon engaging the IHE case studies team, they conveyed their theory of action regarding IHEs by stating that SCALE seeks to achieve the following goals:

1. Reform undergraduate STEM courses;

2. Promote collaboration between STEM and education departments on preservice teacher education;

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

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

However, SCALE leaders did not define or operationalize the construct of organizational culture or state measurable objectives for the four goal areas articulated for the IHE case studies team. Unable to measure progress towards a set of clearly defined objectives, or evaluate the program according to a set of established criteria, this evaluation design focused on describing program activities, assessing how well subsequently observed effects met stated goals, and analyzing the relationship between the institutional context (with a specific focus on cultural phenomenon) and program activities. Given the paucity of research designs and research-based indicators for measuring institutional change over time, conducting such an evaluation became problematic. Thus, this effort is in many ways an exploratory effort to develop and field test an evaluation design that measures how an educational organization's unique contextual features interact with an intervention.

Methodology of the IHE Case Studies

This section includes a brief description of the rationale for the research, the theoretical framework guiding the research, and the research design. For a more detailed description of the study's methodology, see the Appendix.

Conceptual Framework

This evaluation is designed and implemented with careful attention to the need for high-quality evaluation of STEM education programs, particularly in complex institutional environments such as IHEs. To achieve the goal of improving K–20 STEM education, policy makers, funders, and practitioners are placing greater weight on methodological issues in program evaluation, with particular focus on basing decisions about program replicability and expansion on knowledge-based claims (Lawrenz & Huffman, 2006; Mosteller, Nave, & Miech, 2004; Kelly & Yin, 2007). Programs such as the NSF MSP program entail "research and development, requiring high quality evidence of effectiveness in order to ensure intellectual rigor and broad applicability" (NSF, 2005). These requirements further contribute to an interest in evaluation.[2] There is also widespread pressure to improve the methodological rigor of evaluations of STEM education programs (U.S. Department of Education, 2007). Some researchers note that education research has had a difficult time establishing itself as a science, in part due to the lack of accumulated knowledge, replicable studies, and transparency about methodological issues (Kelly & Yin, 2007).

Studying and evaluating change processes in complex institutional environments presents two inter-related challenges that are addressed in this qualitative case study. First, researchers who study STEM education reform are surfacing difficulties associated with studying change processes in complex institutional environments (Patton, 2006; Clune et al., 1997). A particular challenge found in many evaluation studies is that researchers have tended to focus on discrete elements, such as curriculum or assessment practices. For example, Anderson and Helms (2001, p. 4) argue that reformers need to "come to grips with the totality of this complex situation" in

[2] The MSP program sponsored a 2008 conference with the theme "Claims-Based Outcomes: What do we know? How do we know what we know? What do we still need to know?"

order to fully understand these complex dynamic systems, and if and how they should accept, reject, or adapt reform initiatives.

Second, research on reform implementation in both higher education and K–12 has also found that policy directives are frequently adapted and transformed by individual agents at the local school or IHE level (Ball & Wilcox, 1998; Spillane, Reiser, & Reimer, 2002). The process of interpreting policy interventions and adapting them to one's own local situation is sometimes called sense-making, where institutional actors "make sense" of their environment and select appropriate actions (Birnbaum, 1988). Increasingly, researchers are also recognizing the importance of this process and of how local contextual factors such as organizational structure and leadership shape the sense-making process, which is an important departure from the view that teachers operate in classrooms as if they are immune from exogenous forces such as the MSP program (Coburn, 2001; Spillane, Reiser, & Reimer, 2002). These topics are interrelated because local contextual factors shape the sense-making process, as individuals may be inclined—if not required—to attend to contextual features of their organizations, especially the cultural norms of administrative units such as academic departments (Gamoran et al., 2003; Coburn, 2001). However, research in this area is complicated by a paucity of theories and methods that adequately address the multilevel and recursive nature of the relationships among context, culture, and individual cognition, particularly for application in program evaluations.

In response to these concerns, this study of SCALE at CSUN seeks to identify contextual factors salient to STEM education reform, their relationship to group- and individual- level cultural phenomenon (i.e., mental models), and their collective influence on the SCALE intervention. Our methodological approach is to analyze the SCALE project through the analytic lenses of institutional theory and cultural models theory from cognitive anthropology. Thus, we are treating IHEs as complex organizations comprised of technical systems, political entities, social and cultural communities, and individual-level practices, each of which interact and collectively comprise the institution's context (DiMaggio & Powell, 1983; Colbeck, 2002). In addition, an institution's context is not a passive backdrop to individual actions, but is itself a dynamic setting in which individual agents are located according to the interactions among their own habitus (i.e., personal dispositions), capital (social, economic, or cultural), and the rules of a particular field (Bourdieu, 1977). The institutional field also extends beyond a single organization's boundaries to include clusters of similar institutions (e.g., comprehensive IHEs), and the "social conditions under which inter- and intraorganizational power relations are produced, reproduced, and contested" (Emirbayer & Johnson, 2008, p. 1).

In addition, we employ here a *distributed* theory of culture in contrast to a commonly used theory of culture that seeks to establish a unitary and stable set of cultural norms for a specific group of people (e.g., the math department). This approach focuses on the distribution of knowledge and beliefs across and within groups, with particular attention to the differential internalization of cultural norms by individual actors based on an individual's cognitive processes and unique position in the local social, political, and cultural environment (Shore, 1996; Atran, Medin, & Ross, 2005). The underlying research paradigm guiding this approach is that of ethnographic research, where we attempt to describe the IHE context and the SCALE implementation in a grounded and multidimensional fashion, based largely on the perspectives and experiences of local participants (Agar, 1996). Potential benefits to the STEM education community are twofold. First, for programs aiming to affect institutional transformation or cultural change, this approach may enable evaluators to systematically assess if and how an institution's context and culture act as (a) mediating variables that influence reform, and (b) as specific outcomes of the reform itself. Second, given the widespread interest in changing the culture of schools and IHEs, the approach may offer program planners and policy makers tools to better understand their institutions and the ultimate effects of investments in reform.

Research Design and Methods

The research questions for the IHE case studies line of work are 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. Hence, we 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?

This case study uses a repeated cross-sectional design, with in-depth interview data collected at Time 1 (T1; June 2006) and Time 2 (T2; June 2007). Other data collected for this research included official university and SCALE documents, and observations of SCALE meetings. Non-random sampling procedures were used to identify interview respondents, which included 18 at T1 and 16 at T2, for a total of 34 interviews with 25 unique individuals. In addition, we draw on interviews conducted with SCALE leaders and UW staff, conducted for the CSUDH and UW-Madison case studies to collect information on program planning, implementation, and evaluation.

Interviews were coded using a structured approach to grounded theory which is based on a coding scheme we call the *institutional context framework* (ICF). The ICF was developed as part of the preliminary analyses of the SCALE IHEs (Hora & Millar, 2006), and includes the following code families: external environment, internal structure, resources (fiscal and social), pervasive values, individual sense-making, and practices. The ICF is our contribution towards systematically identifying aspects of the institutional context (i.e., indicators) that influence STEM education reform. Using the ICF, interview data were systematically coded, reduced, and inductively analyzed for recurring patterns and themes in order to identify contextual factors salient to SCALE, group- and individual- level cultural norms, and individual sense-making processes. Generally, at least three observations regarding a specific aspect of the institutional context (e.g., tenure policies) or SCALE activities were required for inclusion in the analysis. Additional analytic procedures included (a) a causal network analysis that allows for the graphic representation of the relationships among these multilevel phenomenon, and (b) an exploratory analysis of mental models and their constituent cultural schema, as they are situated within the institutional context of CSUN. We used established methods of qualitative analysis to verify our findings, including triangulation of sources, actively seeking disconfirming evidence, and member-checking findings to ensure their accuracy.

Limitations

This research is designed to (a) explore faculty sentiments at one intervention site, (b) investigate the initial impact of SCALE activities at that site, and (c) generate a theoretical and practical approach for analyzing STEM education projects. Accordingly, the sample of respondents interviewed for this research does not constitute a random or representative sample of CSUN overall, or of individual CSUN colleges or academic departments, and is not intended to be generalizable to other IHEs or other IHE faculty. This micro-level analysis builds on the strength of the ethnographic case study approach. The interpretations and claims in this case study go only as far as is warranted by the methods used and the data collected. Since 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. Finally, attrition of faculty and program participants at CSUN resulted in different populations available for interviews at T1 and T2. As a result, reported changes are based on data from 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 the Intervention Site: CSU Northridge

In this section we briefly review the features that are prominent elements of CSUN, the field in which the intervention was enacted. A more detailed analysis of how these and other features dynamically interact and actually serve as mediating variables for the SCALE intervention is provided later in this section.

Mission

Part of the California State University (CSU) system, CSUN focuses on undergraduate education and provides affordable opportunities for a broad cross-section of California's population (CSU System, 2008). IHE mission statements serve as public declarations of an institution's primary goals and objectives; CSUN's mission statement follows:

> California State University, Northridge exists to enable students to realize their educational goals. The University's first priority is to promote the welfare and intellectual progress of students. To fulfill this mission, we design programs and activities to help students develop the academic competencies, professional skills, critical and creative abilities, and ethical values of learned persons who live in a democratic society, an interdependent world, and a technological age; we seek to foster a rigorous and contemporary understanding of the liberal arts, sciences, and professional disciplines, and we believe in the following values. (CSUN, 2008)

In addition, CSUN's stated values include a commitment to teaching, scholarship, and active learning, a commitment to excellence, respect for all people, and alliances with the community.

Demographics, Academic Programs, and Governance

Institution Type

CSUN is in the middle tier of California's three-tiered system of higher education. This three-tiered system is comprised of the research universities in the University of California system, the master's-granting universities in the California State University system, and the community college system. In terms of the influential national Carnegie Foundation ranking of IHEs, CSUN is a "Master's-L" (also known as comprehensive), a designation for large universities that do not grant doctorates, but have master's level programs (Carnegie Foundation for the Advancement of Teaching, 2006). The accrediting agency for CSUN is the Western Association of Schools and Colleges.

Student Body

The demographics of the CSUN student body (both undergraduate and graduate students) in the fall of 2007 were as follows: 32% white, 14% other, 27% Latino/a, 12% Asian-American, 8% African-American, 6% International, and under 1% American Indian and Pacific Islanders (CSUN Office of Institutional Research, 2008). The fall 2007 enrollment at CSUN was 35,446, which makes it one of the largest of the 23 California State Universities (only smaller than the CSU institutions at Fullerton, Long Beach, and San Diego). Of the total enrollment, only 77% (27,418) of the students were full time, a fact that places CSUN at a disadvantage relative to CSUs with a higher proportion of full-time students, because state funding policy is based on "full-time equivalents" rather than "headcounts." The CSUN student body is 88% undergraduate and 12% graduate students, 59% female and 41% male. With the average age of undergraduate and graduate students at 23.3 years and 33.5 years, respectively, many students are not traditional age. The numbers of first time freshmen (4,130) and new undergraduate transfers (3,989) are almost identical, and 83% of these transfers come from California community colleges (CSUN Office of Institutional Research, 2008). The CSUN student body, as some respondents noted, differs significantly from that of research universities, where most students matriculate directly from high school, live on or near campus, and graduate within four or five years.

Degree Programs at CSUN

In the 2006-2007 academic year, CSUN conferred 5,682 bachelor's degrees and 1,623 master's degrees. In fall 2007, the top undergraduate majors were general psychology (2,068 students), liberal studies (1,800), radio/TV broadcasting (1,466), business administration (1,459), sociology (1,322), and organizational systems management (1,297). The liberal studies program is a popular option for students intending to become elementary school teachers. Biology (1,099 students) is the only STEM discipline in the top 10 majors at CSUN. Education degrees dominate the master's level: the top graduate degrees that year were educational administration (627), counseling (403), and special education (279). (CSUN Office of Institutional Research, 2008).

Organizational Structure and Governance

CSUN is comprised of nine colleges, including the Eisner College of Education and the College of Science & Mathematics. There are 56 departments within these colleges, which offer 60 baccalaureate degrees, 45 master's degrees and 28 types of teaching credentials. There are also numerous research centers and institutes at CSUN, including the Center for Research and Innovation in Elementary Education, and the Inter-disciplinary Mathematics based Research and Education Center. The administration is comprised of a president, a provost (who is also vice president for academic affairs), and vice presidents for student affairs, administration and finance, and university advancement (CSUN, 2006). The office that is most directly engaged in SCALE-related activities is the provost and academic affairs. The governance system in the CSU system emphasizes departmental and faculty autonomy regarding the educational functions of the university.

Faculty and Workforce Characteristics

Instructional Workforce

Of the 2,159 faculty at CSUN in fall 2007, 1,308 were part time (61%), and 851 (39% were full time (CSUN, 2008). Some of the part time faculty are what respondents called "freeway fliers:" instructors who commute on Los Angeles freeways from campus to campus since they hold temporary appointments at multiple IHEs in the area. The composition of CSUN's workforce is consistent with national trends in higher education.

Faculty Workload

According to CSUN documents, the faculty workload at CSUN is governed by two policies, the California Faculty Association (CFA) collective bargaining agreement (CSU, 2006) and the CSUN Administrative Manual, Section 600 Academic Personnel Policies and Procedures (CSUN, 2005). The CFA agreement sets forth the broad parameters of faculty workload, benefits, and personnel policies that the CSU system must observe (CSU, 2008). The CSUN administrative manual further specifies that the normal faculty instructional load is 12 weighted units of instruction and the equivalent of 3 weighted units for advisement, committee assignments, and office hours. However, administrators may reduce this instructional load by assigning non-teaching responsibilities such as administrative duties, instruction related activities, research or program development activities reimbursed by the university or external funders, and leaves of absences without pay (CSUN, 2006). Thus, each faculty member at CSUN is generally expected to teach the equivalent of four courses a semester, and satisfy administrative duties and student support services.

Recruitment, Tenure, and Promotion Policies

The faculty reward and promotion system, also known as RTP, is one of the most important and influential aspects of institutional life. At CSUN, these policies are governed by statutes in the Administrative Manual, Section 600: Academic Personnel Policies & Procedures. Section 621.1 of the manual states that in making appointments, the following factors should be considered: excellence in scholarship and training, interest and skill in teaching, promise of professional growth, and qualifications of personal maturity (CSUN, 2005). For tenure review, the procedure is as follows:

1. A department personnel committee reviews personnel files and submits a recommendation.

2. The department chair makes an independent evaluation,

3. The personnel committee of the college, the dean, and finally the president submit recommendations.

4 The president makes the final decision.

In reviewing official CSUN documents, we found evidence that the policies governing RTP at CSUN encourage and support the practice of active learning pedagogies and research activities on teaching and learning. The university-wide RTP guidelines specifically identify pedagogy-based research, as well as discipline-specific research, as an acceptable form of publication for the excellence in scholarship criteria.

Relations with K–12 and Higher Education Sectors

Local K–12 Outreach

CSUN has a strong tradition of engagement with K–12 schools and districts, which many respondents cited as a historical consequence of being the dedicated IHE for the San Fernando Valley. CSUN is also the training school for future teachers in the LAUSD schools in what is now classified as Local District 2; preservice and in-service professional development field training offered by CSUN faculty has created strong ties with the district and individual schools. Other outreach activities focus on recruitment, such as bridge programs that bring promising high school students to CSUN to participate in IHE-level scientific research. CSUN faculty commonly participate in field days at schools or public events, operate programs to engage K–12 teachers in laboratory research, and conduct recruiting trips to local high schools and community colleges. Generally speaking, according to respondents, these efforts are not intended to recruit future math or science teachers, but rather to raise the profile of CSUN in the wider community, and to encourage promising students to attend CSUN and go on to further graduate work.

For example, two of the many K–12 outreach programs are Tomorrow's Scientists and the California Science Project. Many respondents mentioned Tomorrow's Scientists. Its goals are to recruit and train future science teachers in the liberal studies Integrated Teacher Education Program (ITEP; described in more detail below), and to provide these future teachers an opportunity to teach a real science lesson to seventh grade students from a nearby LAUSD school. Another program is the California Science Project (CSP), a well established K–12 professional development program funded by the state and the University of California system. CSP professional development activities are led by IHE faculty, and focus on disadvantaged schools and districts throughout the state. The CSUN faculty participate in the San Fernando Valley Science Project, which includes summer institutes in inquiry-based science with Saturday follow-ups throughout the school year.

Educational Reform Environment

At the time of this research, CSUN was in the midst of two major educational reform initiatives: a university-wide transformation effort known as the Learning-Centered University (LCU) initiative, and the Teachers for a New Era (TNE) project. The LCU initiative is comprised of three major elements: (a) maximizing experiential learning opportunities for students, especially in the first two years; (b) building a learning community among students; and (c) making a sustained and purposeful effort to educate high school students about career tracks. The last point, according to a respondent, is "one of the major gaps that haunts the relationship of K–12 to universities," since many high school students have little sense about the variety of possible careers and how to select an educational track to acquire the appropriate training. According to respondents and documentary evidence, the LCU initiative permeates many aspects of institutional practice at CSUN, including announcements for position openings, many CSUN official documents and publications, and the orientation session for incoming faculty. Another highly visible manifestation of the LCU initiative is the requirement that each department develop student learning objectives (SLOs) for each course.

Teachers for a New Era is funded by the Carnegie Corporation of New York, the Annenberg Foundation, and the Ford Foundation, as a response to critics who charge that IHEs are failing to prepare quality teachers (CSUN TNE, 2006). Since teacher training programs are a significant aspect of the mission of the CSU system in general, and CSUN in particular, the university and the TNE project share a goal to improve the quality of the teacher preparation pathways at CSUN. CSUN was awarded a 5-year TNE grant in 2002 that will continue until 2009 using carry-over funds from the first five years of the award (CSUN, 2006). TNE is a comprehensive initiative with many different lines of work, and to adequately account for these activities is not within the purview of this case study. TNE and the MSP program have almost identical goals regarding improving preservice programs in IHEs by increasing interdisciplinary collaboration and improving undergraduate STEM instruction.

Teacher Education Programs and State Teacher Credentialing Policies

Of particular relevance to the SCALE and the MSP program are the teacher preparation pathways which provide future K–12 math and science teachers their training in disciplinary content and pedagogy. The elementary and secondary teacher education programs at CSUN are administered by the COE, but STEM and education faculty collaboratively plan and implement the preservice curriculum. The major pathways that lead directly to a teaching credential from CSUN are described below. Several respondents stated that the traditional credential program (at the graduate level) and the liberal studies program (at the undergraduate level) are by far the largest teacher preparation pathways at CSUN.

The traditional credential program is a fifth year post-baccalaureate program in the COE, which requires a year of pedagogy-focused coursework and student teaching. Another graduate-level option for students at CSUN is the Accelerated Collaborative Teacher (ACT) program. The ACT program is a partnership between CSUN and Local District 2 of LAUSD, which provides a fast-track credential program for students who are placed immediately at a LAUSD school while taking education courses at CSUN. No STEM courses are required for either of these programs. One of the undergraduate level pathways is the liberal studies teacher preparation option, which is a program for obtaining a bachelor's degree only, and is intended for students who plan on enrolling in a traditional credential program or the ITEP junior option (see below).

Another pathway is ITEP, which is a program for obtaining a bachelor's degree in liberal studies and an M/S credential concurrently. The students are cohorted for this full-time program and take at least five courses in STEM departments. Finally, the four-year integrated program (FYI) is a freshman-only program for concurrently obtaining a bachelor's degree and a secondary credential in the areas of English or mathematics. Of particular relevance to SCALE and the MSP program are the subject matter programs, which lead to a bachelor's degree in a specific discipline and provide adequate preparation for the state subject matter tests that lead to a secondary credential (i.e., junior or high school). Each subject matter program must be specially approved by the state, and at CSUN only the math and geology departments offer this option.

III. The Institutional Context

Significance of Institutional Context

Because reform efforts such as SCALE interact with various elements of the institution and coexist with extant reform initiatives, it is critical to understand the context in which a reform effort unfolds (Patton, 2006; Katzenmeyer & Lawrenz, 2006; Anderson & Helms, 2001). Researchers in both K–12 and higher education have established that a primary reason instructors do not passively receive policy directives and translate them with complete fidelity to the classroom is that they are inclined—if not required—to attend to contextual features of their organizations, especially the culture of administrative units such as academic departments (Birnbaum, 1988; Gamoran et al., 2003; Coburn, 2001). Insights into the processes by which features of the institutional context dynamically interact in ways that lead actors to resist, adapt, or adopt reform efforts like SCALE can improve our understanding of the relationship between instructional policy and local implementation, and provide actionable knowledge for program planners.

How the Institutional Context Influenced SCALE

This case study shows that the factors that affected how the SCALE reform effort played out include not only degree programs and governance structures, but also material and human resources, group identities fostered by structured interactions, and individual dispositions and practices—all of which were influenced, in turn, by external factors. Analysis of these factors enables us to understand the often non-linear and sometimes unpredictable interactions between a reform effort, an institution, and its members. With this focus, we emphasize the importance of situating an intervention within its local context and of systematically opening up the black box of reform implementation by identifying which contextual factors are actually salient to the reform. We present context factors for SCALE at CSUN using the structure of the institutional context framework.

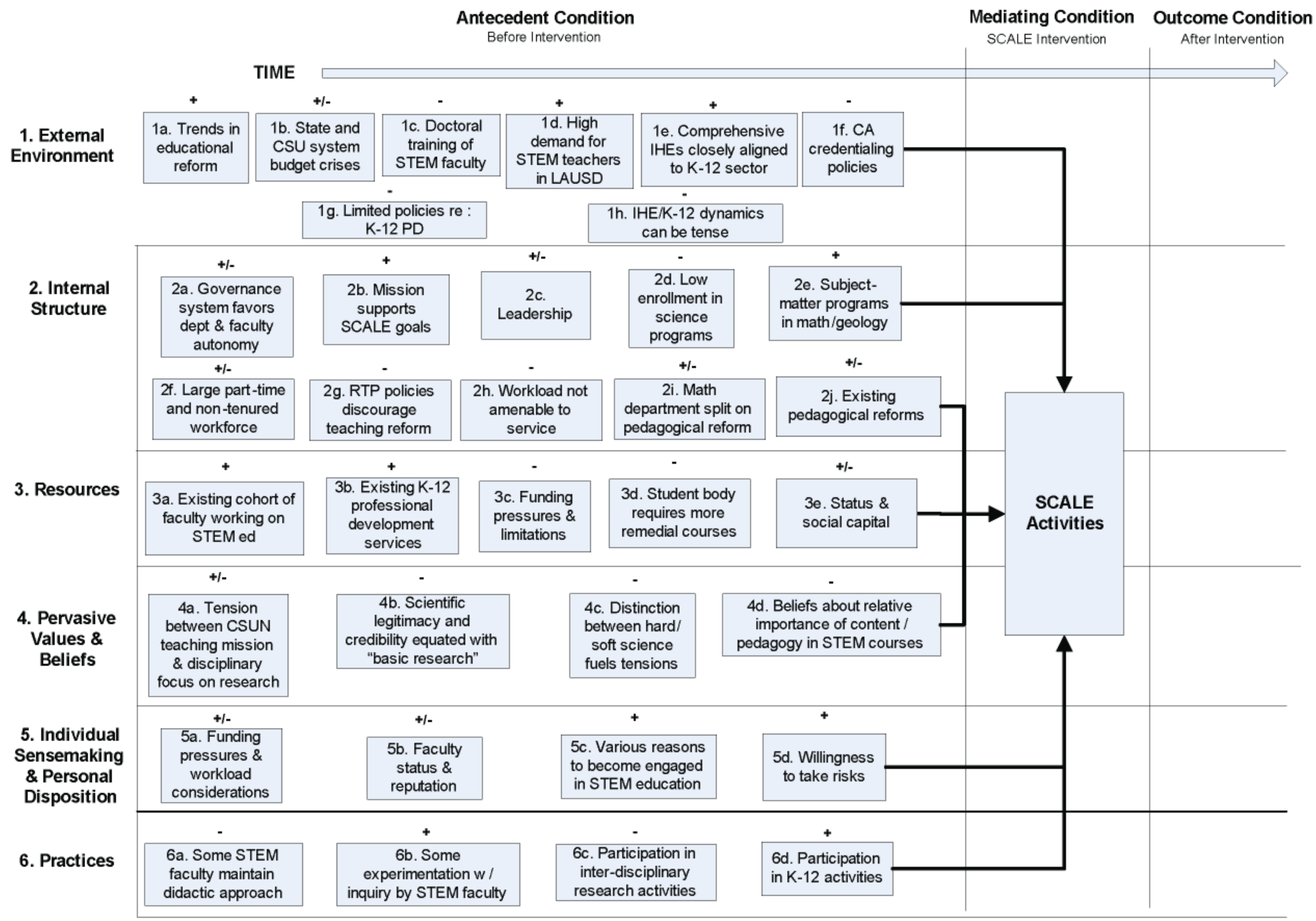

Figure 1. **Contextual factors at CSUN relevant to SCALE.**

This section presents findings on how contextual factors at CSUN interacted with the SCALE MSP. Upon analyzing interview transcripts, documents, and field notes from observations and interviews, we identified key factors within the institutional context that were activated by the SCALE intervention, and played either a supporting or inhibitingrole. We assigned a valence to each factor (*supporting* +, or *inhibiting* -) based on respondent views or our own interpretation of the relationship, and organized these findings by the ICF categories. This section is organized by these categories, as is Figure 1, which summarizes the key findings.

External Environment

This category of the ICF includes factors external to CSUN pertaining to institution type, national and state education policy, academic training of faculty, economic forces affecting education, and local K–12 characteristics.

Trends in educational reform take root at CSUN (+). CSUN has many grant-funded programs aimed at reforming some aspect of institutional life and practice. The primary intent of these programs (here called reform initiatives) is to change existing policies, structures, or programs. Some of the reform initiatives at CSUN, including the LCU initiative and the TNE project, are part of a national trend in educational reform. Several organizations and government agencies are supporting educational reform in the STEM disciplines, including the NSF, the Carnegie Foundation, and the NRC. This national trend had taken root at CSUN well before the SCALE initiative arrived on the scene, and served to sensitize faculty and administrators to the rationale behind reform, develop networks of participants, and generally to lay the groundwork for new projects. Of note, some respondents aware of this trend conveyed that the MSP emphasis on leveraging the content expertise of STEM faculty to address K–12 educational issues is a strategy that is considered insulting and misguided by some education faculty.

State and CSU system budget crises frustrate faculty yet make external funding attractive (+/-). Several respondents observed that the CSU system is currently in the midst of a budget crisis, with current or impending cutbacks in hiring, increases in class sizes, and a general atmosphere of fiscal restraint. According to one respondent, CSUN is losing positions through attrition and reduced replacement rates. Perhaps more relevant to individual faculty and the SCALE goals though, is the increase in average course size, which some respondents cited as a major constraint on using active learning pedagogies. In addition, as class size grows, so too do the demands of office hours and grading, and some respondents felt that their time to devote to research and service activities was reduced by the demands of serving a growing student body. One outcome of the budgetary situation is that other IHEs, including regional community colleges, may offer better salaries and encourage CSUN faculty to leave their positions. However, this situation also serves as a supportive factor for SCALE, as the pervasive sense of a resource-limited environment makes all external funding particularly attractive for administrators and faculty.

Lack of pedagogical training during STEM doctoral work negatively impacts quality of teaching (-). Respondents frequently cited the influence of the Research-1 universities on their professional lives. In particular, all faculty respondents noted that during graduate school they received no training in pedagogical methods and had to learn on the job. For example, one respondent said she had no training in teaching, despite her experience as a teaching assistant, other than a public speaking course she took in order to do research presentations. An administrator cited this feature of research universities, from which most CSUN faculty are hired, as having a significant—and unacceptable—impact on the quality of teaching at CSUN.

STEM teachers are in demand in LAUSD schools (+). LAUSD is one of the largest school districts in the country, and hires a significant portion of its teachers from the CSU campuses. Los Angeles County currently has a shortage of math, science, and special education teachers, and LAUSD is actively seeking teacher applicants in these areas. In fact, through the LAUSD Teacher Recruitment and Student Support Grant Program (TRSS), the district is offering prospective new hires incentives and reimbursements of up to $18,000 to teach in low-performing schools in these subject areas. A respondent noted that student teachers get snapped right up and that local districts want more graduates, which is problematic because CSUN enrollment figures in the COE are dropping. Teacher shortages in LAUSD increase the value to both K–12 and IHE training institutions reforms focused on STEM preservice teachers.

Comprehensive universities are closely aligned with MSP goals (+). The missions and programs of comprehensive universities such as CSUN are closely aligned with the goals of the MSP program, including a focus on teacher training, undergraduate education, and developing IHE/K–12 partnerships. For example, teachers at LAUSD participate in several CSUN-sponsored professional development programs, and many COE faculty have close ties with administrators and teachers throughout the system. The district and CSUN are further connected since most of the students at CSUN are from Los Angeles County and are graduates of LAUSD schools. Several respondents also noted how CSUN's close affiliation with the K–12 sector serves to engender a keen awareness of the interrelatedness of the local K–12 sector and CSUN: many CSUN students come from the schools and communities surrounding the university, and return to live and work in those communities. Thus, in contrast to many research universities (e.g., UW-Madison), CSUN personnel were already conversant with the goals of the MSP program and the university had an established track record in these areas.

CA teacher credentialing policies discourage interdisciplinary collaboration (-). CSUN teacher preparation programs are built around the state's teacher credentialing system, which requires a broad liberal arts education for elementary teachers or an undergraduate degree in a discipline for secondary teachers, coursework on pedagogy, and student teaching. However, the state policies governing teacher training create a division of labor between the COE and College of Natural and Behavioral Sciences (CNBS) regarding teacher preparation, such that pedagogy and content are addressed in separate degree programs. 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, while content-based coursework are housed and administered by the CNBS and their respective departments. In most cases, there is little coordination between the two colleges in order to provide students a coherent and structured preservice experience.

> One of the odd and frustrating things at this university is the gigantic gap between the undergrad [coursework and graduate] credential programs. Despite all this work together [on TNE], it may actually not do a thing for our teacher candidates, [because] as undergrads all they're doing is majoring in their subject. So they're a math major. And they can opt for this math education strand but it doesn't mean anything credential wise.

> It just means that they're taking a set of courses that's more oriented towards education than others, but when they walk out of the door they've got a math BA or BS and nothing else. Now, they can then choose to enter a credential program, which if they come to CSUN is in the College of Education. And they only get one math-specific course at that point, and that's the math methods course. It's unusual for an undergrad to come out of a CSUN math major and go right into the credential program. We don't see that continuity at all. It's more likely that they've come from the workforce where they've been for the last 10-15 years. It's a pretty small pipeline immediately back to us. (COE faculty)

It must be noted that CSUN has several programs and initiatives that address this predicament, including the subject matter programs in math and geology and the ITEP programs (see below). However, the prevailing condition is that of a bifurcated preservice system that is more aligned with the state requirements and less aligned with the MSP goals of a coherent preservice pathway for future STEM teachers.

Policies governing the type and quality of in-service PD for K–12 teachers are lacking (-). Although California has content standards and a curriculum framework for K–12 schools, it has few policies or regulations governing the type and quality of PD offered to in-service teachers. Instead, districts, based on their own criteria, ultimately decide how best to provide instructional support and PD. Since these criteria usually include compliance with state content and curricular standards, most PD workshops and seminars used by a district closely align their content with these standards. The only two programs that have some policy leverage over PD are the California Beginning Teacher Support and Assessment (BTSA) and the National Board for Professional Teaching Standards, both of which include professional development requirements for the completion of their respective licenses, and have general guidelines for PD quality. In the case of the BTSA, K–12 districts have the authority to select these approved vendors. Thus, even if SCALE and other MSP programs provided high-quality PD, there is no way to ensure that LAUSD teachers would not participate in other PD opportunities, some of which may not be aligned with the principles of active learning promoted by SCALE.

Dynamics between IHEs and K–12 educators can be tense (-). Some respondents indicated that in many cases IHE and K–12 educators suffer from problematic dynamics, based largely on the sentiment that people in the ivory tower have little understanding of what life is like in the trenches. Thus, when faculty make suggestions about how to teach or manage their classrooms, some K–12 educators bristle and resent being told what to do. Some STEM and education faculty noted, however, that this is an over-generalization and that many faculty have taught at the K–12 level and are committed to improving that sector through their research and preservice training. Another by-product of this dynamic is that faculty, particularly STEM faculty, who exhibit empathy and respect for their K–12 colleagues are highly valued and in some cases considered unprecedented. This situation is particularly salient to SCALE efforts that bring IHE and K–12 educators together, as this is a widely agreed upon backdrop to such interinstitutional efforts.

Internal Structure

This category of the ICF includes factors pertaining to the internal structure of CSUN, including the organizational structure (governance, teacher education programs, STEM degree programs), student body composition, instructional workforce composition, personnel policies, leadership, and active and historic reform initiatives.

Governance system and autonomy exert strong influence on faculty (+/-). The governance system of CSUN, and its emphasis on departmental and faculty autonomy, was cited as a factor that strongly influences faculty practices at CSUN. This system favors departmental and faculty decision-making control regarding academic programs and related policies. Faculty autonomy can serve as a supportive influence to SCALE goals by allowing faculty significant leeway in how they prioritize their professional lives and make instructional decisions. However, this autonomy may also work against SCALE goals as faculty are under no obligations to adopt inquiry-based teaching practices or collaborate with their colleagues in the COE.

CSUN mission supports undergraduate education and teacher preparation (+). As the former San Fernando Valley College, there is a strong history of connection with the local community, which has made its way into the institutional saga. Several respondents explained that CSUN has a historic and primary identity as a community-based institution, and that this history and identity give the university pervasive influence in the community. A respondent who recently relocated from a research university found a strong culture of teaching and was a bit blindsided by the intensity and coherence of the faculty and administration's commitment to its students and teaching. Many faculty also expressed the sentiment that the institution has a historic and moral obligation to serve the needs of K–12 schools in the area. Despite this feeling, we heard conflicting perspectives about the viability of realizing this obligation, due to workload pressures, and complications arising from working with as complex and politicized a district as LAUSD.

Multi-tiered leadership generally favors pedagogical reform (+/-). As at other IHEs, several layers of leadership influence the day-to-day operations of CSUN, each with its own unique leadership positions. These layers and positions include the upper administration (e.g., provost's office), college level (e.g., dean's and associate dean's), and departmental level (e.g., department chair and particularly influential faculty). CSUN provides varying degrees of support for pedagogical reform at these different levels, which may result in somewhat inconsistent messages delivered to faculty. According to respondents, these mixed messages have included some decisions about faculty tenure and promotion that vary in their evaluation of the value of pedagogy-based activities, and divergent public declarations about the relative value of research and teaching in faculty life. As a result, the supportive leaders provide a supportive element to projects like SCALE, but the varied support at different administrative levels may contribute to a confusing and potentially discouraging institutional environment for faculty.

Pipeline of preservice majors for CSUN science departments is limited (-). According to some respondents, while the lack of science majors at CSUN severely restricts the pipeline of future high school science teachers, more alarming is the low number of existing science majors who are considering teaching K–12 as a career option. One respondent observed that while math has a large cohort of students who plan to teach high school math, there is not a similar population for science. In the sciences, students generally plan on becoming doctors or entering industry in some fashion. This problem is noted in a TNE report, as follows.

> It must be strongly stated at the outset that single-subject science faces a unique challenge in the preparation of teachers in secondary education compared to those in mathematics, the arts and humanities, and social sciences. The population of baccalaureate candidates whose stated career goal is to become a high-school teacher of science is very small in the departments of Biology, Chemistry and Biochemistry, Geological Sciences, and Physics and Astronomy. Because of the small numbers, it is currently not feasible to create a curriculum specifically for prospective teachers of high-school science. The problem is not unique to CSUN. The severe shortage of high-school teachers of science is a highly publicized national problem. The number of students majoring in science is dwindling, and most of these majors are planning careers as professionals in industry or higher education. (CSU Northridge, 2006)

Other respondents corroborated the sentiment that students generally "don't come to choose a science major to be a teacher." Several respondents stated that low enrollment in chemistry, physics, and geology was a major concern for reasons of funding and the long-term health of the departments. This presents a considerable problem for projects such as SCALE that hope to influence a cohort of preservice students: this cohort may not actually exist. In response, many faculty and administrators in the CSUN STEM departments are focused on recruiting students from area high schools and community colleges. Respondents noted that these recruitment efforts are going beyond traditional science fairs and other K–12 outreach to a more targeted focus on aligning the pipeline of students from community colleges and high schools to CSUN. For example, as one respondent noted, CSUN is exploring a dual admission system with community colleges where students take the correct introductory courses while working directly towards a CSUN degree.

Math and geology subject matter programs require inter-departmental collaboration (+). One of the requirements for obtaining a single-subject (secondary) teaching credential in California is to provide evidence of subject matter proficiency, which can be done by completing an approved IHE subject matter sequence, or by passing the California Subject Examinations for Teachers (CSET). As noted above, only two departments at CSUN have subject matter programs, math and geology. These four-year programs build in all of the coursework required to pass the CSET. One respondent stated that without this type of preparation, a student with a math or science baccalaureate would need to take another semester of coursework to get adequate breadth in their subject area. Another respondent noted that CSUN used to have more subject matter programs in the sciences, but found that few of the students enrolled in the program planned to get their bachelor degrees at CSUN or to obtain a teaching credential. Instead, they were using CSUN as a "fly-by" in order to avoid taking the CSET, and thus consumed considerable administrative resources in the process. These programs entail close collaborations between STEM and education faculty in creating course curricula, and pay close attention to fusing content and pedagogy. As a result, these programs represent probably the best example of a blended program leading to a secondary science or math teaching career, and some respondents hope that the eventual success of these programs will be a major recruiting point in the future.

Large part-time and non-tenured workforce complicates efforts to reform STEM instruction (+/-). Several respondents noted that the growing trend in U.S. higher education to hire non-tenure track faculty, especially to teach lower division courses, has important implications for reform efforts such as SCALE, since the MSP focus is on full-time faculty.

However, some respondents noted that many lecturers and adjunct faculty have been at CSUN for several years, and are deeply integrated into departmental operations. In fall 2007, 61% of the faculty positions at CSUN were held by part-time instructors, and only 39% by full time instructors (CSUN, 2008). The part-time faculty are not on the tenure track and play significantly different and less influential roles in departmental policy-making and administration than full-time faculty. Thus, for important leverage points that may influence STEM instruction, such as syllabus development and student assessment, part-time faculty may have less influence than their colleagues. Yet, because these faculty are not subject to the pressure of obtaining tenure, they may be more likely to be able to participate in a reform initiative.

Departmental tenure and promotion policies discourage teaching innovation (-). Several respondents, including faculty and administrators, noted that across the CSU system faculty are experiencing increased pressure for research and publication productivity. As one respondent noted, the goal is to bring the standards of faculty scholarship more in line with research institutions. Faculty respondents generally felt that this shift in policy is placing further demands on their limited time, and reducing their prospects for participating in service activities such as SCALE. As one respondent noted, "You don't get published for participating in a grant," and since many faculty use summer breaks as an opportunity to conduct research and write journal articles, summer professional development for K–12 teachers was cited as a relatively low priority. Furthermore, for faculty who are actively engaged in pedagogical research, respondents stated that administrators generally do not understand that educational research takes longer than traditional scientific research, which means that faculty who participate in this type of research will be less productive than others in terms of articles submitted and published. Given these pressures on faculty, several respondents noted the need for two types of support: (a) release time afforded primarily through grants and also through committee work; and (b) support and mentorship in writing articles and conducting research.

Workload is heavy and not amenable to service (-). Several respondents, including both faculty and administrators, observed that the teaching load in the CSU system is extremely high compared to many IHEs, making research and service activities difficult to accommodate. Given the prominent role that research and publications play in tenure and promotion considerations, faculty usually allocate any time beyond their teaching responsibilities to research and/or writing. One respondent who recently relocated to CSUN from another university called the mix of teaching load and research expectations at CSU a "worst nightmare." Several respondents described their workload as overwhelming, and used the words like "frazzled" and "a struggle" to describe their professional lives. A common element across all of the respondents was a perceived lack of time to accomplish all of the tasks that they wished to. Some faculty also expressed some anger towards the CSU and CSUN administrations. Faculty explained that with class sizes growing and with increasing demands to publish scholarly works, they also were expected to participate in the LCU initiative and to focus on assessment issues. As one respondent stated, "You can't get blood out of a turnip." Another criticism expressed by some respondents was that, while administrators stated that they would treat pedagogy-based research as scholarly work, they did not understand (as noted above) that education research generally takes longer, and is less tidy than traditional scientific research. Thus, a TNE faculty member or others who are conducting pedagogy research may not be as productive as other faculty when it came to publications.

According to several respondents, faculty are usually only able to accommodate service activities such K–12 professional development workshops into their heavy workload when they receive release, or are assigned time from department or college administrators. Generally, assigned time is granted for administrative duties, such as serving as department chair, or through grant and/or university funding that buys out a portion of the faculty member's teaching load. This enables faculty to participate in activities such as TNE or SCALE without requiring an unsustainable level of effort. In cases where assigned or release time is not available, faculty generally participate in service activities only during the summer break, which is also an ideal time for research activities.

Math department strongly divided on pedagogical reform (+/-). CSUN's math department has long been split by the controversy over constructivist pedagogical strategies in mathematics, also known as the math wars. Numerous respondents noted that the atmosphere in the mathematics department is tense due to the political and ideological nature of the debate, which some felt had long ago ceased being a collegial discussion over methodology. One respondent observed that the division, which is not unique to CSUN, is sad because all of the faculty are committed to math education and improving student learning. The division manifests itself in two ways relevant to SCALE: the revision of the liberal studies math curriculum, and relations between IHE faculty and K–12 personnel. Many respondents were heartened by recent collaborations between the COE and the small cohort of pedagogy-minded math faculty who are revising the liberal studies curriculum to infuse pedagogical content knowledge into the curriculum. Some respondents indicated that reform efforts such as SCALE should only engage the faculty in this cohort.

Unfortunately, several respondents reported that the efforts of this cohort are being actively challenged by another cohort of math faculty who disagree with the constructivist approach. One faculty member stated that the best argument for reforming an entire STEM department is to avoid situations where a group of faculty actively undermines the efforts of others. In addition, some respondents noted that the debate has resulted in real harm to IHE and K–12 relations, since it has left K–12 teachers feeling defensive about their own teaching styles, and confused about the best pedagogical approach to employ in their classrooms.

Existing pedagogical reforms set the stage with support and skepticism (+/-). As previously noted, several nation-wide pedagogical reform efforts are addressing STEM education and preservice training, and that three such efforts—TNE, CSP, and LCU—already were underway at CSUN. These reforms set the stage for SCALE by familiarizing faculty with the core issues (e.g., active learning strategies, interdisciplinary collaboration), creating networks of STEM and education faculty, and initiating programs and activities that were aligned with the goals of SCALE. For example, one of the activities of the TNE project was an attempt to hire tenure-track faculty who would focus on STEM pedagogy and outreach in their departments. By doing so, the TNE project would guarantee itself a long-term presence and influence at CSUN, particularly since most of the hires had unique Memoranda of Understanding that officially sanction their focus on pedagogical research and K–12 activities.

However, the flip side of such precedent is that some faculty were skeptical of the rationale behind such reforms, and were less inclined to think highly of SCALE. For example, the TNE project had some difficulties in actually hiring these pedagogy-focused faculty, as some departments disagreed on the responsibilities of the position or even the basic premise of the TNE project. Furthermore, some respondents noted that being identified as “the K–12 expert” has negative consequences.

> Already some people in the department weren’t particularly excited about TNE and don’t really feel as if it’s their department’s business to be worrying about making teachers. Then, they’re unwilling to give up, let’s say, a position to bring someone in whose research work is going to be education. Now interestingly, I don’t think it’s giving up a position, I think that position was extra. (STEM faculty)

Reactions to LCU among faculty respondents were generally supportive regarding the intent of the initiative, but mixed regarding its implementation and ultimate impact on faculty life. Some reported that they and their colleagues are still not sure precisely what it means, and others view it as an additional burden from the administration. Considering the overwhelming workloads, one respondent stated that some resistance is not surprising, and that change doesn’t happen in higher education without resistance. This respondent noted that “at first blush, the LCU shifts responsibility to the student, but it requires significant work by faculty.” Despite these challenges, most respondents report that there is significant buy in from the faculty for the ultimate goals of the initiative. They explained that this buy-in is concomitant with the knowledge that current CSUN students may soon be teaching future CSUN students, and thus faculty had a vested interest in ensuring that they were being taught well.

Resources

This category of the ICF includes factors pertaining to material resources (e.g., time, funding), and social resources (e.g., networks).

Active and historic reform efforts fostered social network of STEM educators (+). As previously noted, the STEM disciplines have a strong history of participating in educational reforms, and these active and historic efforts have fostered networks of STEM educators and laid the groundwork for future projects such as SCALE. The funding and employment opportunities afforded by these projects played a significant role in developing the readily identifiable cohort of faculty who are particularly active and experienced in STEM education. This community is recognized by K–12 personnel as a valuable resource when they need collaborators or expertise pertaining to STEM education. In a similar fashion, personnel at CSUN recognize that there are people on campus who have experience in working with pedagogical issues and in the K–12 sector. It is worth noting that these networks in many cases extend beyond the confines of CSUN, as many personnel have extensive personal networks within their disciplines and specialty areas. These networks provide a resource for sharing ideas and building knowledge, particularly through professional meetings and electronic communications.

> One nice thing about CSUN is being in this Teachers for a New Era program, [where we have] 30 or 40 people [in science and math] who are dedicated to improving teacher education from all different perspectives and it’s wonderful. It’s a great place to be because there’s nobody slamming the door in my face saying, “I can’t be bothered.” There are always people that want me involved because they have another idea and so, to me, it’s a great place to be doing this right now. (STEM faculty)

Some respondents singled out the example of Dr. Steven Oppenheimer, who is a cancer researcher in the biology department at CSUN, and a leading proponent of engaging K–12 teachers and students in STEM research. According to these respondents, Dr. Oppenheimer has established positive relationships with several K–12 districts, which gives other faculty immediate credibility with the K–12 personnel.

K–12 professional development services already exist at CSUN (+). Members of the previously mentioned cohort of faculty devoted to STEM education often design and facilitate professional development programs for K–12 teachers. In addition, faculty in the COE regularly provide professional development for K–12 teachers through a variety of programs and thus serve as a resource for K–12 districts. These entities, their skilled staff, and their positive reputation in local K–12 districts, each serve as a supporting factor to the SCALE project.

Funding pressures limit resources (-). As previously noted, the state and CSU system budget crises are deeply affecting faculty at CSUN. As a result, there is a consistent financial pressure on all CSUN personnel to compensate for declining state funds by obtaining external funding to sustain or even enhance current teaching programs and research capacity. CSUN lacks additional staff and other resources available to adequately instruct undergraduate students. Under pressure to increase enrollment, departments often respond by just “churning out undergraduate students,” so that faculty can devote more time to seeking external funds to build research programs, developing a track record for fundraising, and accomplishing other tasks for which college and departmental funds are not available.

Student body requires more remedial courses. (-). Several respondents raised the issue of inadequate student preparation as a major factor influencing their work at CSUN. While some respondents viewed the generally poor level of preparation of incoming students as an unavoidable aspect of living in a large, urban area, they noted that CSUN has had to address the “realities of student abilities,” by increasing the amount of remedial coursework for incoming students. One administrator noted that students who come to CSUN with no more than 10th grade math (Algebra 2, a California state requirement), or after having been out of school for several years, “generally flounder.” This is supported by the fact that over 80% of incoming students fail the introductory math assessment. One respondent noted that the mathematics preparation of incoming freshmen was “sad,” and that students lack “sub-high school skills” such as adding fractions or basic geometry. Some respondents argued that the increase in remedial courses drains departmental resources and further increases the teaching challenges they face.

Status and social capital influences ability to participate in reform (+/-). Some respondents noted the importance of their tenure status and associated social capital (e.g., social status, authority, and reputation) in enabling them to participate in reform activities. These respondents stated that junior faculty must focus on teaching first and then research and publications in order to adequately develop a portfolio for tenure and promotion. Thus, the RTP policies of the department and their inherent authority play a powerful role in shaping how junior faculty budget their time.

> And it’s easier for me to do all this because I’m such a senior faculty. Whereas a lot of junior faculty that get involved, have been involved in SCALE, there’s actually more pressure on them because of all these different requirements, but also there’s more

> pressure in general for new science faculty at CSU. More publications, more grants. (STEM faculty)

Furthermore, respondents noted that if a faculty member's disciplinary reputation is sufficiently high (as measured by high-prestige research, grant funding, and publications), then their colleagues may be more forgiving if they become involved in K–12 outreach or pedagogical reform.

Pervasive Values

It is important to note that we do not claim that all faculty, administrators, and staff at CSUN exhibit the following pervasive values. However, because the values presented here were expressed by many respondents from different social groups and administrative units, it is reasonable to surmise that these values are widely shared by many people at CSUN. Moreover, each individual may have personal interpretations or versions, shaped by backgrounds, personality, social position, discipline, and other situational or demographic variables.

CSUN's teaching mission and disciplinary traditions are in tension (+/-). One of the defining features of CSUN is the oft-cited tension between the teaching mission of the university on the one hand, and the disciplinary traditions and their attendant norms and practices on the other.

> I would say [undergraduate education] is a priority, but the big priority of the department and the college is research. I mean, even though we're an undergraduate teaching institution, and our primary goal is to teach—because we're assigned twelve units of teaching every semester, research is just being piled on top of that. (STEM faculty)

As the former San Fernando Valley College, there is a strong history of connection with the local community, which has made its way into the institutional saga. Several respondents explained that CSUN has a historic and primary identity as a community-based institution, and that this history and identity give the university pervasive influence in the community. Many faculty also expressed the sentiment that the institution has a historic and moral obligation to serve the needs of K–12 schools in the area. Despite this feeling, respondents expressed conflicting perspectives about the viability of realizing this obligation given the demanding workload (see below) and the disciplinary traditions that often worked against this teaching and service oriented mission.

> [At CSUN faculty] will be pulled two ways. [First], is the department, which is locally situated in a region that has a local habitation and a name and demography to it. They'll be pulled that way by asking about their classes. [Second], they'll be pulled abstractly on the other axis towards the discipline. This is a hierarchy of performance and achievement that is national and international in scope and standard, and the farther it removes itself from contamination with the region, the more successful people are, just given the way the hierarchy works. So what we can provide here is a route to success that we reward if we try to bridge those two things. But I think if you're interested in the career ladder…you have to subscribe to the axis of disciplinary research. So I think that's a real tension that people feel as they move up the line. There's some people who can

> overpower it and deal with that, but I think, that's where a lot of people get oppressed and concerned. (Administrator)

The idea that the disciplinary axis influences faculty regardless of their geographic and institutional situation was often credited to doctoral programs, which both train students to become technical experts in a field and socialize them into discipline-based behavioral and intellectual norms. Further reinforcing these norms and values is the fact that once students are awarded the Ph.D. and granted entry to a discipline, their discipline becomes the primary source of their identity as a professional academic. While the predominance of the disciplinary value of research accomplishments serves to inhibit the goals of SCALE, the teaching oriented mission of CSUN serves to support SCALE. The resulting tension has important implications for interdepartmental collaborations and for dictating how individual faculty members prioritize their workload, both of which are critically import to the SCALE project.

Scientific legitimacy and credibility equated with basic research accomplishments (-). Perhaps the most frequently cited aspect of faculty life at CSUN was the demanding workload and its implications for the prioritization of research, teaching, and service activities. This conception of the priorities is a function of both CSUN's RTP policies and the way disciplinary expectations and traditions are instantiated at CSUN. No STEM respondents had prior training in pedagogy in their graduate training. Instead they received training that consistently placed higher value on conducting research and acquiring expertise in a specialty area of their field. The lack of training in pedagogical issues often results in a reliance on teaching "the way I was taught," which was described as a practice that "was taken for granted." A practical corollary of this factor is the departmental practice of separating teaching and research activities. For example, some STEM departments have hired faculty members specifically to focus on outreach and education—in effect, to not pursue research in the discipline. However, some respondents emphasized that even though colleagues may not be particularly interested in STEM education, they find it useful to have somebody around who is proficient in these matters; such people help the research oriented faculty address the broader impacts criteria required by NSF and other funders, and enable the other faculty to focus on their research.

Both STEM and COE faculty feel pressure to conduct research. The importance of achieving legitimacy and credibility in a particular discipline is viewed as a critical ingredient to academic success in general, and for interdepartmental collaborations in particular. Competence in a discipline and specialty area is made legitimate and credible by a faculty position, publications, and an active research program. This said, greater credibility is often ascribed to faculty in STEM disciplines than in education. This is evident from statements indicating that STEM faculty and academic staff who are engaged in educational activities need impeccable STEM credentials in order to the shore up their legitimacy with disciplinary colleagues. The high value placed on STEM disciplinary credibility also is evident in the fact that STEM faculty often question the STEM discipline credentials of faculty who specialize in math and science education in the School of Education. Respondents also indicate that academic staff, even those with impressive academic background and achievements, do not fit into the established hierarchy of higher education achievement and thus may be less desirable than faculty for projects such as SCALE.

Distinction between hard and soft sciences fuels long-standing tension between departments in the COE and some STEM departments (-). A salient corollary of faculty members' close professional identities with their disciplinary traditions is that different faculty may hold value systems that differentiate disciplines in a hierarchical order. In particular, academics commonly distinguish between the hard and soft scientists, where the hard sciences are considered more rigorous, as they take an approach based on reproducible experimental data, and the soft sciences are considered more interpretive, and anecdotal. This distinction is evident in the following comment:

> A gap still persists between education and the social sciences on the one hand and math and science on the other. [STEM faculty] all understand that observation is mediated by instruments and no one's going to argue that piece at all with you. But there's still this belief that science fact and science theory is out there independent of perception, their understanding of pedagogy is that it is just there and can be apprehended and should be. And you could explain to them that that contradicts their other attitudes and they'll say, "Yes, it does," but it doesn't really matter, they'll just go back to it in some ways. So I think that's why you have to sort of go back to, deal with the training issues that are involved with that. (Administrator)

Attempts to engage STEM and education faculty in joint efforts to improve the curriculum and pedagogy for preservice teachers are hampered by a historical and persistent mistrust between these groups. This division is evident in the way one respondent explained that TNE faculty in STEM departments use the TNE initiative as a "way to give cover to someone in Arts and Sciences to work on education." Most respondents in the COE observed that throughout their academic careers they have regularly been treated as sub-par, mostly because education is viewed as a "soft" and "applied" science. On the other hand, several respondents stated that the division between the two colleges was not as bad at CSUN as at their previous institutions, where STEM faculty rarely interacted with education faculty. The existence of several intercollege collaborations, particularly for the liberal studies program, are testimony to the existence of a cohort of faculty from both colleges who have overcome this division.

Faculty disagree about the importance of content and pedagogy in preservice STEM courses (+/-). Respondents made clear that within certain departments there are major disagreements about the courses required to effectively train a K–12 teacher, and the approach that the university should take in designing and offering these courses. This issue is particularly touchy in math. For example, some STEM faculty have responded to the problem of declining mathematical performance by advocating an increase in the number of content courses required for preservice teachers, with a subsequent decrease in the number of methods courses. Furthermore, the selection of the appropriate content for preservice teachers is not a simple matter. Some respondents observed that a reliance on the core content courses as currently taught in STEM departments is a mistake, since research indicates that accumulating courses in a major does not automatically make someone a good teacher, and that the problem is that there is no "connection between the content preparation and the pedagogy." Because agreement on these matters is required before effective action can be taken, we assess this disagreement as exerting a negative effect on SCALE efforts.

Individual Sense-Making

This category of the ICF includes various IHE-related elements of an individual's sense-making process, including workload considerations, status, background and training, and personality.

Funding pressures and workload exert strong pressures on faculty time (+/-). As previously noted, demanding faculty and academic staff workloads present a major barrier to participation in a STEM education project such as SCALE. Faculty responsibilities also include research and publishing, teaching, advising, service, and miscellaneous duties including writing proposals. Thus most faculty and staff are unavailable to participate in STEM education reform activities, unless a person has a grant that can buy out teaching responsibilities, holds a position that requires participation in STEM education, or is extremely motivated. Most faculty respondents stated that while they struggle with their various professional responsibilities, invariably their top priority was ensuring that they were adequately prepared to teach. They conveyed that the primary factor motivating this decision is a personal commitment to high quality teaching. They also noted other factors such as explicit encouragement from the administration and the implicit pressure to adhere to the institutional culture of teaching. However, this desire is in constant tension with faculty's other responsibilities, particularly those pertaining to research and its implications for an individual's tenure and promotion prospects (see above). Thus workload demands are a critical interpretive frame used by CSUN personnel when assessing participation in STEM education activities. This said, faculty emphasized the importance of grants such as TNE (which reduces the teaching load), or SCALE (which provides stipends) as a factor that makes service activities possible for all faculty, regardless of seniority status.

Faculty status influences time management (+/-). Decisions about time management are a particularly important issue for junior faculty who are under pressure to "publish or perish." Respondents noted that junior faculty must focus on teaching first (in order to get through the day adequately), and then on research and publications. Once tenure is achieved, respondents observed that the balance of responsibilities may shift again, as faculty either focus entirely on their research to the detriment of their teaching, or become passionately engaged in teaching or service. The common theme here is that senior faculty with tenure have much more freedom to decide how they allocate their time and resources. It is also important to note that faculty who are not on the tenure-track generally experience other pressures. While they may remain extremely busy with teaching and research responsibilities, the pressures of tenure do not influence their decisions.

Various personal reasons motivate engagement in reform efforts (+). Respondents identified a variety of personal, political, and practical reasons for becoming involved in K–12 activities. Some faculty from both STEM and education field were former high school teachers and were predisposed to involvement in pre- and in-service activities. In addition, some of these faculty were directly engaged in K–12 education through their research or their teaching responsibilities in the secondary or elementary education programs. Several STEM faculty noted that they had a particularly innovative professor in their graduate training, which led to an intellectual curiosity about teaching and learning. In any case, respondents indicated that they became engaged in programs like SCALE for diverse personal reasons.

Intellectual curiosity and willingness to take risks (+). Willingness to learn and go outside of one's comfort zone emerged in interviews as an important element of personal disposition that affected willingness to engage in a K–20 education improvement activity. Among the reasons expressed for participating in SCALE and similar projects was personal desire to learn about a new topic (whether the K–12 curriculum or STEM pedagogical content knowledge), and to change departmental policies governing teacher education.

Practices

This category of the ICF includes factors pertaining to an individual's classroom instruction (e.g., planning and delivery) and task-based collaborative activities with both IHE and K–12 partners.

Some STEM faculty maintain a didactic approach to STEM instruction (-). Some respondents expressed the view that their approach to pedagogy is informed and influenced by their own pedagogical training, or lack thereof, and in many cases replicates the approach of their mentors. Many respondents observed that the traditional teaching model used in IHEs is the transmission of content, in which the instructor conveys a body of information, usually through a lecture, with the expectation that the students will absorb the information. Some respondents also noted the difficulty in adopting a more student-centered approach, given the need to cover a prescribed set of content in a given class. In light of research on learning, this factor has a negative effect on projects such as SCALE.

Some STEM faculty experiment with an inquiry-based approach (+). An extension of the presence of a STEM education cohort at CSUN is that some STEM faculty were conversant with or at least are sympathetic to pedagogical reform in math and science. Although these faculty vary in their relative levels of expertise with specific theories and methods for inquiry-based instruction, their reported teaching practices are a factor that is supportive of projects like SCALE. However, even for these faculty there is a stated need to balance the desire to employ techniques such as group work with the need to cover a certain amount of content in a short period of time.

Respondents report participation in interdisciplinary activities (+). Several respondents cited a cordial and active collaborative relationship between STEM and education faculty, particularly for liberal studies which has several active cross-college faculty committees that successfully design curriculum and develop programs. For example, an earth sciences faculty member teaches a biology course for the ITEP freshman cohort, and coordinates with an education faculty member who teaches a concurrent science education course that is required for the students. Together, the two courses are intended to fuse the disciplinary content with appropriate pedagogical methods.

However, respondents indicated that outside of the liberal studies program, STEM faculty have limited opportunities to participate substantively in preservice programs. This is especially the case for the single subject credential, where there is little to no collaboration between the two colleges. According to several respondents, this lack of collaboration is due not to overt hostility between the colleges, but rather to lack of a rationale to collaborate. Two exceptions are in the math department: the FYI math program, and the math education option for undergraduate math majors. For these programs, a cohort of math faculty works with math educators in the COE to revise courses, infusing pedagogy content knowledge into courses. For example, the university committee on educator preparation and the liberal studies committee both include members from departments across campus. Some respondents cited these committees as providing a unique vantage point on university happenings that is not available to other faculty.

Respondents report active participation in K–12/IHE collaborations (+). Respondents reported numerous collaborative activities between CSUN and local school districts, and noted that these support SCALE efforts. These activities include both structured and unstructured collaborations. Unstructured collaborations include informal faculty interactions with LAUSD schools, usually in the form of math or science outreach efforts. As described above, there are several examples of structured and long-term programs at CSUN that involve K–12 educators and/or students in one way or another. These programs, especially the teacher preparation programs in the COE, and professional development programs such as the CSP, are key elements of CSUN's reputation as an IHE that is intimately involved with the K–12 community. According to respondents, awareness of and identification with this reputation is widely shared by the faculty, and STEM faculty, who themselves are not engaged in K–12 activities but who are acutely aware of their institution's reputation and mission. We assess this factor as having a positive affect on efforts such as SCALE.

IV. Findings on the SCALE Intervention

This section presents a summative evaluation of SCALE activities at CSUN, consisting of descriptions of the activities from March 2005 to August 2007, observed outcomes of these activities, and analyses of the longer-term consequences of each intervention. We summarize the project's background, goals, activities, and outcomes and discuss the influence of the institutional context on SCALE. This discussion more realistically links project outcomes with contextual factors, thereby avoiding the problem of presenting outcomes as if they function in an institutional vacuum, independent of their context (Anderson & Helms, 2001).

At the time of the SCALE intervention, there were at least three other educational reforms efforts underway : the provost's LCU initiative, the TNE initiative, and the CSP. Since many SCALE participants were also involved in these other projects, it is difficult, if not impossible, to isolate the specific effects of SCALE on these individuals. Similarly, since each project was exerting pressure on various aspects of the institutional context of CSUN, it is challenging to identify where the effects of SCALE begin and of other programs end. As a result, some of the findings described in this section may be the result of any combination of these initiatives. In other cases, however, it is possible to link a specific program to a specific outcome, and in these instances the relationship is clearly identified.

Background

This section includes a brief discussion of the local precedents and the theory of change for the SCALE project.

Origins of SCALE and Local Precedents

When it began in 2003, the organizations partnering within SCALE were UW-Madison, the University of Pittsburgh, and four urban school districts (Denver Public Schools, Los Angeles Unified School District, Madison Metropolitan School District, and Providence Public Schools). CSUDH became a partner early in 2004. In the fall of 2004, a CSUDH math faculty member who was active in SCALE met with both a math and a science faculty member at CSUN to explore the prospect of SCALE activities at CSUN. CSUN's active involvement in SCALE began in spring 2005 as faculty began designing professional development institutes for K–12 teachers.

As with many STEM education reforms, the SCALE project at CSUN built upon previous efforts that had cultivated an experienced and motivated cohort of personnel, and established the procedural groundwork for future initiatives. As noted above, the LCU, TNE, and the CSP were particularly influential in these regards. In fact, a SCALE participant noted that she had been approached by a colleague at CSUDH, who was actively involved in SCALE, because of her previous experience with the CSP and other STEM education initiatives. Thus, without these previously existing and extant reform efforts, it is unlikely that CSUN would have been brought into the SCALE project in the first place. Once introduced, SCALE was brought into the orbit of a community of STEM and education faculty who were already active in the CSP and TNE initiatives. These faculty became part of a larger cohort of CSUDH and CSUN faculty who were guided by of the SCALE leaders from UW-Madison and CSUDH. Apart from the CSUN provost, who had an advisory role in SCALE, no CSUN people helped to lead the SCALE project, in contrast to the other two IHEs (UW-Madison and CSUDH) included in the IHE case studies line of work. The significance of this leadership dynamic and its role in how SCALE was designed, implemented, and perceived at CSUN should not be underestimated.

Furthermore, the SCALE project at CSUDH is closely aligned with the Quality Educator Development (QED) project (funded by the U.S. Department of Education's Teacher Quality Enhancement Project), so that both SCALE and QED collaborated to design and implement these institutes at CSUN and elsewhere in the Los Angeles basin. Thus, it is necessary to take into account not only other CSUN-based reforms when evaluating the SCALE project, but also a CSUDH-based reform initiative that, in effect, served as the local conduit through which SCALE activities occurred.

Theories of IHE Change

SCALE is a systemic reform initiative that involves IHEs and K–12 partners to improve math and science teaching and learning through the entire educational spectrum. The SCALE theory of change posits that to achieve lasting improvements in K–12 STEM education, the entire continuum of teacher training and professional development must be improved, with particular attention to improving the role IHE faculty play in designing and implementing preservice curricula and in-service programs. The SCALE theory of change is based on a systemic understanding of the educational systems that inform and support K–20 math and science education. *The SCALE theory of change pertaining to IHEs* holds that, if improvements in IHE participation in teacher preparation and professional development are to be sustainable and significant, then it is necessary that:

1. STEM faculty improve their approaches to teaching and learning;

2. STEM and education faculty collaborate effectively to improve teacher preparation; and,

3. Leaders at different levels of the institution work to overcome the conservative nature of the IHE by supporting faculty participation in teacher preparation.

It also is important to consider the *broader theory* of change held by IHE actors, including SCALE leaders at UW-Madison and CSUDH. Their implicit theory of change was based on insiders' understanding of the complex and loosely coupled properties of IHEs, and was focused on "planting small seeds of change at points in the system deemed most likely to eventually yield large changes, and do so by building on and collaborating with other change initiatives that complement SCALE goals, and by identifying and working with individuals already interested in these goals" (Hora & Millar, 2008).

This approach is known as the "campaign approach to change," which involves mobilizing people around a strategic theme that has staying power at a particular institution (Hirschorn & May, 2000). A key strength of this approach is that the main actors are able to identify strategic opportunities for leveraging resources. These may include combining resources with other change efforts or institutions to achieve like goals, or seizing an opportunity, such as the appointment of a sympathetic new departmental chair or dean, to promote a reform agenda. This approach also entails a key challenge, which is that leaders must have a deep understanding of the institutions involved. Another challenge is that leaders may find it difficult to know if and when a project is meeting its own criteria for success because goals, objectives, and strategies are not clearly stated prior to implementation.

In contrast to UW-Madison and CSUDH, the campaign approach to change was not used to implement SCALE at CSUN; there were no CSUN leaders within SCALE, and the UW-Madison and CSUDH leaders did not have deep local expert knowledge of CSUN. Having neither a CSUN-based leader nor a theory of change specific to CSUN, SCALE, in effect planted its interventions at CSUN. In effect, at CSUN, UW-Madison and CSUDH SCALE leaders used an approach to institutional change designed for UW and CSUDH. Because it was CSUN faculty who implemented this work, the operative theory of change at CSUN was less that of SCALE's and more that of the LCU, TNE, and CSP projects and their implementers.

Evaluation Criteria

This section includes a brief discussion of the criteria used to determine program outcomes. Evaluators are increasingly recognizing that interventions in complex environments such as education, public health, and research management often result in a variety of outcomes beyond those originally envisioned by the program designers (Patton, 2006). Researchers argue that a mechanistic worldview of evaluation, as embodied in the commonly used linear logic model, will "fail to identify many of the most important results of these processes" (Connick & Innes, 2001, p. 1). Accordingly, instead of focusing only on the outcomes as delineated by program designers at the outset of an intervention, evaluators need to view the context of the intervention as a complex system, in order to identify a wide array of possible outcomes (Patton, 2006). This more context-sensitive approach was necessary due to the lack of measurable objectives provided by SCALE leaders. It is also important to note formulating traditional evaluation measures (e.g., measurable objectives) does not require use of a linear logic model approach. However, the decision to formulate measurable objectives would strengthen context-sensitive evaluation designs that account for context, culture, and cognition.

Using this approach, we found there is little precedent in the evaluation literature for categorizing types of outcomes that may result from an intervention in a complex environment such as CSUN. Lacking precedent, we chose to organize program outcomes according to their location in the ICF framework. In addition, we organized outcomes in terms of:

1. First-order outcomes, which were those that program implementers articulated and anticipated, and

2. Second-order outcomes, which were those that program implementers did not anticipate.

Changes to the institutional context most often emerge as second-order outcomes. Evidence for both types of outcomes is based on second-party evaluations, documentary evidence, or reports of changes by at least three respondents. In cases where only one or two respondents consider a particular change to instructional practice or behavior important, these changes are reported and the number of respondents claiming the change is specified. It is interesting to note that most of the first order changes appear in the external influences, internal structure, and practices categories, while most of the second order changes appear in the resources, pervasive values, and individual sense-making categories.

SCALE Activities: March 2005 to August 2007

SCALE activities at CSUN have centered exclusively on summer professional development institutes for LAUSD K–12 teachers in math and science. During the period from March 2005 to August 2007, SCALE implemented the activities described here in detail. When outcomes of each activity are presented, we indicate the relevant category within the ICF with an italicized phrase. The first and second order outcomes, organized by the ICF categories, are summarized in Figure 2. Finally, since SCALE activities in southern California were conducted in close collaboration with the QED project (based at CSUDH), the following section refers to the projects jointly as SCALE/QED.

Science Institutes

Background. One of the primary goals of the SCALE project was to develop high-quality professional development for K–12 teachers in the form of immersion units (SCALE, 2003). 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 (4 weeks), focusing intensely on a particular concept or big idea in the content area (Lauffer, 2004). Each immersion unit provides a coherent series of lessons designed to guide students in developing deep conceptual understanding that is aligned with key science concepts and the essential features of classroom inquiry specified in the state standards of the district for which each is designed.

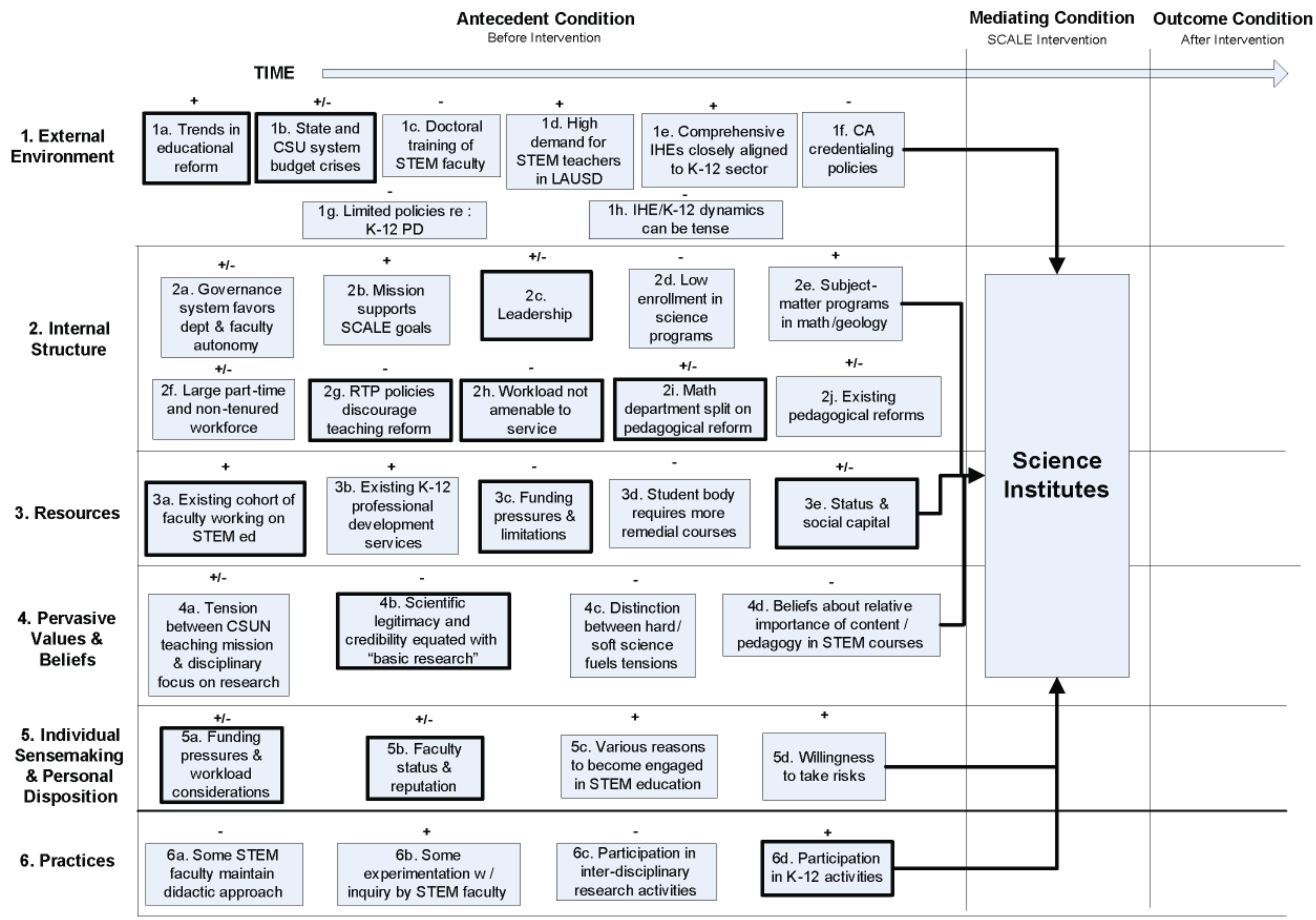

Figure 2. **Contextual factors related to the Science Institute activity.**

In each unit, students learn 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. The immersion units were delivered to K–12 teachers through an intensive weeklong professional development session that took place during the summer break.

Goals and objectives. In the original SCALE proposal, the overarching goal for the science immersion units was to "(D)evelop and implement immersion STEM learning experiences to ensure that every student in our partner districts experiences the process of engagement in an extended (e.g., 4-week) scientific investigation at least once a year (SCALE, 2003)." The specific benchmarks for this goal included developing and piloting immersion projects at different grade levels, developing professional development materials for unit implementation, conducting professional development sessions across the partnering K–12 districts, and facilitating the institutionalization of the units into district curricula. However, there were no measurable objectives assigned to these benchmarks for this activity. [3] Further, while CSUN respondents clearly articulated the larger science institute goals for IHE participation and outcomes, they were less specific about the objectives and strategies for achieving those goals. SCALE leaders indicated that these larger goals for IHE faculty inclusion are:

1. To have STEM faculty ensure that content is accurate, and to have education faculty ensure that the pedagogical methods are accurate;

2. To engage all IHE faculty as learners and to impart a new understanding, appreciation, and experience with inquiry-based instructional methods; and

3. To develop local capacity for professional development by "training the trainers."

However, absent measurable objectives related to IHE participation and outcomes pertaining to the science immersion unit activities, it is very difficult to assess if and how SCALE achieved its goals in this area. As noted above, were we using a linear logic model to evaluate the program, and focusing only on the outcomes formulated by the program designers, this situation would pose a problem. Because we instead are using a context-sensitive approach, we scanned a wide array of data on SCALE activities, including descriptions of the project's implementation and participant data to identify outcomes, ranging from those specifically attributable to the program to changes in institutional context.

How the institutional context influenced the activity. The science institute activity was influenced by the institutional context of CSUN in several ways (see Figure 2). These are described below and referenced according to their location in the ICF. We note that, on the one hand, CSUN participants can be thought of as operating as independent agents in this activity, as they did not officially represent CSUN or their departments. On the other hand, because they brought to the science institutes perspectives that had been indelibly shaped by their experiences and positions at CSUN, and their participation in SCALE was shaped, in part, by the structural features of their positions at CSUN, we view them in the context of CSUN. It is important to

[3] An evaluation of the QED project that focused on activities at CSUDH may have articulated measurable objectives for the science institutes.

note that some factors have a cascading effect, such as national trends in educational reform (1a in Figure 2) leading to local pedagogical reforms (2j), which in turn cultivated a cohort of STEM educators at CSUN (3a). By linking the most immediately visible factors back to their origins, it becomes possible to identify which factors exert influences on discrete projects such as SCALE, and thus more accurately trace the precise nature of how complex systems interact.

- *Prior to SCALE.* A first effect of the context on SCALE was the demanding workload (2h) which, combined with the academic calendar at CSUN, resulted in a limited pool of potential participants in the SCALE initiative. Many faculty respondents indicated that summer was the best time for them to conduct research activities, which some viewed as their core activity (2g, 4b). In addition, research productivity is highly valued and encouraged at CSUN as it brings in valuable external funding in a time of budgetary crisis (1b, 3c), elevates the prestige of individual faculty, their departments, and the entire university, and is an explicit goal of some CSUN administrators (2c, 3e, 5b). As a result, some faculty indicated that it was not feasible or desirable to commit to an entire week of SCALE activities (5a). A second influence of the institutional context on SCALE somewhat mitigated the first. A pre-existing cohort of STEM and education faculty who had been engaged in K–12 PD activities provided a ready-made pool of potential facilitators for the science institutes (1a, 2j, 3a). These faculty had been involved in CSP and other long-standing activities for several years, and were viewed by many respondents as an easily identified cohort of STEM educators. A third influence was the prior experiences of these individuals, which deeply shaped their expectations and skill sets regarding K–12 PD and were thus introduced into the science institutes. For example, some STEM faculty participants had been had been engaged by the CSP primarily as a content expert in their field, and thus expected to participate in SCALE in the same fashion (6d).

- *During SCALE.* The science institutes at CSUN were *peripherally* influenced by two contextual factors during the project's implementation phase. First, the demanding workload continued to exert an influence on the faculty participants (2h). While they had successfully cleared or re-arranged their schedules to participate in the institutes, some still felt pressure from their other current or pending work obligations. While neither a surprise nor a situation unique to CSUN, this bears highlighting as an important backdrop for faculty as they engage in reform initiative such as SCALE.

  Second, other reform initiatives were simultaneously occurring at CSUN during the science institutes, including the provost's LCU initiative, TNE, and the CSP (2j). While none of the initiatives were directly involved in the science institutes, each shared the support of the CSUN administration and to a certain degree, the aforementioned cohort of STEM and education faculty cohorts on campus. Thus, each activity had the potential to influence the other in myriad ways, including the diffusion of new ideas and the unintended consequences of one initiative's activities spilling over into another (e.g., newly developed relationships or frustration with reform efforts).

Activities. The activities related to the science institutes include the design of the immersion units, and then the actual summer institutes. This section includes a brief description of both sets of activities.

- *Institute design process.* The immersion unit design process involved interinstitutional teams who collaboratively developed grade-specific science immersion units, each of which were designed to address LAUSD science standards. During 2004-05, UW staff and other SCALE leaders intended to bring the CSU STEM and education faculty plus LAUSD science experts together to collaboratively design a high-quality unit, with the focus on K–12 teacher learning and instructional improvements. As a result of working on immersion units and modeling active learning pedagogies, UW staff and SCALE leaders soon realized that they could also use this immersion in-service project as an opportunity to help STEM and education faculty improve their own approach to undergraduate teaching.

  > What happened was that as we were developing the immersion units, [one UW 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)

  As a result, the UW staff and SCALE leaders began to more explicitly develop the design process to engage all participants, including IHE faculty, as learners and practitioners. A key mechanism for incorporating faculty professional development into the design of the immersion units during 2005-06 was the leadership study group, which was comprised of representatives from UW, 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. By asking the leadership study group members to learn how to model the active-learning pedagogy embedded within the immersion units, SCALE institute leaders enabled a more intentionally professional development experience for the CSU faculty and LAUSD teachers. This experience included learning both core elements of subject specific pedagogical content knowledge and tricks of education, including classroom management.

  UW-Madison staff at WCER, CSUDH and CSUN STEM and education faculty, and LAUSD science experts and teachers collaborated to develop immersion units for the following four grades:

  - Fourth Grade: Rot it Right
  - Sixth Grade: Plate Tectonics
  - Seventh Grade: Variation and Natural Selection
  - Eighth Grade: Density and Buoyancy

- *Institute activities and participants.* UW staff in collaboration with CSUN and CSUDH STEM and education faculty, and LAUSD science coordinators and teachers, co-facilitated five science institutes in 2006, and eight science institutes in 2007. Each institute was a 5-day workshop. For the 2006 institutes 108 LAUSD teachers participated. Facilitators included nine LAUSD science experts or teachers, one CSUDH physics faculty, one CSUDH education faculty, two CSUN education faculty, one CSUN geology faculty, and two CSUN biology faculty. For the 2007 institutes, 162 LAUSD teachers participated. Data were not available for the affiliation of the 27 facilitators for the 2007 institutes.

Outcomes: First-order. The first-order outcomes for this SCALE activity, and the category in which they are positioned in the ICF framework (see Figure 2), are as follows:

- *SCALE provided professional development workshops to LAUSD teachers (1d, 1g).* In accordance with the primary goal of this activity, SCALE provided high-quality professional development workshops to 270 LAUSD science teachers.[4]

- *SCALE engaged IHE faculty as learners (1c, 2j, 6d).* As previously noted, UW staff had hoped that by asking the leadership study group members to learn how to model the active-learning pedagogy embedded within the immersion units, the study group members would experience professional development themselves. This included learning core elements of subject-specific pedagogical content knowledge and tricks of education including classroom management. Several respondents reported that in their previous K–12 professional development experiences, they had been given only the role of content expert, which they performed in public lectures, study groups, or workshops. Faculty who participated in the SCALE math and science institutes, particularly the members of the leadership study group, reported a vastly different experience. In fact, several faculty reported that they had to shift from their accustomed role of the content expert to a new role as a student of learning theory and inquiry-based pedagogies.

  > I think I've gone from kind of the official content contact person to now working more with the philosophy of the immersion unit. So instead of automatically giving them [K–12 participants] an answer, I'm writing that on the left hand side of my notebook so that [I can identify] if some of the content questions are out of sequence for what we're doing in the immersion unit. I write those down and save those questions so that when we come to a content piece or an activity that is more relevant to the question, then I can bring the question back and discuss it in terms of what our content activity is that time. [I learned that] through all of the facilitation practice and the PD development. (STEM faculty)

  This educational experience provided some STEM faculty participants the pedagogical training that they did not receive as doctoral students. Interestingly, this change was not limited to STEM faculty, as an education faculty participant also reported a shift in how they participated in PD.

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[4] See Osthoff, E. SCALE Grade 6 Plate Tectonics science immersion units and professional development institutes: Design, delivery, and teacher experience. Also, other reports in this series include: Classroom observations of enacted immersion lessons in Grade 6 LAUSD classrooms: Impacts of an inquiry approach on lesson structure, student engagement, cognitive demand, and student involvement, Teacher Reflections on first-time enactment of the SCALE Grade 6 Plate Tectonics immersion unit: Supports, challenges, and effects on classroom instruction and student learning experience, SCALE Plate Tectonics Plate Tectonics science immersion unit implementation: Effects on instructional content in Grade 6 LAUSD classrooms, and Effects of implementation of the SCALE Plate Tectonics science immersion unit in LAUSD classrooms on student achievement on district assessments and student work on extended tasks.

> I had a tendency in professional development to kind of pop in to the learner-teacher mode so I have to be very disciplined in terms of following the model that's been developed. (COE faculty)

- *SCALE is giving faculty pedagogical tools to use in their own classes (2j, 6a, 6b).* Based on self-report, SCALE is influencing individual faculty instructional practices through participation in the institutes. Yet without classroom observations or further investigation, it is impossible to assess the veracity of these self-reported changes, or the nature of any changes. However, it is clear that through participation in the math and science institutes, CSUN faculty are learning new pedagogical methods and tools that may be transferred to their instructional practices at CSUN. In some cases, this has meant specific pedagogical methods. For example, one faculty member used several of the problems from math institute, and also gained "well-grounded expectations" about how well students should be able to do, and a new confidence in leaving students to do more mathematical work like explaining and organizing solutions. For that faculty member, the experience amounted to "evolution, not revolution," since he had been previously exposed to inquiry-based methods in math education. One life sciences faculty who had used the Fast Plants program in the past was considering adding an inquiry-based exercise, and hadn't thought to do so until participating in the science institutes. In another case, UW staff noted that CSUN faculty reported using methods learned in the institutes.

> He was telling me that, "I used a think-pair-share in my class today." I said "Oh yeah, on what?" And he said, "Well, it doesn't matter on what, I used it, this is my first time, and it was great, they loved it. They were talking to each other and it was great." So it was kind of groundbreaking for him and that was before he'd even facilitated an institute. I mean that was just from what he'd learned from reading the immersion unit and talking with us and planning. (UW staff)

This direct transfer of institute-based methods to the CSUN classroom was corroborated by other faculty respondents. In other cases, institute participation has given CSUN faculty a new understanding of pedagogy. One respondent noted that the emphasis in the institutes on being transparent has helped her to become a better educator by encouraging her to examine pedagogy from multiple perspectives. Another respondent stated that the readings about pedagogical content knowledge spurred changes to pedagogical methods employed in IHE courses. In several cases, faculty reported that the institutional pressure to improve teaching practices, via the LCU initiative, helped make faculty more attuned to the potential applicability of new methods to their own courses. Faculty also noted that tools gained through immersion units directly address the mandate for student learning outcomes by the CSUN administration.

> [I have used] some of the assessment ideas to see if my students are actually beginning to take ownership of what I'm talking about during a lecture. That's something that I hadn't done in the past. I've been teaching for a while now and other than quizzes or exams, these assessments are very, very simple to determine understanding. It's an easy way for me to check where I am, where they are, determine if my class, the majority of my class, understands key concepts that we're talking about. (STEM Faculty)

Outcomes: Second-order. The second-order outcomes for this SCALE activity, and the category in which they are positioned in the ICF framework (see Figure 2), are as follows:

- *SCALE is influencing other reform initiatives (2j).* As previously noted, prior to SCALE there were other similar initiatives active at CSUN, including the CSP. Since the small cohort of STEM and education faculty who have been engaged in the CSP for several years were largely the same group who participated in SCALE, there was a natural opportunity for cross-fertilization of ideas and innovation. In fact, some respondents indicated that their experiences in SCALE were leading directly to changes in how the CSP was designed and implemented.

  > Another thing that's been interesting is that [CSP facilitators] have transferred the Deborah Ball model with the yellow and blue eggs into [the CSP], so we're carrying that beyond the SCALE immersion unit workshops. [Also] we're trying to use the [SCALE facilitation] model where we do have co-facilitation since most of us at CSUN have been involved with SCALE, so we've transferred that model into the [CSP]. (STEM faculty)

  In addition, respondents viewed SCALE and the CSP as being complementary initiatives, to the extent that K–12 participants were encouraged to enroll in both activities.

  > First of all we encourage our teachers to do both projects, that they are different so they can get value out of doing both. And we did have overlap the last two years. We've had teachers that did both programs. (STEM faculty)

- *Further expanding and training the STEM education cohort (3a).* An outcome related to the cross-fertilization among reform initiatives is the further growth and professional development of this small cohort of STEM and education faculty. SCALE contributed to the growth of this cohort by recruiting new faculty and instructors to become institute facilitators, including faculty from other IHEs (e.g., CSU Los Angeles, El Camino Community College). By bringing new people into this small cohort, SCALE played an important role in enlarging the professional resources available to this group, and increasing the likelihood for the cohort's future sustainability.

  In addition, by engaging this cohort in an intensive professional development experience of their own, SCALE infused new ideas and perspectives into this cohort. While some members of this cohort had been actively seeking out learning opportunities through other venues, the SCALE experience was described as a more concerted and intensive experience than others. Thus, SCALE was a vehicle for taking some members of this cohort to the next level in terms of their knowledge of inquiry-based teaching and learning, and provided them with concrete tools that could be easily adapted to their own courses.

- *SCALE represents a more intensive type of interaction with K–12 than previously experienced (1h, 6d).* According to faculty respondents, the design process for the SCALE institutes represented a new type of collaboration with K–12 personnel. Where previously STEM faculty provided content expertise for professional development or outreach programs, they now were forced to model a new pedagogical approach that merged content and pedagogy. Where previously education faculty had mentored preservice teachers or conducted research in K–12 venues, they too were placed into the unusual position of modeling a STEM-based active learning pedagogy. Another difference from previous professional development experiences that a respondent observed was close collaboration with LAUSD science experts, with IHE and K–12 staff interacting as equal partners in designing and facilitating the science institutes.

> One of the advantages to SCALE for me has been the fact that I'm actually working side by side with people from LA Unified central offices and science branch. And though they have always supported our programs, they have not witnessed what we do and we haven't witnessed what they do, and I think that this has been a very good PR move for us in some ways and for them, because we are now in communication. (STEM Faculty)

This outcome is notable, as fostering interinstitutional partnerships is a core goal of the MSP program. In this case, the new lines of communication represent an important professional resource for both the K–12 and IHE participants, similar to the previously mentioned networks that Dr. Oppenheimer had developed over the years with local K–12 districts. Since his networks had proven to be important resources for younger faculty, who took advantage of the goodwill and contacts he had developed, these new relationships may result in similar resources for future faculty.

Another effect of these new relationships is the slow chipping away of hierarchical stereotypes that sometimes inhibit K–12/HE collaborations.

> What happens in some of these cases is people [in K–12] look at you like "You're a doctor, [you're an expert]," and therefore they get defensive, thinking "Well, I don't need somebody with a PhD to tell me how to teach," Again, that's a cultural thing and some of that is brought on by the [reputation] that some professors have with others, which I kind of resent. [In SCALE], that's wiped out. In other words, we've now got to know each other well enough for them to realize that we're not coming in as higher ed faculty to tell you how to do it, we're coming in to share and collaborate with you. (STEM faculty)

Finally, this respondent also observed that this improved insight into "what's going on in actual classrooms" has influenced her own preservice teaching and involvement in other K–12 PD activities.

- *Some faculty participants are resistant to engagement with institutes (6a, 6d).* Systemic and individual barriers to successful adoption of improved instructional methods prevail at CSUN, despite the existence of an institutional mission that values teaching excellence, and extant reform initiatives like the LCU or TNE initiative. As a UW staff person noted, the first step in learning new methods of instruction requires people to be fully committed, and "present in mind and spirit." This respondent noted that some CSUN STEM and education faculty who participated in the science institutes were not particularly engaged with the co-facilitation process, and thus did not successfully learn how to model an active learning pedagogy for the K–12 teachers.

> During one institute, a faculty member was up at the front lecturing about inquiry. As I watched, it was clear that he just didn't get what we were doing here. As if what we were

> training LAUSD teachers on had nothing to do with him. He seemed to know everything, theory-wise, about education. He was like a living textbook, and he delivered his PD just like that. It was almost like there was no thought on his end that this work applies to him, too. (UW staff)

This respondent also emphasized the importance of self-reflection, where a learner is willing and able to assess the learner's own instruction and critique it effectively. Again, some faculty were more amenable to this critical aspect of pedagogical improvement than others, and those whom some respondents considered not self-reflective included both STEM and education faculty. Another respondent noted that one participant, a part-time faculty member, was not actively engaged in the facilitation of the workshops and did not even participate as a content expert. According to this respondent, the faculty member instead graded participant coursework and generally "faded into the background." The respondent also questioned why a part-time faculty member had been selected to participate if a goal of SCALE was to influence the STEM department itself. Furthermore, the respondent noted that the faculty member was known to be antagonistic to constructivist pedagogies, which raised additional questions about their selection.

SCALE/QED Math Institutes

Background. The other primary SCALE activity at CSUN was a series of professional development workshops for LAUSD math teachers (junior high and high school). While the math institutes should be viewed as a joint SCALE and QED effort, the institute's leaders and materials originally came from CSUDH's Mathematics Department's Center for Math and Science Education (CMSE). The CMSE has operated a CSUDH-based mathematics project for several years, for which faculty have designed and implemented mathematics professional development institutes for K–12 teachers.

Goals and objectives. The goals of the math institutes were 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 to better equip teachers to lead their students to a deeper understanding of mathematics. The advertisement for the institutes also notes that the designers hope to develop a core community of K–12 leaders to become resources for other educators. Furthermore, according to a respondent, a goal of the pre-algebra institute was to de-politicize math education by focusing more on the commonly held goal of improving student learning, and less on the ideological and/or political aspects of math curriculum.

How institutional context influenced the activity. The math institute activity was influenced by the institutional context of CSUN in several ways, which are described below and referenced according to their location in the ICF (see Figure 1).

- *Prior to SCALE.* First, the ideological schism that has long prevailed in the CSUN math department (2i) served as an important and unshakeable backdrop to the SCALE math institutes, and effectively limited the pool of potential facilitators. The department is split into two camps with divergent perspectives on math education, one of which is, and one of which is not sympathetic towards a constructivist approach to math education. Members of the former would be the most likely recruits to facilitate the SCALE institutes. Indeed, one COE respondent noted that this group is well known to most education faculty to the extent that they simply ignore those mathematicians who are antagonistic towards their efforts. Second, some members of this cohort were either tenured or close to retirement, which afforded them a certain degree of professional security and insulation from the critiques of their colleagues (3e, 5b). These faculty would also not be subjected to potential recriminations or retributions through venues such as RTP committees.

- *During SCALE.* The split in the math department played a direct role in the 2006 math institutes, as one of the facilitators proved to be somewhat antagonistic to the intent of math education reform in general, and the design of the math institutes in particular (2j). This particular facilitator had been selected by the department chair and not by the SCALE leaders from CSUDH or UW-Madison. Another factor influencing the math institutes was the TNE initiative, in which some math department faculty were already engaged prior to SCALE (2j). As a result of the simultaneous initiatives, information and ideas from one influenced the other.

Activities. In the summers of 2006 and 2007, SCALE sponsored math institutes for middle school (pre-algebra) and high school (algebra) teachers. According to respondents, the two math institutes were designed in slightly different ways. In 2006, the pre-algebra institute was largely modeled after a similar workshop used at CSUDH, while the algebra institute was loosely based on a CSUDH workshop but with significant modifications made by the facilitators. The institute design process for the algebra institute was described by one respondent as problematic, with insufficient time to work with co-facilitators, and minimal guidance regarding unit structure, sequencing of activities, and the actual content of the institute. In 2007, the facilitators had a 4-day training led by CSUDH personnel, which included analyses of videotaped PD sessions. Respondents noted that this training, combined with more time for planning and experience from the previous year, led to a more satisfactory and coherent series of workshops.

The SCALE/QED mathematics institute strategies are to use an inquiry-based methodology while focusing on the LAUSD mathematics curricula and instructional guides. During each of these 120-hour institutes, the teachers work with materials specially selected to increase the algebraic thinking and problem solving capacities of the teachers in order to help them develop their own mathematical explanation structures. According to official advertisements, these institutes included unit development and lesson planning, discussions of current research addressing English language development (ELD) and math issues, and explorations of assessment methods that could inform instructional practice.

Cross-institutional teams including CSUN STEM faculty, MMSD personnel, and LAUSD personnel then co-facilitated 15-day math institutes (2 in 2006, 2 in 2007) for a total of 83 LAUSD teacher participants.

Outcomes: First-order. The first-order outcomes for this SCALE activity, and the category in which they are positioned in the ICF framework, are as follows:

- *SCALE provided professional development workshops to LAUSD teachers (1d, 1g).* In accordance with the primary goal of this activity, SCALE provided professional development workshops to 83 LAUSD math teachers. Available evaluation data did not address the effects of the workshops on participant knowledge gains or other similar outcomes.

Outcomes: Second-order. The second-order outcomes for this SCALE activity, and the category in which they are positioned in the ICF framework, are as follows:

- *SCALE complemented the efforts of other reform initiatives (2j).* As previously noted, prior to SCALE there were other similar initiatives active at CSUN, including TNE. Since the small cohort of STEM and education faculty who have been engaged in TNE were largely the same group who participated in SCALE, there was a natural opportunity for cross-fertilization of ideas and innovation. In fact, some respondents viewed their dual participation in SCALE and TNE as complementary.

> I don't think I can separate [the effects of SCALE or TNE]. I think that this is sort of an ongoing sort of professional evolution for me. TNE's focus is what we do here in the university, while SCALE is much more about trying to connect with teachers and influence in-service [training]. So why neglect one or the other? It seems clearly the case that both are interesting. (STEM faculty)

- *SCALE helped to expand and train the cohort of math educators (3a).* An unanticipated outcome related to the math institutes was the further growth and professional development of the small cohort of math educators in the math department. SCALE contributed in a small way to the growth of this cohort by recruiting a junior faculty and an adjunct faculty member to become institute facilitators. However, as previously noted, one of these facilitators was generally not supportive of the rationale behind the institutes, and reportedly had an unsatisfactory experience. In addition, by engaging this cohort in an intensive professional development experience of their own, SCALE infused new ideas and perspectives into this cohort. While some members of this cohort had been actively seeking out learning opportunities through other venues, such as TNE, the SCALE experience provided an opportunity for faculty to test out new ideas and integrate their knowledge regarding active learning strategies and student assessment.

> One of the cornerstones of the SCALE grant is getting teachers to do things like unit planning that will help encourage them to include what they've learned in their own teaching. [In 2006], we recognized the importance of it but I think we felt somewhat unfamiliar with and unconnected with the various forms and materials that they [CSUDH faculty] were using. So this year [2007] we tried to do it ourselves and we did something that I think was successful in various ways. We looked through the math instructional guides and chose concept units, and particular topics that are in the focal points issued by the NCTM and tried to have teachers refashion these units, build plans that would sort of lead them to go through these units in a more reflective way. And so a lot of our institute was based on problem-solving and explanation (STEM faculty).

Thus, SCALE was a vehicle for taking some members of this cohort to the next level in terms of their knowledge of inquiry-based teaching and learning, and provided them with concrete tools that could be easily adapted to their own courses.

- *SCALE became involved in the math department schism (2i).* One unanticipated SCALE outcome was involvement in the math department schism. In 2007, Dr. David Klein, a member of the department who has a national reputation as a strong opponent of NSF-funded math education reforms, wrote a letter to the editor of the *American Journal of Physics* critiquing the SCALE project. The principal investigator (PI) of SCALE wrote a response that was published, and as a result, the SCALE project became actively involved in the math department schism.

V. Exploring How Culture Mediates and Influences STEM Education Reform

As previously noted, some pervasive values and beliefs at CSUN posed a significant challenge to affecting the types of institutional and pedagogical changes envisioned by the SCALE project. As a result, we now turn to a detailed analysis of how cultural factors mediate and influence STEM education reform. By taking this fine-grained approach to studying culture, we hope to articulate the specific content and processes comprising cultural dynamics at CSUN, as opposed to relying on generalizations about the institution's culture. In this section, we analyze the mental model of one CSUN faculty, how it is situated in the institutional context of CSUN, if and how STEM education reforms interacted with the mental model, and effects of STEM education reforms, if any, on the mental model.

Using a Distributed Theory of Cultural Analysis From Cognitive Anthropology

Background

This focus on sense-making is inspired by research on reform implementation in both higher education and K–12, which has found that policy directives are frequently adapted and transformed by individual agents at the local school or IHE level. The process of interpreting policy interventions and adapting them to one's own local situation is sometimes called sense-making, where institutional actors "make sense" of their environment and select appropriate actions (Birnbaum, 1988). Increasingly, researchers are recognizing the importance of this process and of how local contextual factors such as organizational structure and leadership shape the sense-making process (Coburn, 2001; Spillane, Reiser, & Reimer, 2002). These issues are important due to the oft-cited slow rate of change in IHEs and the poor fidelity of policy interventions to the undergraduate STEM classroom. A focus on instructor sense-making is an important departure from the popular view that external pressures (e.g., MSP program) are de-coupled from the classroom, which operates in an autonomous vacuum immune from these exogenous forces (Coburn, 2001). Instead, as we have seen, forces such as doctoral training programs at research universities are introduced into a new institutional context, where they are in turn subjected to local conditions and reinforced, rejected, or assimilated.

Of particular interest to sense-making theorists and STEM education reformers is the role that the constellation of pervasive values and behavioral norms collectively held by groups within an institution (commonly known as institutional or organizational culture) plays in shaping individuals' sense-making processes, and ultimately, their behaviors and interpersonal relationships (Becher & Trowler, 2004; Van Maanen & Barley, 1984). If it is true that values, beliefs, and tacit assumptions play an important role in reform implementation, then it is extremely important to understand precisely *how* culture manifests during the implementation process, and if it influences the observed outcomes of the reform. Further, as this case study demonstrates, pervasive values and beliefs do not exist in a vacuum within organizations, but instead are shaped and influenced by the technical and social constraints of the institutional context. Thus, a cultural account of the implementation process must also attend to the recursive relationship between culture and the institutional context.

The challenge of empirically situating individual sense-making into complex institutional and cultural contexts is inadequately met by the dominant approach to understanding and analyzing organizational culture, which produces static and homogenous sets of vaguely defined values, beliefs, or artifacts (Bate, 1997; Van Maanen & Barley, 1984; Knight & Trowler, 2000). In particular, many studies fail to address the degree to which group members adhere (or not) to the dominant knowledge in their organization (Ross, 2004). Moreover, some studies of organizations ignore the role of time in cultural process, thereby obscuring the origins and evolution of commonly held beliefs and values and, ultimately, our understanding of the actual processes of cultural change within organizations (Hudelson, 1997).

Complicating the methodological challenges of measuring the sense-making process and its contextual determinants is the interdisciplinary nature of the topic, and the subsequent panoply of theories, methods, and analytic procedures currently in use. For example, researchers are addressing this topic by studying decision-making processes (Coburn, 2005), causal mapping (Shavelson, Ruiz-Primo, & Wiley, 2005), organizational learning (Akgun, Lynn, & Byrne, 2003), and mental model composition (Webber, Chen, Payne, Marsh, & Zaccaro, 2000). For the purposes of this study, we have drawn on cognitive anthropology to develop an approach to study the roles that culture, context, and cognition (i.e., our interpretation of sense-making) played in the implementation and ultimate outcomes of the SCALE project at CSUN.[5]

A New Approach: Situated Mental Models Theory

In contrast to a commonly used theory of culture that seeks to establish a unitary and stable set of cultural norms for a specific group of people (e.g., the math department), we employ here a *distributed* theory of culture. This approach accounts for cultural phenomenon at the group and the individual levels by conceptualizing culture as knowledge and practice that is distributed across and within groups, and is also internalized by individual members of a group (Shore, 1996; Atran, Medin, & Ross, 2005). Furthermore, according to this approach culture is not simply the aggregate of individual cognition, but is comprised of the constellation of knowledge and beliefs held by group members that is also reified, reinforced, and reproduced by social action and instantiated in artifacts and other cultural forms (Shore, 1996). In this way,

[5] In the future, we will thoroughly review these various literatures to ensure that the most appropriate and valid methods are used to study STEM education reforms.

some cognitive anthropologists are striving to maintain a dual focus on the importance of the individual and the presence of a group-level culture (Quinn, 2005).

The idea that an individual's cognitive processes shape how information (e.g., visual or aural stimuli) is processed and interpreted is an old concept in psychology and the cognitive sciences (Rumelhart, 1980; Schank & Abelson, 1977). Schema theory is one of the core ideas in cognitive psychology which posits that incoming information must be reduced in its specificity (e.g., color, context) and chunked into more simplified units that can be stored in short term memory. The schema that individuals internalize constitute "unconscious mental structures that underlie molar aspects of knowledge and skill" (Brewer, 1987, p. 188). As individuals internalize information and experiences from their physical and socio-cultural environment, or schematize them, they become deeply embedded in the cognitive processes of the brain through repetition, reinforcement, and attachment to key life events or emotions (Shore, 1996). In addition, schema tend to be domain-specific (e.g., plate tectonics) and may be attached to specific stimuli or environmental conditions.

Importantly, cognitive psychologists distinguish between schema as underlying knowledge structures, and their *episodic* representations, generally called mental models, which are formed in active engagement with environmental stimuli (Brewer, 1987).[6] These episodic representations are more complex "global knowledge structures constructed at the time of input" that may be comprised of various interlocking schema that collectively comprise the explanatory structures that actors use to filter (by omitting or transforming) environmental stimuli (Brewer, 1987, p. 189). Further, there are different types of mental models that serve different purposes for individuals as they interact with their technical, social, and cultural surroundings (Shore, 1996). For example, there are orientational (e.g., spatial models, social orientation models), diagnostic (e.g., checklists), conceptual (e.g., theories, classificatory models), and task models (e.g., scripts for specific task completion). As with individual schema, mental models may also become associated with specific stimuli or environmental conditions.

Some cognitive anthropologists also suggest that mental models are comprised of combinations of different types of schema (D'Andrade, 1995; Strauss & Quinn, 1998). Some schema can be considered cultural since they are internalized from instantiated cultural forms that are "part of the stock of shared cognitive resources of a community" such as the Star-Spangled Banner or tacit food habits pertaining to specific mealtimes and holidays (Shore, 1996, p. 47).[7] Thus, individual mental models are comprised of a variety of schema, some of which can be explicitly linked to instantiated cultural forms (e.g., rituals, artifacts) or socially sanctioned beliefs and practices for a specific group. In addition, cultural schema may be internalized differently by particular members of the group, and may be tacitly held and never actually surface in everyday interaction. It is also possible that an individual may internalize the cultural

[6] The use of the term "mental model" is ubiquitous and has been critiqued for its lack of conceptual clarity and definition, particularly in organizational science (Lakomski, 2002). The term is more precisely defined in cognitive psychology, especially in its relationship to schema. However, the construct still suffers due to lack of attention to variability, change, and distinctions between constituent schema that are idiosyncratic vs. internalized from cultural forms. We use the term here as a bridge to discussing different types of schema and the cultural model construct.

[7] It is important to note that by labeling a specific schema as "cultural," we am not implying that the mind does not mediate all historical, social, and cultural environments (Vygotsky, 1978; Wertsch, 1991).

schema from a variety of different groups of which they are members (e.g., church, department, family).

In organizational life, an individual's mental model and its constituent schema are imported into a new institution, and over time certain models may adapt to the unique policies, structures, social groups, and behavioral norms extant in a given organizational unit (Lakomski, 2001). Once situated into the environmental context of a workplace, these mental models are activated in response to environmental stimuli, such as a new syllabi or a policy intervention, such as the MSP program. However, mental models and schema are not immune to change or evolution, and may be altered in response to new information or shifts in the environmental context of the workplace. In addition, individual cognition and practice may create or reinforce core elements of this environmental context in a recursive relationship (Giddens, 1984). Researchers have long argued that over time multiple individuals with similar mental models can alter institutional structures and traditions (Clark, 1998).

As a result, mental models must be viewed as simultaneously situated within and influenced by the organizational context (organized in terms of the ICF in this study), and shaped by the individual's unique personal experiences and social position in that context. In sum, we believe that this approach—by accounting for how individuals variously interpret, internalize, and instantiate organizational values, attitudes and knowledge—enables evaluators and researchers to develop a more adequate understanding of organizational culture than an approach that presents knowledge as uniformly shared and distributed across a complex organization. We posit that this distributed approach to culture is particularly suitable for evaluating systemic reforms (like the ones that SCALE is attempting in higher education) for two reasons: (a) Faculty are particularly autonomous agents who exhibit high degrees of variability and independence and thus may hold cultural schema that are not evenly shared across their departments and other groups; and (b) SCALE is attempting to introduce into the environment new cultural schema that individual faculty may internalize in various ways. We hope this provides an approach to the study of organizational culture in IHEs that is more nuanced and empirically sound and thus of value to the STEM education community.

A Note on Measuring Situated Mental Models

The question of how mental models and their constituent parts are instantiated into an empirically observable form is a critical issue. For some researchers working in laboratory settings, schema or other aspects of cognition can be observed through experiments involving research subjects making causal judgments or comparing subjects' recall of critical events over time.[8] It is considered more challenging to observe cognitive processes in non-laboratory settings, as there are more variables to account for and thus less control over the stimuli affecting a research subject. Some researchers have focused on highly standardized workplace environments in order to analyze how the mental models required for completing a task, such as navigating a battleship, can be de-centralized among a group's members and how critical information can be embedded within artifacts (Hutchins, 1995). However, for researchers interested in cognitive processes in non-standardized environments where cognitive processes

[8] These are only two selected examples of lab-based research on cognition.

may not be easily instantiated or embedded in physical form, the role of discourse and narrative plays an important role (Quinn, 2005). This is a critical issue for researchers in management, education, and industry who wish to understand how cognitive processes unfold in complex environments (Lakomski, 2002).

Researchers seeking to empirically observe cognitive processes commonly analyze dialogue in interview transcripts (Brewer, 1987; Quinn, 2005). In addition, sense-making theorists have long used structured interviews to elicit respondents' decision making and interpretive processes (Dervin, 1998). In the field of cultural anthropology, researchers have been using surveys (e.g., paired comparison, freelist), participant observation, and in-depth interviews to explore the cultural components of individual sense-making and knowledge (Atran, Medin & Ross, 2005; Quinn, 2005). As our data for this evaluation were limited to interviews, we chose to work within the interpretive tradition of Strauss and Quinn (1998) that uses natural discourse to identify the cultural aspects of individual cognition.

For this research, we have focused on individuals' statements of fact (e.g., tacit assumptions), values, or beliefs about STEM education reform as evidence for the schema that comprise their mental models. Individual schema were considered cultural only if they met two criterion: (a) the schema was expressed by at least three individuals within a specific social group at CSUN (e.g., entire university population, college, department), and (b) the schema was explicitly linked to this specific social group by at least one respondent and/or observation-based evidence. As a result, this study does not attempt to present an account of the culture of an entire organization or even its administrative sub-units, but instead presents the pervasive cultural schema held by group members in a specific domain under consideration.

We then build on and extend this approach to cultural model analysis by explicitly linking mental models and cultural schema to specific factors in the local institutional context, and by attempting to develop knowledge that can guide local program planners and policymakers. This is done by drawing on the causal network analysis method, which is "an abstracted, inferential picture organizing field study in a coherent way" (Miles & Huberman, 1994, p. 153). The relationships between individual schema and contextual factors were either explicitly stated by respondents, or formulated through analytic inference. In addition, we draw on the theoretical perspective of Bourdieu (1977) in order to interpret the relationship among individual disposition (i.e., habitus), capital, and the organizational field (i.e., the institutional context(s). *We strongly emphasize that this is an exploratory effort to identify situated mental models, undertaken in order to improve the understanding of the role of culture and the institutional context in STEM education.*[9] (See the Appendix, for more details.)

[9] Future research should be undertaken to build upon this exploratory effort. This research may involve the additional use of methods developed specifically for identifying agreement, such as freelisting and cultural consensus analysis, For the analyses presented here, we identified cultural models using data from two code categories in the ICF: collective values, where respondents were prompted to speak about their group's tacit assumptions, and individual sense-making, where respondents expressed personal perspectives.

Analyzing Situated Mental Models in Action

In this section, we describe the situated mental model of a CSUN faculty member prior to the SCALE project, how the model interacted with STEM education reforms, and its composition at the conclusion of SCALE. The faculty member is in a STEM department, and did not participate in SCALE. The analysis focuses on the following points:

1. The cultural schema for STEM education reform at CSUN, based on the pervasive values identified earlier in this evaluation;

2. The primary contextual factors that shape individual mental models and impinge upon the sense-making process; and

3. The mental models (and salient contextual factors) of the faculty prior to, during, and after the SCALE intervention.

For this analysis, the pervasive values and individual sense-making processes of interest are limited to the domain of STEM education reform, which at CSUN includes not only SCALE but also the LCU, TNE, and CSP initiatives. The presence of multiple reform initiatives was an unpredictable boon for this research, as they laid the cognitive groundwork in advance such that individuals interpreted the SCALE project through existing mental models that had been developed over time. Many CSUN faculty have had ample opportunities to form opinions and solidify perspectives about reform, and thus did not create interpretive frameworks "on the fly." Thus, CSUN faculty generally exhibited a well-formulated set of schema, and were sufficiently self-reflective about their sense-making processes that we did not have to dig very deeply for these data during the interview process.

The Cultural Schema Pertaining to STEM Education Reform at CSUN

As previously noted, during the evaluation of the SCALE project we identified four pervasive values and beliefs pertaining to STEM education reform. These values and beliefs were expressed by individuals in a variety of administrative units, disciplines, career stages, and levels of participation in STEM education reform, and meet the criterion for a cultural schema. Thus, these cultural schema may be considered salient aspects of the institutional context of CSUN that transcend specific social groups or administrative units. To review, the pervasive beliefs and values identified in this evaluation are as follows:

Scientific legitimacy and credibility equated with basic research accomplishments. Since no STEM respondents had prior training in pedagogy in their graduate training, this clearly conveys the higher value placed on research activities and on acquiring expertise in a specialty area of their field. The importance of achieving legitimacy and credibility in a particular discipline is viewed as a critical ingredient of academic success in general, and for interdepartmental collaborations in particular. Competence in a discipline and specialty area is made legitimate and credible by a faculty position, publications, and an active research program. Moreover, legitimacy in a STEM discipline often is more highly valued than in education.

Distinction between hard and soft sciences fuels long-standing tension between departments in the school of education and some STEM departments. A corollary of the faculty members' close professional identities with their disciplinary traditions is that different faculty may hold value systems that differentiate disciplines in a hierarchical order. In particular, academics commonly hold a schema that distinguishes between the hard and soft scientists, where the hard sciences are considered more rigorous, as they take a scientific approach based on reproducible experimental data, and the soft sciences are considered more interpretive, anecdotal, and less scientific. Using this schema, STEM faculty generally are identified with the hard sciences, while education faculty are identified with the soft sciences.

Tension between institutional support for reform and the disciplines. While the predominance of the disciplinary value of research accomplishments serves to inhibit the goals of SCALE, the teaching oriented mission of CSUN serves to support SCALE. The resulting tension has important implications for inter-departmental collaborations and for dictating how individual faculty prioritize their workload, both of which are of critical importance to the SCALE project.

Beliefs about the relative importance of content and pedagogy in preservice STEM courses. Respondents made clear that within certain departments there are major disagreements about the courses required to effectively train a K–12 teacher, and the approach that the university should take in designing and offering these courses. Some faculty adopted the position that preservice courses should focus primarily on covering the canon of their discipline, while others emphasized the importance of pedagogical concerns (e.g., lesson planning, scaffolding, active learning strategies). This particular schema was also linked to an individual's level of exposure to the learning sciences in graduate school or in previous jobs, with those who had little to no exposure tending to feel that content coverage was of utmost importance to preservice training.

Again, it is important to note that we do not claim that all faculty, administrators, and staff at CSUN exhibit these values or beliefs. Instead, while these values were expressed by several of respondents across different social groups and administrative units, individuals may differentially internalize and exhibit these cultural schema depending on their personal backgrounds, personality, social position, discipline, and many other situational or demographic variables.

Primary Contextual Factors That Shape Individual Mental Models and Impinge Upon the Sense-Making Process

As previously noted, our conceptualization of mental models includes both the schema that comprise the cognitive processes of an individual (i.e., cultural and other schema), and the contextual determinants that shape and influence the complexion of these schema and the subsequent sense-making process. Thus, it is important to identify the specific contextual factors that impinge upon the sense-making process and activate an individual's mental model. Based on the data from this case study, we speculate that when faced with a STEM education reform, the following four contextual factors (listed in order of importance) exert the most influence on individual sense-making processes: (a) workload and attendant RTP considerations; (b) availability of fiscal resources, (c) availability of social resources, and (d) leadership.

Of course, the real-time interpretation of a situation is inextricably linked to the unique personal characteristics of the individual, particularly their personality and personal connection to the topic under consideration. For example, if a faculty member has a child in a local K–12 district, that person may be more receptive to or critical of a new STEM education reform effort. Other individual-level factors include personal background, ethnicity, social status, and disciplinary training. Thus, the cultural schema and contextual factors identified in this analysis interact with these idiosyncratic features in a dynamic relationship. Next, we turn to how one faculty member internalized the cultural schema at CSUN, and the unique character of these schema prior to, during, and after the SCALE intervention.

The Mental Model of a STEM Faculty (Non-SCALE Participant) for STEM Education Reform

The following section includes a description of the contextual factors most salient to this respondent's mental model for STEM education reform, and a description of the respondent's actual mental model prior to, during, and after the SCALE intervention. This particular respondent did not participate in SCALE, and the "during reform" phase refers to the TNE effort undertaken in the respondent's department. Figure 3 depicts the processes described below.

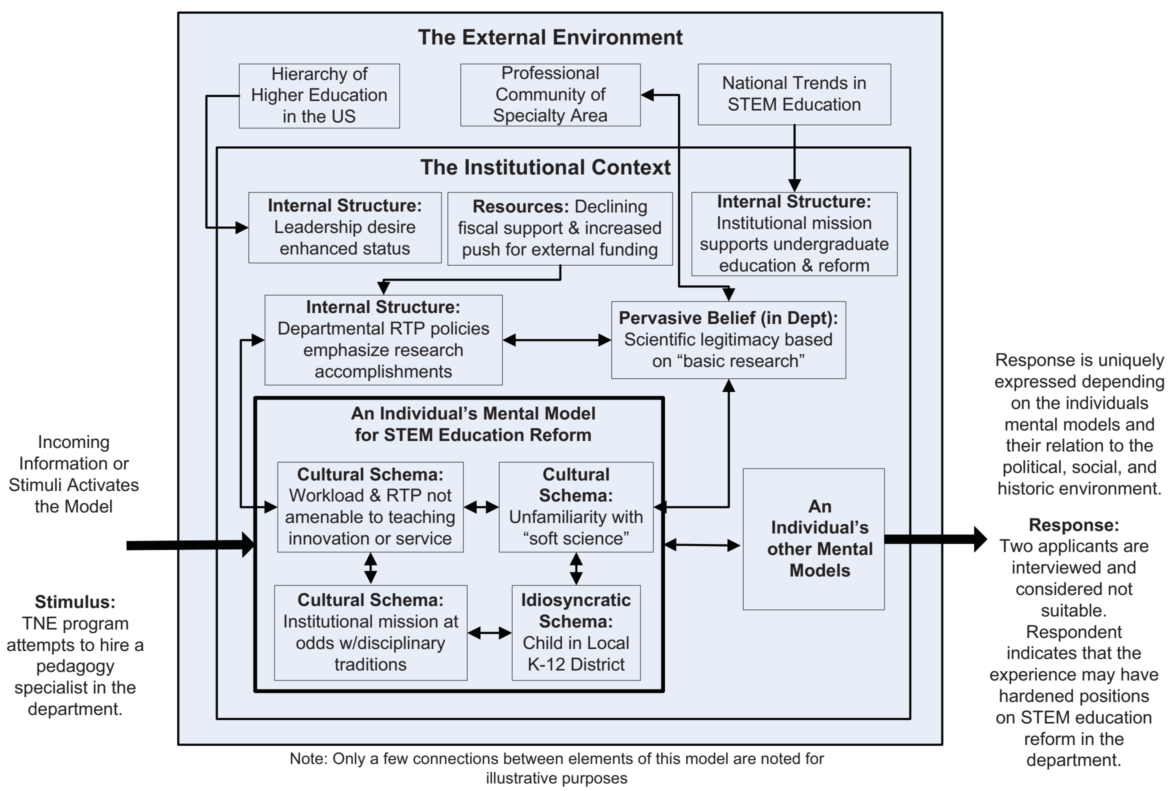


Figure 3. **A faculty member's mental model for STEM education reform.**

This particular respondent was hired relatively recently at CSUN, and it was the respondent's first academic appointment. Thus, the primary contextual factor that shaped the respondent's mental model for STEM education reform was that of workload and attendant RTP considerations. Due to this concern, the approval of peers in the department was particularly important, which made social factors in the college and department particularly influential. Finally, the influence of the respondent's doctoral training was still fresh and deeply shaped perspective on certain topics pertaining to reform, pedagogy, and disciplinary identity. The following analysis includes a description of this faculty's mental model, and its constituent schema, for STEM education reform prior to, during, and after the SCALE intervention.

Within STEM disciplines, research is given priority over teaching and service (CSUN-wide cultural schema). Responses are presented pre-, during, and post-reform.

- *Pre-reform (T1).* As noted above, this respondent was hired relatively recently at CSUN. As a result, the respondent was almost singularly focused on conducting research, publishing research articles, raising external research funds, and teaching the obligatory 12 units per semester. These immediate and practical concerns about time management were related to the cultural schema that prioritizes research over teaching and service activities. This schema makes it unlikely that a new STEM hire would participate in a reform effort, as it would impede progress towards tenure and promotion.

  This cultural schema was expressed by this respondent as a taken-for-granted perspective on academic life in a STEM discipline. As a doctoral student in a major research university, the respondent had never been in an institutional environment where the prioritization of research over teaching and service activities was not the case. Furthermore, this schema was reinforced locally at CSUN by the department's RTP policies and CSUN leadership. When new faculty are hired in this department, they sign a memorandum of understanding (MOU) that specifies the expectation that they will publish at least three research papers prior to their RTP review. There are no corresponding details about expectations regarding teaching or service activities. Furthermore, the respondent noted that some CSUN leaders have conveyed explicit messages regarding the expectations for faculty research productivity, including the statement at a public meeting that junior STEM faculty "should be living in the lab."

- *During reform.* The SCALE project and other reform efforts at CSUN did not directly activate this schema for this respondent. However, since the TNE effort did engage the department in an attempt to hire a pedagogy specialist, this respondent's deep-seated notion about the prioritization of duties was engaged. Since research was considered the top priority in the department, the respondent felt that, while the TNE position "would be nice," it would essentially be useless since "(I)nvesting time in becoming a good teacher is not rewarded and we are not really incentivized to spend inordinate amounts of time developing new teaching tools." Thus, the schema for the prioritization of research rendered this reform attempt superfluous and actively at odds with the prevailing value system of the department.

- *Post-reform (T2).* There were no changes to this schema as a result of the SCALE project and other reform efforts. In fact, the failure of the TNE effort to hire a pedagogy specialist may have reinforced this particular schema by demonstrating that a research-centered perspective is truly the dominant one in the department, in spite of the allure of a fully funded tenure-track appointment.

Beliefs about the relative importance of content and pedagogy in preservice STEM courses (CSUN-wide cultural schema). Responses are presented pre-, during, and post-reform.

- *Pre-reform (T1).* This respondent had neither taught prior to accepting a position at CSUN, nor taken any professional development courses in teaching and learning. While a graduate advisor had once experimented with inquiry-based teaching in a lab, and found that "there must be something going on since they are all so engaged," this experience was trivial compared to the focus on research accomplishments and the mastery of disciplinary content. Thus, the respondent's schema for the relative importance of content and pedagogy in undergraduate STEM courses was almost without content with regard to pedagogy. Because this respondent did not think about pedagogy, the schema for this topic was not about the relative importance of content or pedagogy, but rather about content. Furthermore, as the respondent was not aware of any preservice teachers in the respondent's courses, the respondent had essentially no opinions or beliefs about which approach would be best for that student population.

  However, despite lack of experience and training in education, this respondent had strong beliefs about the factors that led to poor student performance in the STEM fields at CSUN: (a) since most students were non-traditional (e.g., part-time students, parents, English language learners), they did not have the time or energy to adequately devote to the study of STEM fields, and (b) the lack of parental involvement at a young age led to many younger students developing the poor work habits shown by some undergraduate students. Thus, in the absence of a coherent position on this particular schema (which is itself an internalization of the discipline's perspective on this topic), this respondent had developed strong personal beliefs about student learning that have little overlap with findings developed by the learning sciences. In other words, this respondent held a type of folk theory about student learning.

- *During reform.* This schema was directly engaged by the TNE effort to hire a pedagogy specialist in the department. First, a candidate for the TNE position did a teaching demonstration and chose an inquiry-based assignment for an introductory course. The respondent noted that the lesson was "a really interesting way of going about it, which forced [you] to confront what you don't understand first, and then see facts to back up how to get the answer." While the respondent noted "[I could] see how it would be much more effective than just the passive lecture approach," the respondent also agreed with the reaction of a senior faculty member who observed that "he just spent 45 minutes covering something that could have taken 10 in a lecture." The respondent deemed that taking this much time to cover a relatively small amount of content was unrealistic, since CSUN is a small IHE with limited resources, increasing class sizes and heavy faculty workloads.

  Thus, the internal conditions of CSUN, coupled with a familiarity with the passive lecture approach directly shaped the perception that an inquiry-based approach was not feasible, and thus not desirable. Furthermore, this respondent noted that in light of the constraints facing faculty and the aforementioned challenges with student learning, a single TNE hire would not change such large and multi-faceted problems. In other words, this respondent felt that the

TNE hiring effort was a relatively one dimensional response to a more complex problem that included internal policies and external factors beyond CSUN's control.

- *Post-reform (T2).* There were no changes to this schema as a result of the SCALE project and other reform efforts. In fact, the failure of the TNE effort to hire a pedagogy specialist may have reinforced the respondent's default schema favoring content over pedagogy, since there was a less than convincing display of their integration in a single lesson.

Distinction between hard and soft sciences (CSUN-wide cultural schema). Responses are presented pre-, during, and post-reform.

- *Pre-reform (T1).* Even though this respondent had virtually no exposure to the learning sciences during graduate and post-doctoral training, and thus had little reference points to draw upon when thinking about the "soft sciences," this "hard/soft" schema is so pervasive in academia that it underlay this respondent's perceptions of STEM education reform.

- *During reform.* Again, this schema was directly engaged by the TNE effort to hire a pedagogy specialist in the department. In describing the interview with a pedagogy-specialist, the respondent noted the following reaction:

  > They didn't strike as much of a chord with me as basic science. I don't know if I harbor some bias that it's not real research or something like that. I don't really feel that way because I did get something out of the talks, but [there is] one thing. None of the people doing this research had anywhere close to the level of commitment or experience that all the rest of us had doing basic research. That's what some of it boils down to—someone who's been at it for a year or two, that's nothing like what I had to do to get here—6 years of grad school, and 7th doing a post-doc—I had to invest so much more of myself. (STEM faculty)

  This reaction suggests that even if the respondent did not harbor some bias towards educational research, the respondent had a predilection for basic science. This preference and familiarity, and its role as a filtering mechanism when faced with new information, is a classic instance of an individual's schema asserting itself. The respondent's observation about skepticism was due to the applicant not having paid dues also hints at the notion that there is an apprenticeship period in academia, whereby individuals invest time, energy, and money and become accepted members of a disciplinary group. This notion is another manifestation of this schema, and points to the fact that sometimes cultural schema are only made visible during events such as the TNE hiring process.

- *Post-reform (T2).* There were no changes to this schema as a result of the SCALE project and other reform efforts. In fact, the failure of the TNE effort to hire a pedagogy specialist may have reinforced the respondent's schema that distinguishes between the hard and soft sciences.

Tension between institutional support for reform and the disciplines (CSUN-wide cultural schema). Responses are presented pre-, during, and post-reform.

- *Pre-reform (T1).* Given the aforementioned analyses on the dominance of discipline-based perspectives about the relative value of teaching and research, content and pedagogy, and views of the "soft" sciences, it is not surprising that this respondent also exhibited the cultural schema detailing the tension between STEM education reform and the disciplines. This tension was described less as an ideological conflict and more as one based on resource allocation and the fair treatment of faculty.

  > Most of the faculty in our department are of the mind that this concept of a "Learning Centered University" is in direct conflict with the eroding resources provided by the state and that—I don't know how else to say it—you can't get blood out of a turnip. (STEM faculty)

  This perspective echoes other sentiments that efforts such as the LCU and TNE are in conflict with the realities of institutional life, and the cultural proclivities of academics whose first allegiance may be to their disciplines and their standards for research excellence.

- *During reform.* This schema was directly engaged by the TNE effort to hire a pedagogy specialist in the department, which the respondent considered a failure. The department had brought in two candidates for on-site interviews, and neither had been considered sufficiently prepared for a tenure-track position. This estimation was made based on their lack of adequate content preparation (as noted above), which made this respondent skeptical that the candidates could handle the rigor of establishing an independent research program. As a result, the department decided to offer a non-tenure track position. In any case, this experience reinforced the notion that STEM education reform efforts like TNE were out of step with the criteria and demands of this particular STEM department.

- *Post-reform (T2).* There were no changes to this schema as a result of the SCALE project and other reform efforts. In fact, the failure of the TNE effort to hire a pedagogy specialist may have reinforced the respondent's schema.

VI. Conclusions and Recommendations

This section includes our conclusions and recommendations for program planners and policy makers regarding STEM education reforms.

Assessing the Effects of SCALE at CSUN

Without measurable objectives with which to evaluate the SCALE project's activities and progress, it is difficult to make a definitive statement about the relative success or failure of the project. However, in light of the original goal to affect changes to undergraduate STEM instruction, interdisciplinary collaboration on preservice programs, interinstitutional collaborations on in-service programs, and the underlying institutional culture that informs these activities, the effects of the SCALE project must be considered modest. Of note, SCALE focused its efforts on a relatively small and discrete point within the CSUN context—engaging faculty to support K–12 teacher professional development. The SCALE project resulted in outcomes pertaining to the institutional context of CSUN that directly and indirectly relate to the four goals of the project. This was possible largely because the SCALE initiative dove-tailed with other extant reform initiatives that collectively created a very favorable environment for STEM education reform.

Below we summarize the key accomplishments of the SCALE project in terms of specific elements of the CSUN institutional context.[10] By providing an account that situates the project's outcomes within the complex institutional environment of CSUN, as opposed to a decontextualized list of project accomplishments, we hope to provide a more realistic and useful evaluation for program leaders and policymakers. Figure 4 includes these outcomes in terms of the ICF, depicting relationships based on a causal network analysis, and noting a distinction between first and second-order outcomes.

Effects of SCALE on the Institutional Context

The following description of the effects of SCALE on the institutional context is largely drawn from the preceding analysis of the science and math institutes (section III), and the cultural analysis in section IV. Outcomes listed below pertaining to pervasive beliefs and individual sense-making are described in detail in section IV.

External environment.

- SCALE developed four immersion units for LAUSD (first-order);
- SCALE/QED held 13 science institutes and 4 math institutes between 2006 and 2007 (first-order);
- SCALE provided professional development in math and science to 311 K–12 teachers (270 science, 41 math) (first-order);
- SCALE provided a more intensive type of interaction with K–12 than previously experienced (second-order).

Internal structure.

- Aspects of the SCALE science institutes, including institute design and facilitation models, influenced CSP (second-order);
- SCALE activities complemented the efforts of other reform initiatives, including the LCU and TNE initiatives (second-order);
- SCALE became involved in the math department schism. (second-order).

[10] Professional development outcomes for K–12 personnel are not included in this analysis as they did not directly or substantively affect UW-Madison personnel or institutional processes.

Resources.

- SCALE expanded the STEM education cohort and provided professional development (second-order);

- SCALE provided funds (stipends and release time) in a resource-limited environment (second-order).

Pervasive beliefs.

- None

Individual sense-making.

- SCALE engaged two STEM faculty participants as learners, shifting their roles in PD from that of content experts to a blend of content and pedagogy experts (first-order).

Practices.

SCALE provided at least three STEM faculty with pedagogical tools to use in their own courses (first-order).

In addition, to understand the impact of SCALE on CSUN, bear in mind the relationship between the key contextual factors and institutional change processes identified in this study. Universities like CSUN are large, complex institutions comprised of many different, loosely coupled colleges and departments that largely operate according to their own logic, rules, and norms. As such, the contextual factors pertaining to STEM education identified in this study constitute a collection of disparate yet interconnected features that operate in dynamic interaction such that a change in one may yield unpredictable and even imperceptible movement in others.

While SCALE did not create a revolutionary change at CSUN, it leveraged scarce resources (i.e., fiscal and human) to support activities that complemented existing reform efforts. In accidental coordination with the LCU, TNE, and CSP activities, it appears that SCALE served to deepen the cumulative impacts that these projects alone may have made. These impacts were particularly felt in the further development of the STEM education cohort at CSUN. This raises the question about whether stronger outcomes may have been achieved if these disparate reform efforts had been strategically designed and managed according to an explicit theory of change. We speculate that to effect substantive change at CSUN, such a comprehensive strategy is, if not necessary, at least commensurate with the complexity and multi-dimensionality of the leverage points within the institution.

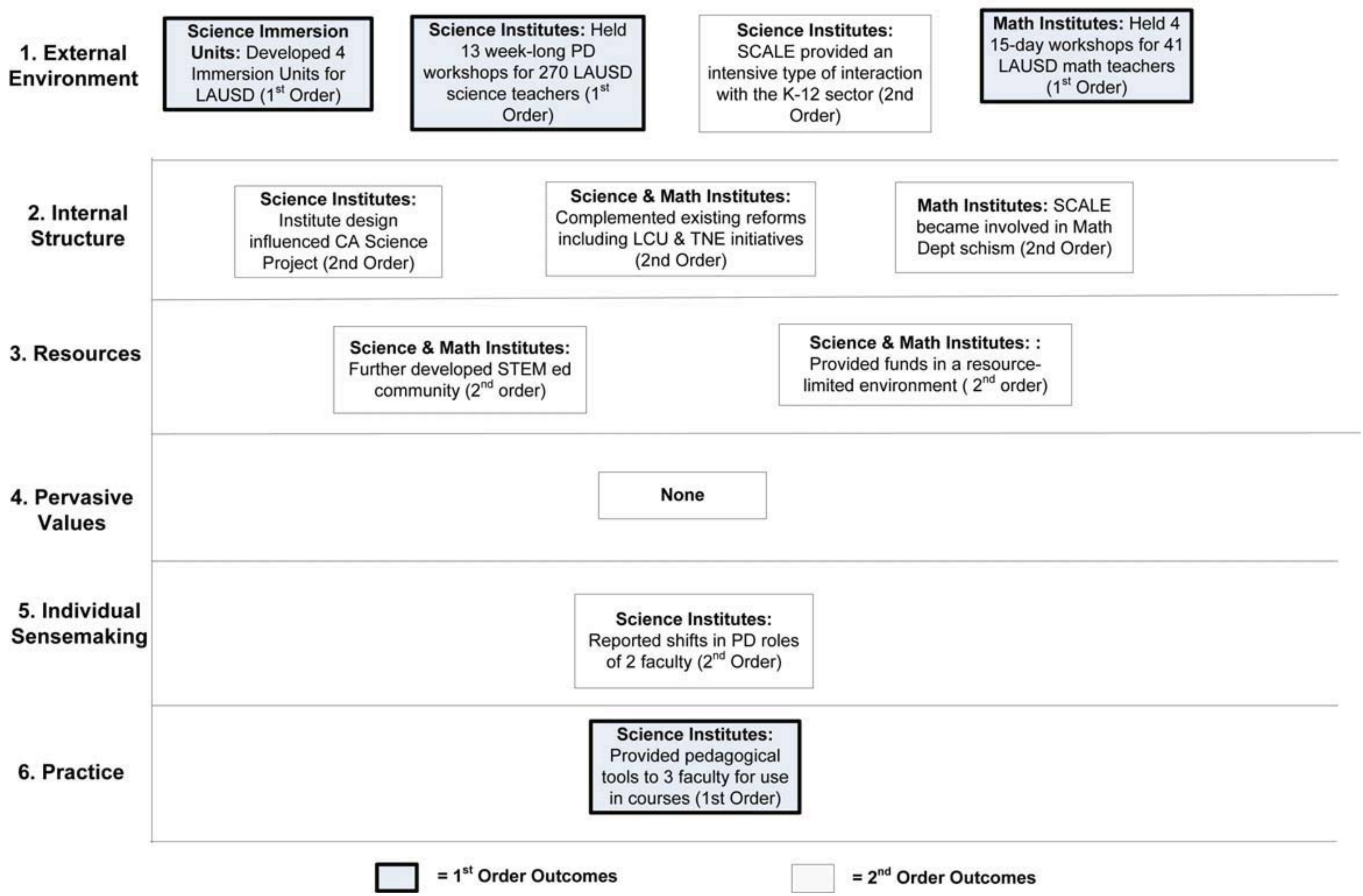


Figure 4. **First- and second-order outcomes of SCALE activities at CSUN.**

The Effects of a Project Implemented Through Distant Leadership

Since there were no SCALE leaders present at CSUN, there was no explicit theory of institutional change. This situation strongly contrasts with SCALE at both UW-Madison and CSUDH. SCALE engaged CSUN primarily as a site for its already existing math and science institutes, and largely ceded the effort at institutional transformation to chance and the extant reforms at CSUN. As previously noted, since the SCALE leaders at UW-Madison and CSUDH did not have deep local expert knowledge, the campaign approach to change used at their own IHEs could not be used effectively at CSUN. That is, there was essentially no connection between SCALE goals pertaining to institutional change and SCALE implementation strategy. In effect, SCALE planted its interventions at CSUN and relied on other local experts to conduct a change initiative that was explicitly linked to other reforms and whose operative theory of change at CSUN was less that of SCALE's and more that of the LCU, TNE, and CSP projects. An enduring lesson from SCALE at CSUN is that multi-institutional reform efforts should focus on recruiting local leaders who are sufficiently informed about and active at each partner institution. While SCALE was fortunate in engaging local leaders in K–12 districts (e.g., LAUSD) and some IHE partners, local leadership was lacking at CSUN. As previously noted, one effect of this situation was that there was no coordination between SCALE and other extant STEM education reform initiatives. This suggests that multi-institutional reforms should pay attention to cultivating local leaders instead of relying on a top-down, or in this case, externally managed, leadership strategy.

Lessons Learned From the Cultural Analysis of CSUN

Several core findings were derived from the analysis of the situated mental model of the CSUN faculty, and of the pervasive values and beliefs at CSUN pertaining to STEM education reform. These findings can be considered lessons learned from the interaction between the models and STEM education reforms (i.e., SCALE, TNE, CSP, and the LNC initiatives), and the ultimate effects of these reforms on the models at the conclusion of SCALE. The following section includes the lessons learned from these analyses.

There is a Cultural Complex of Scientific Legitimacy and Credibility

Anthropologists sometimes describe clusters of similar practices (e.g., rituals, tool-making, languages) as "cultural complexes." For example, archeologists have named a period in Wisconsin's pre-history the "red ochre complex" for the common use of red ochre in burial sites throughout the central and southern parts of the state. Since these sites contained evidence of warfare and exotic artifacts, the complex refers not simply to the use of red ochre but also to the unique social, economic, and environmental contexts in which this practice developed (Birmingham & Eisenburg, 2000).

Since the cultural schema pertaining to the beliefs and practices of STEM faculty were so coherently related and embedded in specific conditions, we consider these schema and their related contextual variables to be a cultural complex for scientific legitimacy and credibility. This complex is characterized by:

- Disciplinary prioritization of research, teaching, and service (STEM disciplines);
- Distinction between hard and soft sciences that fuels long-standing tension between departments in the college of education and some STEM departments; and
- Beliefs about the relative importance of content and pedagogy in preservice STEM courses

This cultural complex is particularly resilient in part because it is developed through years of intense training and socialization in communities of practice whose membership is carefully screened (Lave & Wenger, 1991). As such, any STEM education reform effort should at the very least be cognizant of this complex and its unique instantiation at local sites.

Mental Models are Hard to Change

Findings reported in section III indicate that a few faculty who participated in the SCALE-led summer institutes experienced some change in their views and teaching practices. Essentially all who experienced change were already disposed to make the types of changes sought by SCALE. Bearing these very limited outcomes in mind, while also considering our analysis of one individual's schema, we speculate that it may be very difficult to change most faculty's mental models for STEM education reform. This difficulty is consistent with the research on the difficulty of affecting behavioral change in education and the resiliency of culture (Stensaker & Norgard, 2001; Tobias, 1992).

STEM education reform may tap into uniquely resilient and rigid cultural schema that are part of the aforementioned cultural complex of scientific legitimacy and credibility. If so, the mental models studied here may be unusually resilient and difficult to change, in part because they have been learned over the course of several years of training and are integrated with local contextual factors that serve to reinforce and reproduce them.

Contextual Factors Shape Mental Models

This analysis focused on the role of contextual factors in how STEM education reform is interpreted, implemented, and ultimately effective in a unique institutional environment. One of the primary ways that the institutional context influences reform initiatives is in shaping the mental models of faculty. Factors that were particularly influential for STEM education reform included doctoral training, budgetary conditions, institutional mission, leadership, social networks, RTP policies, the cultural complex of scientific legitimacy, and the influence of the workload on individual sense-making. As such, mental models should not be viewed as cognitive structures that operate in a vacuum, as is the case with lab-based research in cognitive science or psychology. Instead, situated mental models operate in a real-world and complex setting which makes their study (and operation) more difficult, and quite possibly, their manipulation more problematic.

Professional Communities are Critical in Culture Formation

Some of the contextual factors most salient to mental models are the professional communities of which individual faculty are members. Some of these groups extend beyond the confines of a faculty member's home institution and may include disciplinary societies, colleagues in a specialty area, and their alma mater. In any case, these social groups often develop their own particular language, behavioral norms, and belief systems that are particularly resilient (Lave & Wenger, 1991).

A typical STEM faculty member's professional communities are not likely to have strong ties to educational reform or the learning sciences. This is not true, however, for faculty who choose to actively engage in educational reform activities. In these cases, they identify groups of like-minded others, in their disciplinary society or at their home campus—as seen at CSUN. These groups may become important venues in which cultural schema that are supportive of educational reform develop, are reinforced, and reproduced to new members. In addition, these collegial groups provide moral support, practical advice, and a community of like-minded professionals. Faculty respondents involved in such groups explained that their education reform community was as engaging and legitimate for them as their own disciplinary communities.

Cohorts of reform-minded faculty were enthusiastically encouraged by administrator respondents, who felt that these internal agents of change were far more effective than external consultants. Regarding interdepartmental relations within these communities, several education faculty respondents stated feeling that STEM faculty respected their training in pedagogy as much as their own content expertise. This went a long way in fostering collegial relations.

A Comprehensive Approach to Culture Change and Culture-Brokers is Important

This analysis suggests that shaping the culture of an organization may require comprehensive efforts to change the structural, social, and symbolic milieu in which individuals operate, in addition to the actual cognitive processes that constitute individuals' habits of mind. This may require leaders to employ a flexible and multi-faceted toolkit of frames through which to analyze their organizations (Bolman & Deal, 2003). In addition, such an effort would benefit from a deliberate and strategic approach by reform or campus leaders, as opposed to an unguided intervention that unfolds according to chance. It is especially important that a local figure play a leadership role, as mental models may operate according to a logic that is inaccessible to external leaders and change agents. In cases where inter-institutional or interdisciplinary collaborations are taking place, it may also be important for a local individual to play the role of a culture-broker. Our case studies of UW-Madison and CSUDH indicate the importance of such an individual, who understands the cultural schema operative within different groups, and can carefully negotiate the divisions or tensions that may exist between the groups and their pervasive values and beliefs.

Key Leverage Points for Institutional Change

We judge that the following seven contextual factors identified in this analysis functioned especially effectively as key leverage points for affecting the types of change sought by the MSP program:

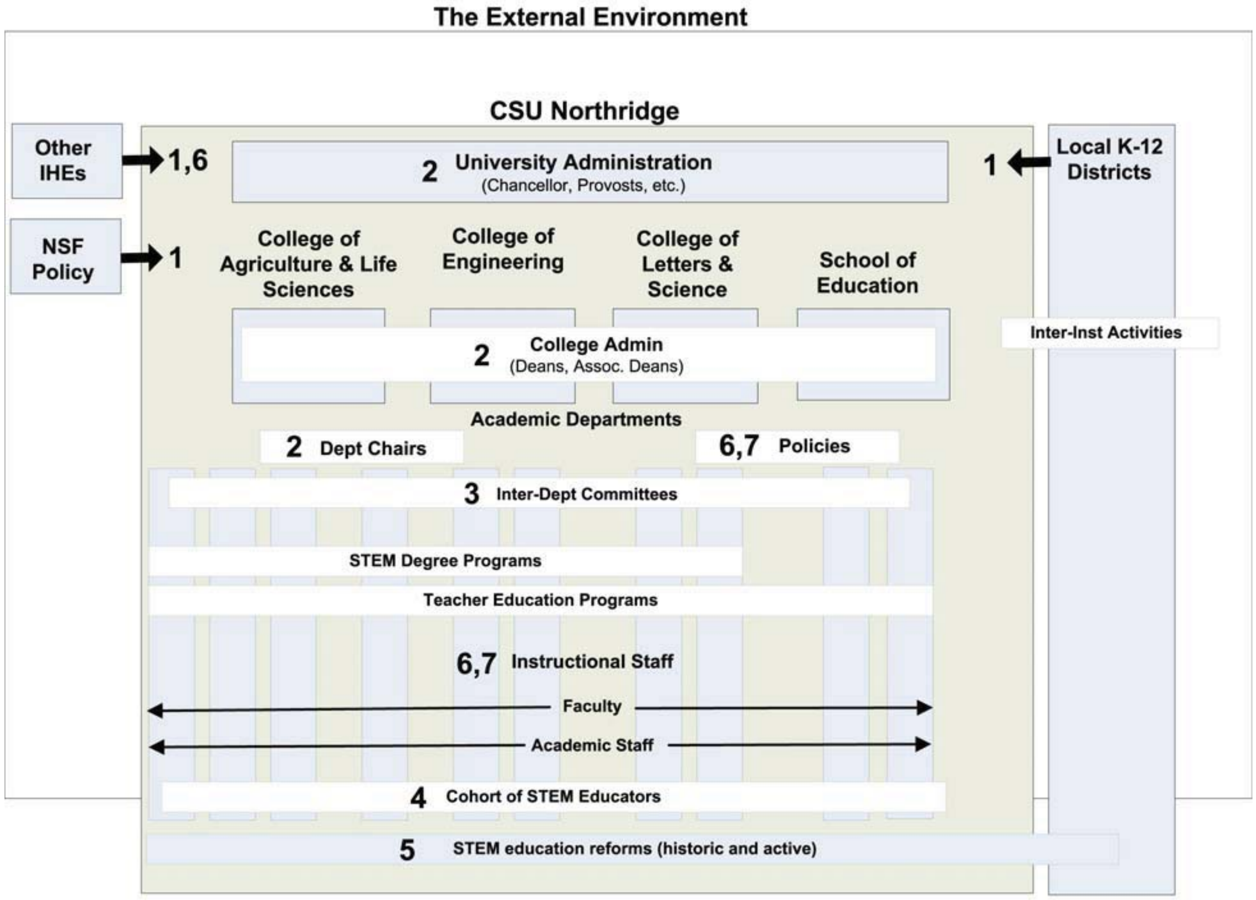
1. Points of contact with the external environment;
2. Leadership at all levels;
3. Decision-making bodies and interdepartmental forums;
4. Networks of STEM educators;
5. Other reforms;
6. Cultural complex regarding disciplinary legitimacy and credibility; and
7. Individual faculty workloads

We identified these points by focusing on: (a) factors that were directly linked to the first and second-order outcomes of SCALE activities, and (b) factors that had particularly strong downstream effects on the institutional context of CSUN. The multi-dimensional framework used in this case study shows that these factors, which we will henceforth refer to as leverage points, include, but are not limited to, factors commonly cited in the change literature, such as policy initiatives, school leadership, or professional community. Furthermore, we note that the leverage points identified in this study should not be viewed as isolated magic bullets that can produce fast and enduring reform across the entire university. Rather, they must be understood as operating in dynamic interaction, such that a change in one may yield unpredictable and even imperceptible movement in others.

Based on our analysis of the SCALE project, we speculate that by engaging the key leverage points described below in a substantive and sustained manner, it is possible that a tipping point may be reached within a particular organizational unit, such that a previously rare practice or behavior becomes widespread (Gladwell, 2000). This analysis is intended only to identify the key leverage points for change in this system, and no claims are made regarding the ultimate outcomes on instructional practices or student learning. We suggest that the leverage points below deserve particular attention by campus leaders and STEM education reformers, since they have the potential to effect a cascade of impacts in a variety of points in the cultural context of an IHE. Figure 5 presents these leverage points in the context of the external and internal environments of CSUN, illustrating that these leverage points operate across many levels of this complex organizations system.

Points of Contact With the External Environment

An IHE has numerous points of contact with the external environment, including accreditation agencies, local K–12 districts who supply students, other IHEs who train future faculty, and government policymakers, to name but a few. In many cases, exogenous pressures, as opposed to internally derived decisions or motivations, are a significant source of the stimuli that require institutional change. While many points of contact with the external environment are beyond the control of CSUN, it is possible to anticipate how these stimuli will influence the institution and act accordingly. For example, respondents noted ways in which the university had



1 = Points of contact with the external environment
2 = Leadership at various levels
3 = Decision-making bodies and inter-departmental forums
4 = Networks of STEM educators
5 = Other STEM education reforms
6 = The cultural complex for disciplinary legitimacy and credibility
7 = Individual faculty workloads

Figure 5. **Key leverage points for institutional change at CSUN.**

been proactive and responsive to changing environmental conditions. An example is the response to a limited pipeline of preservice science majors between local K–12 districts, community colleges, and CSUN. Faculty active in the TNE project conducted a study to assess how local high school students felt about K–12 teaching careers, so that they could adapt their recruiting programs to address their preconceptions, fears, and career hopes. In this way, CSUN was able to respond to an external condition, analyze it, and possibly tailor its internal activities to address the condition's effect on the institution.

Leadership at all Levels

Educational leaders serve a variety of functions, including establishing policies and procedures, setting goals and priorities for the institution, and establishing a particular tone through communications with staff. As such, leaders play a vital role in creating an institutional environment in which change can take place (Kezar & Eckel, 2002). In the case of CSUN, leadership at the upper administration level was critical in establishing the LCU initiative and conveying an unmistakable signal to faculty that pedagogical reform was a high priority. In some cases, leadership at the college and departmental levels operated according to a different set of priorities, which may have hindered the upper administration's efforts. This scenario is largely due to the governance structure at CSUN, and is a predicament for most change initiatives in higher education. Ideally, when faced with an institutional change initiative like the LCU, some sort of compromise could be made among leadership at all levels of an IHE so that their respective needs and priorities could be addressed. Such an approach could also serve to minimize the likelihood of a disjuncture among leaders, some of whom may act (consciously or not) to undermine the change effort.

Decision-making Bodies and Interdepartmental Forums

Certain decision-making bodies, such as the liberal studies committee at CSUN, may be critical to reform efforts such as SCALE, as they are pre-existing venues for inter-departmental collaboration that meet for specific reasons of common interest, and generally have decision-making authority. These organizational units strongly influence the structural factors that shape undergraduate education, and comprise the policy environment that individual instructors must respond to when planning and teaching math and science courses for preservice teachers. It appears that any STEM education reform effort at CSUN aimed at affecting lasting policy changes would need to engage this leverage point. In contrast, committees or working groups established during a grant period may not appeal to a broad spectrum of faculty, and may be less likely to become institutionalized. Furthermore, at a campus as large and decentralized as CSUN, the status quo is that faculty in different departments do not interact in a sustained, goal-directed manner unless individual faculty initiate interdepartmental forums. With regard to achievement of goals such as those SCALE seeks, such forums may provide critical leverage points.

Networks of STEM Educators

Faculty belong to a variety of professional and personal networks, which in some cases can become professional communities if they involve meeting regularly and addressing common problems and tasks. These networks and communities are a key leverage point because through them ideas can spread rapidly, resources can be accessed, and collegial support for new endeavors can be obtained. Particularly important members of these STEM educator networks are faculty and staff who have positions focused on STEM education, which is not uncommon at CSUN. STEM faculty who are already engaged in these activities as part of their normal workload are another key leverage point for reform, as they are well-placed to enact change and do not have to negotiate their workload in order to focus on STEM education issues like other colleagues must. Furthermore, these faculty and staff often have extensive networks and access to STEM education resources that can be utilized to achieve the goals of a reform initiative. It is important to maintain contact with these faculty and staff, and to understand the dynamics of their particular departments regarding STEM education, in order to avoid inadvertently jeopardizing their reputations or careers.

Other Reforms

At any given time several pedagogical reform initiatives may be underway at CSUN or at any other IHE. Some of these may be high-profile initiatives such as TNE, or smaller efforts led by individual faculty. Historic and active reforms offer an important resource through establishing social networks, lines of communication, policies and procedures, and trained faculty or staff. For example, a respondent noted that Dr. Oppenheimer's decades of work with local K–12 districts had led to strong relationships with individual K–12 administrators and teachers that newer faculty were then tapping into. However, a panoply of efforts may also result in an uncoordinated set of activities, each of which only has a local effect. Thus, it may be important to harness the energies and resources of disparate activities into a coherent whole, including standardizing evaluation procedures or explicitly nurturing networks of STEM educators across projects.

Cultural Complex Regarding Disciplinary Legitimacy and Credibility

Given its resiliency and dominance in academia, the cultural complex for disciplinary legitimacy and credibility must be first recognized, and if possible, exploited by leaders of reform initiatives. Achieving legitimacy and credibility in one's field provides two possible opportunities regarding STEM education activities. First, it affords faculty with safety from colleagues' criticism and a strong sense of confidence that is important when departing from the traditional workload of a STEM faculty member. As one respondent stated, if someone's research credentials are solid then they can dabble in less prestigious issues such as education. Second, once faculty achieve tenure and are under less pressure to publish and conduct research, they many have more time to explore other ideas and activities.

Individual Faculty Workloads

Perhaps the most important leverage point for institutional transformation is the daily workload of faculty and staff, which is generally overwhelming and is comprised of demands from a variety of constituencies (e.g., students, colleagues, administrators, funders). This reality must be acknowledged and addressed before faculty can be fruitfully engaged and possibly convinced of the need for an institutional reform. Otherwise, a reform effort may antagonize a workforce that is already under significant pressure. This critical factor may be addressed by buying out faculty's time, ensuring that work on pedagogical reform will be valued by RTP committees, or aligning the goals of reform with pre-existing work responsibilities. (e.g., see leverage point 3, above).

Recommendations for CSUN Leaders and the NSF

This case study, combined with our case studies of UW-Madison and CSUDH, 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 its intended outcomes. We consider this theory of change promising, with the caveat that effective implementation of the theory requires a sophisticated understanding of the multi-faceted nature of the barriers and supports within an IHE. The following recommendations are based on this theory of change and include a set of core concepts that may (a) help CSUN leaders to continually improve their efforts, and (b) help the NSF, Department of Education, and other agencies design polices that more effectively foster achievement of MSP goals for IHEs.

For reform efforts that target institutional culture and individual conceptual change, particular attention should be paid to how the intervention space is designed such that the unique characteristics of a local site (and its organizational membership) are engaged in a fruitful manner. Based on the findings of our three case studies, the following points should be considered when developing such a reform:

Conduct Assessments of the Institutional Context Prior to Program Planning and Implementation

We propose that change efforts 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) suggests that this is important so that change leaders obtain a "clear sense of the idiosyncratic features of the environment" (Treisman, 2007). Such an institutional diagnosis should account for the different aspects of the institutional context as detailed in this case study, including the external environment, internal structure, resources (fiscal and social), pervasive values, individual sense-making, and practices. One of our next steps is to develop a diagnostic tool that is cost-effective and easily administered so that program planners can tailor their programs to their institutional contexts (see below), and also establish baselines for evaluation purposes.

Ensure that Recruitment Efforts Pay Attention to Workload and Cultural Factors

Reform leaders should address and acknowledge the current activities, constraints, and pressures facing STEM faculty when recruiting and engaging them in reform efforts. For example, when presenting a recruitment pitch, begin by acknowledging the successes and present conditions of a particular department and then present the challenges that the reform effort hopes to address. This strategy may help reform leaders avoid appearing adversarial or out of touch regarding the day-to-day concerns of many faculty. This "meet them where they are" stance would also be useful during project implementation. In addition, faculty and staff need a rationale to become engaged in a reform effort. Altruism or a sense of responsibility may not be enough, particularly if the workload pressures are substantial. Thus, a reform effort should explore ways to mitigate the workload by providing release time for faculty, or targeting senior faculty whose workload pressures may be less demanding than their junior colleagues.

Reform efforts should pay particular attention to the cultural complex of scientific legitimacy and credibility, such that the reform does not antagonize an individual's disciplinary identity and related mental models. If this factor is not addressed, reform leaders run the risk of immediately putting off potential participants, which is not uncommon. Thus, reform leaders should consider tailoring their recruitment efforts such that this cultural complex is explicitly addressed by having high-prestige faculty serve as recruiters, and ensuring that the rhetoric used in program recruitment and materials is not overly combative or filled with technical terms from education research. The use of educational jargon can serve as an immediate trigger to the cultural schema distinguishing between hard and soft sciences.

Design Neutral Spaces in Which Different Groups may Interact

Reform initiatives should also focus on designing neutral spaces in which different constituencies can safely and productively interact. This may entail paying close attention to the symbolic nature of meeting spaces or particular facilitators, and the power inequalities that may exist between different groups (e.g., STEM faculty, education faculty, K–12 staff). For example, interdisciplinary forums where STEM and education faculty meet should allow for the productive exchange of ideas, and account for the potential conflict inherent in the cultural schema that distinguishes between hard and soft sciences (see above). Neutral space can also ensure that all participating faculty and staff are integrated into the reform effort, such that participants feel that their expertise and workload are both being valued and addressed.

Recruit a Skilled Culture-Broker When Working with Interdisciplinary Groups

When working with individuals from different institutional or disciplinary backgrounds, it is helpful to have a skilled facilitator, or culture-broker, who can negotiate the potential divisions and cultivate the points of cognitive and practical overlap that may exist among groups. In this case, critical leverage point in altering faculty members' mental models of STEM education reform may entail surfacing of their assumptions about STEM education reform, and encouraging them to think like novices—processes likely to be accomplished through skillfully facilitated experiences.

Marshal Existing Resources and Reform Projects to Collectively Target Key Leverage Points

The large number of STEM education reform leaders and existing projects at CSUN represent a significant pool of resources and institutional knowledge that could be more effectively marshaled. At the present time, these projects are loosely coordinated, if at all, due to their different missions and the sheer size of IHEs. However, this should not keep reform leaders from meeting on a regular basis to share notes, combine resources when advantageous, and when appropriate, collectively leverage existing political, social, and fiscal capital to exert pressure on strategic points in the system of STEM education.

Focus on Developing Cohorts of STEM Educators in Specific Departments

We also recommend that clusters of faculty with STEM education expertise be recruited in specific departments in order to achieve critical mass and minimize departmental resistance to pedagogical change. Whereas an individual change agent working in a hostile or disinterested institutional environment is unlikely to convince colleagues to change policies or practices, a small group of colleagues amenable to reform has a chance to effect change. In addition, the STEM education experts would benefit from having a supportive community of colleagues with which to share ideas and resources.

Furthermore, instead of focusing exclusively on engaging STEM faculty, which is the wont of current reform initiatives such as the MSP, we recommend an even more deliberate focus on particular groups of faculty and staff. The following four groups represent particularly rich opportunities for programs such as the MSP: (a) STEM and education faculty who are already engaged in educational activities; (b) academic staff who already are engaged in educational activities; (c) STEM and education faculty who occupy key administrative positions relevant to STEM education; and (d) STEM and education graduate students.

Carefully Design Top-Down Structural Reforms With Attention to the Moving Parts of the Institution

Campus leaders should consider potential policy levers, such as requiring faculty to assess student learning outcomes, as leverage points to support campus-based efforts. However, these efforts should be carefully designed to be responsive to the multifaceted contextual factors operative at a particular institution, including existing policies, pervasive values, and resources. As this case study suggests, particular attention should be paid to the mental models, and their constituent cultural schema, of individuals likely to be impacted by a reform. Research on the implementation of reforms fostered from the top shows that these efforts fail largely due to resistance of local agents, whose interests, needs, and cultural norms run counter to the perceived intent of the reform (Spillane, Reiser, & Reimer, 2002). An institutional needs assessment (see above) focused on identifying the cultural conditions of administrative units most likely to be affected by policy change can provide this type of understanding.

Next Steps

This line of work for the SCALE project includes case studies of two other IHEs, CSUDH, and UW-Madison plus a final cross-case analysis for all three sites, written for a practitioner audience in mind. This cross-case analysis of SCALE activities at its IHE partner sites will focus on further developing a diagnostic approach to evaluating STEM education interventions in complex organizations. In particular, this analysis will explore the prospects of linking changes in the institutional context to changes in instructional practices and ultimately, student learning outcomes.

Appendix
Methodology

This research used a repeated cross-sectional qualitative case study. The qualitative case study 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). This design seemed particularly appropriate for highlighting contextual factors that affect an MSP project's implementation processes and outcomes. Moreover, its focus on how and why is expected to yield valuable information for program funders and planners (Owen & Lambert, 2001). We selected this design—in contrast to a longitudinal study that would follow a single cohort who participated in a single intervention—because of the emergent nature of the SCALE project and the reality of participant attrition in projects of this nature. We decided to capture the effects of a large number of project activities and their varied participant populations, understanding that we were sacrificing the ability to attribute program effects to a specific intervention in a robust fashion.

Sampling Procedures

The primary unit of analysis for this research is the individual, and the sampling universe for this research included all CSUN personnel. We then used two sampling frames to identify participants in the study: (a) participants in any SCALE activity, and (b) personnel in administrative units that were the focus of SCALE, including STEM and education departments, administrators, and academic staff. Nonrandom sampling procedures were used to identify SCALE participants, and snowball sampling was used to identify nonparticipants who differed with regard to their experience with STEM education reform. *Nonparticipants with little experience in STEM education reform were included to test and/or confirm findings from the SCALE participants, as the latter may constitute a biased sample regarding their perceptions of the institutional context.*

Data collection took place at two points in time: Time 1 (T1; June 2006) and Time 2 (T2; June 2007). At T1 a total of 18 interviews were conducted, and at T2 a total of 16 interviews were conducted (see Table A1). Due to respondent unavailability and faculty turnover (at both CSUN and with SCALE) only 5 SCALE participants were interviewed at both T1 and T2.[11] In addition, we draw on interviews conducted with SCALE leaders and UW staff, conducted for the CSUDH and UW-Madison case studies to collect information on program planning, implementation, and evaluation.

Sources of Evidence: The Data

The data collected for this study are in-depth interviews, documents, and field observations of meetings and informal settings. The interviews were semi-structured using a

[11] At T1 another researcher conducted 7 interviews in early 2006. A similar interview protocol was used by both researchers.

Table A1
Number and Role of Respondents at Time 1 and Time 2

	T1 (June 2006)		T2 (June 2007)	
	Total respondents	SCALE participants	Total respondents	SCALE participants
STEM faculty	7	4	10	8
Education faculty	6	1	4	2
Administrators	5	0	2	0
Sub-Totals	18	5	16	
Total respondents	18		16	

standard interview protocol for different types of respondents (i.e., STEM faculty, education faculty, administrators, etc.).

Ethnographic Interviews

The interview protocol focused on eliciting how respondent approaches to the SCALE goal areas (i.e., STEM instruction, interdisciplinary and inter-institutional collaboration) are related to their institutional environment, if at all.

Following James Spradley (1979), we use the "ethnographic interview" method that, instead of rigidly adhering to a structured interview protocol, focuses on eliciting native terminology and topics of interest that may guide the line of questioning. While we were guided by a structured protocol in the manner advocated by Spradley, we used subtle probes to ensure that respondents identified the relationships between their sense-making, tacit assumptions (cultural schema), and the institutional context. For example, one question was: "What factors influence your participation in preservice programs?" Responses may include references to state policies, departmental teaching assignments, or personnel preferences. We then probed and asked precisely how state policies relate to their participation in preservice programs, and so on.

Using these interviewing methods we were able to elicit two types of information used to explore the relationships among individual-level cognition, group-level culture, and the institutional context. First, we used the relationships between factors identified by respondents as input for the causal networks, which graphically depict how factors at each level dynamically interact in a manner that either supported or inhibited achievement of SCALE goals (see below). Second, to obtain data for our analyses of cultural schema, we asked specific questions about tacit assumptions pertaining to the SCALE goal areas, although often we found it necessary to infer these assumptions. In either case, we probed by asking if the belief or value was shared by any group of which they were a member. In this way, we were able to ascertain with which group the assumption, belief, or value could be associated.

Documents and Field Observations

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 RTP policies. Documents were identified by both respondents and researchers and were analyzed at both T1 and T2. Field observations of the research site were also conducted, including three SCALE-related meetings, informal observations of respondents' work environment, and of public presentations of the SCALE project. Finally, the preliminary case study of SCALE activities at UW-Madison (Hora & Millar, 2006) provided the analytic foundation for the present study.

Data Analysis

The analytic procedures for this research draw on established procedures of qualitative analysis. These include inductively coding interview transcripts using the grounded theory method of Strauss and Corbin (1990), causal network analysis that graphically organizes the data by time and sequence (Miles & Huberman, 1994), and an exploratory analysis of cultural schema (Strauss & Quinn, 1998; Quinn, 2005).

Coding Interview Transcripts Using a Grounded Theory Approach

Using the findings from preliminary analyses of data from all three IHEs, we developed a coding paradigm called the *institutional context framework* (ICF). A coding paradigm is a structured coding scheme used to analyze data and identify discrete themes and patterns (Strauss & Corbin, 1990; Ryan & Bernard, 2003). A coding paradigm is especially necessary in this instance in order to categorize and reduce the multidimensional data we had collected. The classification framework is organized into six broad categories that include more specific topics that are sub-codes used in our analysis (see below). It is important to note that the categories used to code the data are derived from analyses of complex institutional environments that are exclusively focused on STEM education, teacher preparation, and IHE/K–12 partnerships (Hora & Millar, 2006). As a result, it is possible that the framework adequately models only categories and topics related to SCALE goals.

The six broad categories of the ICF are listed below.

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

2. *Internal structure:* Organizational structure (governance, teacher education programs, STEM degree programs), student body composition, instructional workforce composition, personnel policies, leadership, and reform initiatives.

3. *Resources:* Material resources (e.g., time, funding), and social resources (e.g., networks).

4. *Collective beliefs and values:* The beliefs, values, and tacit assumptions operative among groups at UW-Madison, including the institution as a whole, colleges, departments, and smaller communities or "sub-cultures."

4. *Individual disposition and sense-making:* The primary elements of an individual's sense-making process, including workload considerations, personality, background and training, views on instruction, and status.

5. *Practices:* An individual's classroom instruction (e.g., planning and delivery) and task-based collaborative activities with both IHE and K–12 partners.

We then developed a three-step coding system that consisted of the following: (a) the ICF categories; (b) topics considered barriers or enablers to SCALE as identified by either the respondent *or* the analyst; and (c) changes attributed to SCALE activities. This coding structure was designed to facilitate later data queries that would identify relationships among factors, particularly if a category in the ICF was considered a barrier or an enabler to SCALE goals. We then coded both T1 and T2 interviews using NVivo qualitative analysis software, and conducted queries of the coded interviews as a first step in identifying the themes for the case study.

Queries were conducted based on high frequencies of code sources and references (as seen in Table A2), and analyst judgments regarding the importance of the topic based on field notes and analytic inference. In this report sources refers to the number of interview transcripts that include the code, and references include the actual number of codes applied to the transcripts.

Table A2
Summary Report of NVivo Coding

Most Frequently Used ICF Codes	Number of Sources	Number of References
External Influences		
Local K–12 Characteristics	23	60
Institution Type	20	56
Field of Higher Ed	20	48
Alignment	6	15
Education Policy	19	33
Economics	7	13
Doctoral Training	13	18
Individual Perspectives & Sense-making		
Learning & Pedagogy	30	231
Workload Considerations	26	70
Legitimacy & Credibility	25	80
Colleagues	32	285
Teacher Ed	25	124
K–12	27	113
Epistemology of Disc	21	34
Home Institution	31	280
Background & Training	29	104
Student Body	26	94
Primary Motivations	30	160
Career Status	23	66
Internal Structure		
Teacher Ed Programs	22	88
Change Processes	25	96
Hiring & Personnel Policies	30	121

Most Frequently Used ICF Codes	Number of Sources	Number of References
Workforce Topics	15	33
Reform Initiatives	30	250
STEM Degree Programs	14	27
Leadership	23	57
Influence of Location	13	27
Student Body Topics	22	67
Politics & Power Relations	19	36
Practices		
Rationale Behind Instruction	28	93
Lesson Delivery	16	31
Inter-College Collaboration	29	116
Inter-Institutional Collaboration	13	23
Research & Publishing	27	69
Engagement w/ Pre-service	24	80
Committee Work	18	35
Service	20	50
Resources		
STEM Ed Community	10	33
Funding	25	94
University-wide Colleagues	11	27
Time	27	71
Department Colleagues	12	19
Shared Meanings		
Department Norms	29	129
Distinctions Between Groups	31	172
University Norms	26	103
Individual in Relation to Sub-Group Norms	26	60

Next, we conducted matrix queries to search the coded interviews for specific combinations of codes; in this instance we were most interested in text that had been double or triple coded with ICF categories, the second pass (barriers/enablers), and the third pass (changes attributed to SCALE). Coarse category results are presented in Table A3.

Table A3
Sample NVivo Matrix Query for First Pass (Internal Structure) and Second and Third Pass Codes

	Enablers to SCALE	Barriers to SCALE	Changes attributed to SCALE
1 : Teacher Ed Programs	19	26	16
2 : STEM Degree Programs	14	22	6
3 : Governance	7	17	3
4 : Instructional Workforce	14	20	8
5 : Personnel Policies	9	29	7
6 : Leadership	9	9	5
7 : Student Body Topics	8	14	3

It is important to note that frequencies alone were not sufficient for identifying key factors and/or findings, as the codes were sufficiently broad to allow for a range of perspectives. It was necessary to conduct a more in-depth analysis of the coded text in order to ascertain the specific nature of the factor under consideration, which we did by reviewing all of the coded text and actively seeking disconfirming evidence from the interview transcripts and other data sources (Miles & Huberman, 1994). Once the most frequently cited factors had been identified, we then assigned a valence in order to denote a positive (+) or negative (-) influence on SCALE activities, based on a respondent's indication of the nature of the factor, or our own analysis of the factor and its relationship to SCALE goals. Each weighted factor was then linked to those SCALE activities to which respondents associated it. Again, we constantly referred back to the data when making these assignments and actively sought disconfirming evidence in the interviews and documents. We then used the following criteria to evaluate if a factor would be included in the final analysis: (a) document-based evidence of institutional phenomena, SCALE activities, or SCALE outcomes; and (b) at least three respondent accounts of institutional phenomena, SCALE activities, or SCALE outcomes. The resulting factors constitute the primary data for this case study.

Causal Network Analysis: Situating the Factors Within a Time-Ordered Display

Using the results from the coding, we organized the factors in a time-ordered display in order to identify relationships between factors at T1 and T2, and how SCALE mediated the implementation process between the two points. A causal network is "an abstracted, inferential picture organizing field study in a coherent way" (Miles & Huberman, 1994, p. 153). Factors identified in the data are located on the y-axis according to where they are categories within the ICF, and on the x-axis (which denotes time) according to whether they occurred at T1, T2, or as a SCALE activity.

Exploratory Cultural Schema Analysis

Working within the interpretive tradition of Strauss and Quinn (1998) that uses natural discourse to identify cultural models, we analyzed the cultural schema for math instruction held by two key subgroups active in the SCALE project. *We strongly emphasize that this is an exploratory effort to identify cultural schema, undertaken in order to understand the role of culture in STEM education.* First, we analyzed text coded for the ICF category "collective values and beliefs" for all respondents. When at least three respondents expressed a similar value or belief pertaining to STEM education reform, we classified it as a cultural schema. Using this process, we identified various cultural schema, some of which were shared among certain groups (e.g., biologists).

Second, we analyzed if and how these schema were engaged or illuminated during the activity for one faculty member. This evidence is based on the respondent's accounts of experiences and perceptions during the activity, and how personal beliefs, or counterpart's beliefs, values, and tacit assumptions were made visible.

Third, we analyzed changes in the respondent's cultural schema and/or personal mental models that could be attributed to the activity, either by the respondent or by analytic inference. Our focus on personal mental models when analyzing project outcomes, as opposed to the sub-group's cultural model, was necessitated given the small sample size. Our assumption is that any changes due to the SCALE intervention pertain not to the cultural schema of this group but only to the individual respondent.

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