2008 American Educational Research Association
Division G: Social Context of Education

Using cultural models to understand faculty sense-making processes within the structural and socio-cultural context of a comprehensive university

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Objectives and Background

Initiatives to improve teacher quality and student achievement in math and science are increasingly focusing on the role that science, technology, engineering, and mathematics (STEM) faculty play in the teacher preparation process (NSF 1996; NRC, 2000). Since pre-service candidates must take prescribed sequences of STEM courses, the quality of these courses plays a direct role in these students' future knowledge of the STEM disciplines. However, deficiencies in graduating students' content knowledge and high rates of attrition among undergraduate science majors indicate the need to improve STEM undergraduate education as a part of broader reforms to K-12 education (e.g., Handelsman et al, 2006; Seymour & Hewitt, 1997). In addition to the traditional focus on technical systems, in recent decades researchers have focused on the importance of the subjective, non-rational qualities of Institutions of Higher Education (IHE) as an important mediating variable that may inhibit or support reform initiatives (Birnbaum,1988; Tobias, 2000; Seymour 2001; Henderson & Dancy (in press); Walczyk, Ramsey, & Zha, 2005). For example, Seymour (2001) highlights the important role that departmental values and practices play in determining how faculty view their instructional practices.

In this vein, research on reform implementation in both higher education and K-12 has found that policy directives are frequently adapted and transformed by individual agents at the local school or IHE level (Coburn, 2001; Spillane et al, 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, 1991)[1]. Increasingly, researchers are recognizing the importance of this process and how local contextual factors such as organizational structure and leadership shape the sense-making process (Coburn, 2001; Spillane et al, 2002).

One of the commonly cited components of sense-making is the tacitly held set of values, beliefs, and assumptions regarding what are acceptable or expected behaviors within a group (Weick, 1995). Often described as the "culture" of an IHE or an academic department, these phenomena are believed to directly influence behavior within organizational units (Tierney, 1988; Berquist, 1992; Deal & Peterson, 1999). In organizational research overall, there are few empirical studies of the specific processes by which cultural phenomena within complex organizations influence sense-making, and the subsequent implications for reform implementation. If this "black box" of cultural influences on reform implementation is better understood, it may be possible to identify

[1] It is important to note that sense-making is not limited to the interface between policy signals and the individual actor, but also includes other stimuli such as conditions in the institutional environment.

specific aspects of the social and cultural context of educational organizations that act as supports or barriers to pedagogical reform. Some argue for that a precise and nuanced understanding of the influence of contextual variables on STEM education reform is of vital importance for program design, evaluation, and improvement (Katzenmeyer & Lawrenz 2006; Henderson & Dancy, in press). Understanding this process in a manner grounded in empirical research would enable evaluators to properly contextualize their findings and track cultural phenomena as both mediating and outcome variables. Furthermore, given the widespread interest in changing the culture of schools and IHEs, such an advance would give program planners and policy makers the tools to better understand their institutions and the ultimate effects of investments in reform (Deal & Peterson, 1999; Tierney, 1988; Berquist, 1992).

This paper addresses these issues by integrating cultural model theory from cognitive anthropology into an evaluation design, in order to understand the specific constituent elements of the social and cultural context of teaching, and how they shape the tacit understandings of IHE faculty or K-12 teachers. The research described here is based on an exploratory analysis of the National Science Foundation-funded System-Wide Change for All Learners (SCALE) project's activities at a West Coast comprehensive university between 2004 and 2007. This project is part of the NSF Math & Science Partnership program.

Theoretical Framework: Cultural Models within Complex Organizations

One of the shortcomings of some organizational culture research is the tendency to focus on "ideal types" of culture, thereby ascribing to entire universities or colleges a homogenous set of values and subsequent behaviors (Tierney, 1988; Berquist, 1992; Kezar, 2004). This approach, which I dub a unitary approach, is consistent with some studies of organizational culture in management and organizational science, which have been critiqued for focusing exclusively on a static and homogenous assemblage 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 (Van Maanen & Barley, 1984; Ross, 2004). The process of change in cultural forms over time is also commonly ignored, thereby obscuring our understanding of the origins and evolution of commonly held beliefs and values within organizations (Hudelson, 1997). By uncritically adopting such an approach, educational researchers risk reifying the social and cultural context of education into a non-existent and neatly bounded "culture" that does not exist.

The unitary approach to culture also fails to address a perennial problem in anthropology, which is how to account for the relationship among visible cultural forms (i.e., artifacts, ritual, symbolic forms), individual internalization of these forms through social transmission, and how cultural forms are socially transmitted to group members (Ross, 2004). Understanding this process and the likely within-group variability that ensues is vitally important to analyzing complex societies in which uniform agreement and exhibition of cultural forms are highly unlikely, in contrast to more bounded traditional societies or groups (Mintz, 1993; Ross, 2004). While researchers in cultural

anthropology and social psychology have long addressed these issues, such an approach is uncommon in educational research. Exceptions to the dominant reliance on a unitary theory of culture in education include research on the role of scientific disciplines on organizational sub-cultures (Becher & Trowler, 2006), research on academic departments as the primary venue for meaning making and the transmission of cultural form (Siskin, 1987; Van Maanen, 1984), and research on the role of individual improvisation and interpretation in sense-making processes (Weick, 1995). [2]

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 cognitive theory of culture. This approach focuses on the distribution of knowledge and beliefs across and within groups, with particular attention to the underlying dynamics of agreement patterns and the relationship between these patterns and individual cognition (Atran et al, 2005). Researchers theorize that *cultural models* are deeply held explanatory structures that are used by actors in a filtering process to omit or transform environmental stimuli to conform to the expectations of the observer (D'Andrade, 1989; Strauss & Quinn, 1998). Cultural model theory is similar to mental model theory in organizational studies. The latter posits that mental models are "deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action" (Senge, 1994:7). However, the two theories are different in that cultural model theory more systematically attends to the ways in which an individual's mental model interacts with and internalizes information from organizational context. In particular, cultural model theory focuses on the processes by which individuals internalize information from exposure to socially sanctioned and reified activities in their environment, and how, over time and through repetition, these are deeply embedded in the cognitive processes of the brain (Shore, 1996).

This 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 (Craik, 1943). The schemata that individuals internalize constitute "unconscious mental structures that underlie molar aspects of knowledge and skill" (Brewer, 1987:188). 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). Schema can also be thought of as flexible or rigid, depending on if and how personal experiences or local circumstances have reinforced a particular schema (Sims & Lorenzi, 1992). A rigid schema may be at work when an individual is not aware of their own schema (e.g., a taken for granted assumption), or their local environment reinforces or rewards its existence, which leads individuals to see no need to alter or change their schema for

[2] Researchers in both K-12 and higher education are exploring a more nuanced approach to culture in organizations. Future research should integrate findings from these two lines of inquiry and explore the similarities and differences between them.

different circumstances. In this case, even negative feedback may not be sufficient to lead an individual to self-reflection (Sims & Lorenzi, 1992).

Cultural model theorists consider schemata to be cultural when 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, 1996:47). In contrast, some schemata may be internalized from recurring personal and idiosyncratic experience that are wholly individualistic and are not shared in their details by others in community (Shore, 1996). As understood by this theory, communities are always "internally differentiated and cultural models are characterized by different degrees of sharing" (Shore, 1998:1). It is important to note that not only is the cultural model of a group internalized differently by particular members of the group, but that the models may be tacitly held and never actually surface in everyday interaction.

Importantly, there is a distinction in cognitive psychology between schemata as underlying knowledge structures and their episodic representations, generally called mental models, formed in active engagement with environmental stimuli (Brewer, 1987).[3] These episodic representations are more complex "global knowledge structures constructed at the time of input" that may be comprised of various inter-locking schema (Brewer, 1987:189). As such, an individuals' mental model may be comprised of both cultural schema and idiosyncratic schema. **Cultural models are those mental models that primarily draw on cultural schema, but they may also include idiosyncratic schema as part of its composition.** Further, there are different types of cultural models that serve different purposes for individuals as they interact with their technical, social, and cultural surroundings (Shore, 1996). Some of these model types include orientational models (e.g., spatial models, social orientation models), diagnostic models (e.g., checklists), conceptual models (e.g., theories, classificatory models), and task models (e.g., scripts for specific task completion).

An individual's cultural model is then "activated" in response to a particular type of environmental stimuli, such as a social interaction with an upper-level administrator or a memo announcing a new pedagogical reform effort. It is important to note that the composition and tenor of these stimuli are largely determined by the unique context of the organization. As a result, cultural models in use must be viewed as situated within the organizational context, and shaped by the individual's unique position in that context.[4] It is my view that these *situated cultural models* constitute the sense-making

[3] 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 in its lack of attention to variability, change, and distinctions between constituent schemata that are idiosyncratic or internalized from cultural form. We use the term here as a bridge to discussing different types of schema and the cultural model construct.

[4] This perspective is based on a conception of "organization" as a formal arrangement among people who are networked together through policies and tasks. It is important to note that this notion of organization is not without its detractors, and future work on cultural models in organizations will need to explore in greater detail if in fact policy signals from the "outside" interface with cultural models or phenomenon on

framework that individuals use in educational settings. In sum, we believe that this approach—by accounting for how individuals variously interpret, internalize, and instantiate organizational values, attitudes and knowledge—enables us to develop a more adequate understanding of organizational culture than an approach that presents knowledge as uniformly shared and distributed across a complex organization.

Implications for the field

Integrating cultural model theory into research on the social context of teaching is important because it gives researchers the theoretical (and methodological) tools with which to identify socially transmitted networks of values, beliefs, and tacit assumptions relevant to instructional practice. By avoiding an approach to cultural analysis that reifies unitary notions of culture, ignores the influence of local contextual factors, and ignores the role of individual agency in complex settings, cultural model theory offers a new analytical lens that is more aligned with recent advances in cultural anthropology and the cognitive sciences. This analysis may also suggest a way to approach the managerial impulse to "shape" the culture of an organization by integrating traditional efforts to change or alter the structural, social, and symbolic milieu in which individuals operate, with a focus on the actual cognitive processes that constitute individuals' "habits of mind."

As a result, this paper does not contain an account of the "culture" of an entire organization or even its administrative sub-units, but instead, considers the pervasive cultural models held by group members pertaining to a specific domain under considerations. Further, these models are explicitly situated within and linked to local contextual factors, so that program planners, policy makers, and evaluators can see more precisely how the mechanics of cultural process operate within a given institution. By theorizing that organizational change may be dependent upon individuals with similar mental models who either passively or actively act as change agents, this study builds upon previous work organizational innovation (Rogers, 2003) and institutional change in higher education (Clark, 1998). Cultural model theory provides the tools to empirically investigate this process in a way that allows practitioners and leaders to identify specific cultural schema within their organizations that exert positive or negative influences on the domain under consideration (e.g., teacher education programs in IHEs). A cognitive approach to culture is particularly suitable for evaluating systemic reforms that SCALE is attempting in higher education for two reasons: 1) Faculty are particularly autonomous agents who exhibit high degrees of variability and independence that may be in conflict with the unevenly shared cultural models of their department and other groups; and 2) SCALE can be thought of as attempting to introduce into the environment a new cultural model which individual faculty may internalize in various ways.

Methodology

The question of how cultural 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

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the "inside."

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

experiments involving research subjects making causal judgments (Proctor & Ahn 2007) or comparing subjects recall of critical events over time (Hamilton & Fagot, 1988).[6] 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 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).

The research questions guiding this study are as follows:

1) What are the cultural models exhibited by science faculty salient to pedagogical improvement in STEM instruction?
2) How are these cultural models transmitted or reinforced within a group?
3) What are the local contextual factors related to these models, and how do they support or inhibit the goals of the intervention?
4) How do these cultural models affect faculty sense-making of the SCALE intervention and their ultimate participation in the intervention?
5) What effects, if any, did the intervention have on the cultural models of participating science faculty?
6) What are the most propitious 'levers of change' regarding cultural models at this university?

This research took place at one of the SCALE IHE partners, a small comprehensive university on the West Coast. This IHE is located in a predominantly minority and working-class area and has 44 undergraduate majors, 25 Master's degree programs, and several credential programs. This paper is a re-analysis of the data originally collected and analyzed for a larger evaluation qualitative case study that included a process and outcome evaluation of SCALE, an analysis of the institutional context's relationship to SCALE, and an exploratory analysis of cultural models. The original study and this current paper employed similar methods and drew on identical data sets, but differed in how cultural models were conceptualized and reported.[7] This research is a repeated cross-sectional qualitative case study design.

The primary unit of analysis for this research is the individual, and the sampling universe for this research included all IHE personnel at this institution. The data collected for this study are in-depth interviews, documents, and field observations of informal institutional settings and activities. The interviews were semi-structured using a standardized interview protocol for different types of respondents (i.e., STEM faculty, education

[7] The original case study provides a much more exhaustive account of SCALE activities at this IHE and is not limited to an analysis of cultural models.

faculty, administrators, etc.). Documents related to the university were also collected and analyzed, including reports from the university's Office of Institutional Research, strategic plans, external evaluations of related programs, and recruitment, tenure, and promotion (RTP) policies. Forty interviews with 29 individual faculty and administrators were conducted in mid-2005 and early 2007. The interviews were semi-structured and focused on eliciting respondent's experience of their institution, perspectives on STEM education and inter-college collaboration. A typical question was "Can you tell me the factors that influence your approach to planning and delivering lessons in your STEM courses?" [8] The analytic procedures for this research drew on established procedures of qualitative analysis, and integrated them into a multi-method analytic process that was uniquely suited to answer the research questions. 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 models (Strauss & Quinn, 1998).

Using the findings from preliminary analyses of data from all three IHEs, I developed a coding paradigm called the Cultural Context Framework (CCF). 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 data we had collected. The classification framework is organized into 6 broad categories that include more specific topics that are sub-codes used in our analysis: external environment, internal structure, resources (i.e., material, social), collective values, individual perspective and sense-making, and practices**. Topics pertaining to the external environment, internal structure, resources, and collective values provided the raw data for identifying the contextual factors salient to faculty's cultural models.** Using this coding paradigm I identified patterns in the data and relationships among discrete themes by conducting matrix queries in NVivo to identify high incidences of cross-coded text, and by constantly comparing these themes with field and margin notes (Bernard, 2002). I then conducted a causal network analysis of the data by situating the themes and their inter-relationships within the CCF and at three points in time: the antecedent condition prior to the reform, the reform as the mediating condition, and the outcome condition after the reform (Miles & Huberman, 1984). This allowed for contextual factors to be explicitly linked to one another (e.g., tenure policy negatively influences teaching) and to the SCALE project. These attributions were based on respondent statements and analyst inference.

Data sources or evidence

The analytic procedures for the cultural model analysis involved the following different "passes" at the data: (1) All 40 interviews (with 29 unique individuals) were analyzed to identify the salient factors in the institutional context, (2) 13 interviews (9 unique

[8] By leaving "factors" ambiguous in the interview protocol I was explicitly soliciting a respondents' conception of what is supporting and/or constraining their practice. The connections volunteered between the contextual factors and each respondent's practice provided micro-examples of cultural models at work in regards to the policy intervention (SCALE).

individuals) with science faculty to identify the cultural models among this group, and (3) 7 interviews (with 4 unique individuals) to identify any SCALE-related changes to these cultural models. One of the most common ways researchers use dialogue as a way to empirically observe cognitive processes can be done through analyzing interview transcripts (Brewer, 1987; Quinn, 2005). This research builds on this tradition and extends these lines of research by explicitly linking cultural models to specific factors in the local institutional context. I developed an exploratory method to assess the content and contextual underpinnings of cultural models, their role in an intervention activity, and if and how they changed over time. *I strongly emphasize that this is an exploratory effort to identify a cultural model, undertaken in order to heighten understanding of the role cultural models play in policy implementation.*[9]

Working within the interpretive tradition of Strauss & Quinn that uses natural discourse to identify cultural models (1998, 2005), I analyzed the transcripts in two CCF categories—*collective values and beliefs* and *individual perspective and sense-making* - about their approach to STEM instruction. I paid particular attention to statements about the origins of these approaches, and how the local context shaped that approach. I then focused on statements that expressed a core value, belief, or knowledge about STEM pedagogy, and paid particular attention to its origins (e.g., from outside or inside of the institutional boundaries). Most importantly, I used two criteria to determine if the schema was "cultural" and not idiosyncratic: 1) Evidence that core value, belief or knowledge is "part of the stock of shared cognitive resources of a community" if at least 3 respondents expressed the sentiment or conviction; and/or 2) if a single respondent's schema was related to an instantiated cultural model. Then, using the causal network analysis method, I identified contextual factors that were related to these schemata. Finally, in order to verify the credibility and viability of my findings, I utilized an approach common in cultural model research, and asked respondents to review my findings to verify or challenge their accuracy (D'Andrade, 1995).

<u>1) Cultural models exhibited by science faculty (and their constituent schemata)</u>
The analysis resulted in several different cultural schema that science faculty held for various topics ranging from science instruction, student preparedness, their own graduate school mentors, and the pressures of tenure and promotion. From this panoply of data, I identified the core schema that comprised 3 cultural models salient to pedagogical improvement in STEM instruction.

The core schema comprising the model for *teaching undergraduate science*:

- Instruction in a STEM field is based on transmitting facts and direct involvement with lab- or field- based experiences (cultural schema);
- Accomplishment in science, and legitimacy, is acquired through research accomplishments and publications (cultural schema);

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

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

The core schema comprising the model for *interacting with education faculty:*

- There is some value in the learning sciences but little to no understanding of how people learn (cultural schema);
- College of Education (COE) faculty have the tendency to be impatient, arrogant, and/or unfamiliar with
  STEM disciplines (idiosyncratic schema).

The core schema comprising the model for *STEM education reform*:

- There is an uncomfortable tension between the needs of education and those of the STEM disciplines (cultural schema);
- Improving instructional practice would greatly benefit the public, specifically future K-12 teachers (cultural schema).

Again, I am not claiming that these cultural models are monolithic cognitive structures that individual faculty adopt, exhibit, and employ to guide their behavior. Instead, they represent cognitive networks that respondents may use interchangeably with other models in any given context.

2) How the cultural models are transmitted

Respondents identified two key ways that these cultural models were socially transmitted: doctoral training programs at their alma maters, and academic departments within their current institution. In their doctoral training programs, science faculty experienced a pedagogical approach that was almost exclusively focused on using lecture and a didactic method of pedagogy, which is the source for the cultural model for *teaching undergraduate science*.

> I had a PhD in chemistry and had never even really known anything about pedagogy and that kind of stuff and I was thrust, of course, into the classroom. They assume one can teach. (STEM faculty)

Graduate training also implicitly conveyed a value system that placed scholarship in the "hard" sciences much higher than the "soft" sciences. This was conveyed through an explicit disdain for the social sciences in general, and education in particular, and exacerbated by an almost complete lack of interaction with colleagues from these disciplines. This experience led to the formation of the cultural model for *interacting with education faculty*.

> They're [STEM and education departments] really separate, I would be surprised if most of the [STEM] faculty at [a major research university] and many places, even know the names of any of the people in education. (STEM faculty)

Both of these models were then reinforced within faculty's academic departments at this IHE, despite the fact that the institution was a comprehensive university with an explicit teaching mission. As a result of the recurring reinforcement of these cultural models, it appears that they are particularly rigid in terms of their "taken-for-granted" nature. Finally, the cultural model for *STEM education reform* is primarily transmitted within the academic department, as faculty experience "waves" of educational reforms in their IHE and subsequently develop opinions about the policies and programs driving pedagogical reform.

3) The local contextual factors related to the cultural models

The primary contextual factor that respondents cited as being pertinent to STEM education reform does not bear an obvious relationship to the aforementioned cultural models, yet it exerts an unmistakable influence on faculty's sense-making process. The demanding workload of faculty at this IHE includes teaching 4 courses a semester, advising responsibilities, conducting a research program, and participating in professional and community service. Additional pressure is placed on faculty as state budget cuts and the institutional drive to raise their visibility among other IHEs is leading administrators to demand that faculty conduct more active research programs and publish their findings. As a result, the workload is the primary contextual factor through which the cultural models (and STEM education reforms) must be viewed.

Another local factor that is particularly salient to the cultural model for *teaching undergraduate science*, and for *STEM education reform*, are departments' recruitment, tenure, and promotion (RTP) policies. The RTP policies act in concert with workload pressures to force faculty to prioritize their activities, and improving their own teaching skills or participating in reform efforts are generally at the bottom of the list.[10]

> There is again a hierarchy and this university as a whole values 'the scholarship of education,' but at the departmental level if you come in with an article in a pedagogical journal and an article in the primary research journal in your field, I can tell you which one is going to be more highly considered. That's by no means denigrating the quality of the journal; it's just that if you're a scientist that's where you're supposed to be publishing. It's just that if you're a scientist that's your currency. (STEM faculty)

This sentiment illustrates that the cultural schema for scientific legitimacy is particularly rigid. Other contextual factors related to the cultural model for *interacting with education faculty* include state policy that divided responsibilities for teacher preparation between STEM (instruction in content) and COE (instruction in pedagogy) departments, and a local history of conflict between the STEM and COE departments. Indeed, several respondents noted that this particularly IHE had a relatively poor level of collegiality not only between different colleges and departments, but also within departments, which has implications for inter-disciplinary collaborations and encounters.

[10] While the tenure status of faculty determined whether or not this particular factor was of immediate importance to their career, the consideration of status and scientific legitimacy transcended most concerns.

> Within the sciences and between the schools, the amount of contact is minimal and so (we lack) any kind of professional interaction where we get to see our colleagues doing what they do. I think it is probably valuable to remind ourselves that we all benefit from (these interactions). (STEM faculty)

Another important contextual factor at this IHE was the pre-existing cohort of faculty in the mathematics department committed to STEM pedagogy. These faculty had been carefully recruited and cultivated by a faculty member committed to seeing mathematics education improve at this IHE and nearby K-12 districts. A variety of STEM education reform programs had been operated out of the Math Department by this cohort, so most STEM respondents were somewhat conversant in STEM educational reform efforts. While it did not completely assuage existing skepticism about such efforts, the fact that fellow "scientists" were involved in reform activities softened the cultural model for STEM education reform. Further, this cohort of math faculty constituted a community of math educators within the Math Department, which respondents indicated provided an important social support system to these faculty.

Additional factors of note included the presence of active pedagogical reform initiatives at this IHE based out of the Provost's office which resulted in a campus-wide sentiment that reform was actively promoted and supported "from the top." This sentiment was closely linked to a wave of faculty retirements that were bringing large numbers of new and potentially reform-oriented faculty members onto this campus. Finally, the structure of pre-service programs and course sequences which did not require interactions and/or collaborations between STEM and education faculty, as content and pedagogical preparation occurred separately in different degree and/or credential programs. The most logical venues for collaboration were campus-wide committees for the Liberal Studies Program and teacher preparation in general, but these committees involved very few STEM faculty and were sparsely attended.

<u>4) How the cultural models affected faculty sense-making of SCALE</u>

As the SCALE project was introduced to this IHE, the information processing activities of the respondents was schema-driven, as opposed to respondents having to create new interpretive frameworks on the fly. That is, they interpreted the SCALE project through their existing cultural models. For example, when the SCALE project was introduced to this IHE, it was primarily through the cohort of Math Department faculty. This was critical in recruiting some of the science faculty to participate in the effort, as the cultural schema pertaining to scientific legitimacy is a particularly strong sense-making filter for STEM faculty.

> Q: So do you think you were more apt to participate because [the recruiter] was in the math department and not in the college of education?
> A: Yes. You know, for better or for worse, I think that's true.

My analysis at this stage then focused on a series of professional development workshops for STEM faculty, led by an experienced College of Education (COE) faculty member, and was explicitly designed to develop the faculty as reflective practitioners (Schon, 1983; Cochran-Smith & Lytle, 1999). It is in these workshops where the sense-making processes of faculty were most visible, and where this process was particularly pertinent to understanding if and how the SCALE project was affecting any changes to the social and cultural context of teaching at this IHE.

The facilitator of these workshops had been previously involved with faculty professional development on this campus, where she had trained faculty members across campus to infuse skills such as writing into their course design and instruction without "destroying their syllabus." This focus on providing professional development in a way that acknowledged and respected the participants' syllabi and existing skill sets became a critical feature of the workshops. Drawing on previous experiences, the facilitator designed a series of four professional development workshops specifically for STEM faculty. The workshops addressed the following topics: (a) classroom management, (b) active learning strategies, (c) teaching for transfer, and (d) cooperative learning. The goal of these sessions was to improve the professional teaching practices of STEM faculty at this IHE by helping them develop strategies for engaging students actively in their own learning. The facilitator also emphasized the idea of backwards design where faculty, at the outset of a course, identify measurable outcomes for student learning, and then design the course and plan their instruction to get them there. The facilitator noted that because this process requires clarity from instructors about what is expected, and that "clarity in designing curricular learning outcomes is not a natural skill" for many IHE faculty, she decided that helping participants become aware of the pedagogical techniques that they implicitly use or rely upon was an important task.

In this way, the facilitator led respondents in surfacing their tacit assumptions regarding STEM instruction, and modeled an inquiry-based pedagogical approach that was then practiced in both workshops and the participants' classrooms. The workshop participants reported being pleasantly surprised that the facilitator treated them as educators and not simply as STEM content experts. Upon being perceived this way, they began to experience themselves and their instructional practice in terms of pedagogical principles. In addition, the facilitator skillfully negotiated existing tensions and fears that the STEM faculty may have had regarding professional development, which mitigated the cultural schema centered on the impatience of education faculty.

The COE facilitator also successfully surfaced previously unconscious assumptions about teaching and learning, which is an important step in beginning to effect change in the tacit assumptions that inform an individual's practice. This process brought into bold relief the presence of the cultural model for *teaching undergraduate science*. Then, by introducing and modeling a more inquiry-based approach to STEM instruction, the facilitator demonstrated a pedagogical method that was remarkably similar to lab- or field-based instruction, which served to "meet people where they are" in terms of introducing new pedagogical methods.

5) Potential effects of the SCALE intervention on faculty cultural models

It is important to note that multiple interventions were occurring at this IHE during the SCALE project, to which faculty may or may not have been exposed. As a result, assessing the effects of the SCALE intervention on faculty cultural models must take this reality, and the potential influence of extra-institutional forces (e.g., societal trends, circumstances in individual's own life) into account. While the SCALE project did not explicitly seek to change the cultural models held by groups of faculty, both the MSP program and SCALE do have "culture change" as one of their primary goals. Since this evaluation takes a distributional view of culture as opposed to a categorical perspective, we now examine the evidence for changes to the cultural models held by participating science faculty. This evidence is based entirely on respondent self-reports of changes in their own perspectives and behaviors. We report only minor shifts in perspective and understanding, which is consistent with the research on the difficulty of affecting behavioral change in education, and the resiliency of culture (Stensaker & Norgard, 2001; Tobias, 1992). Based on my analysis I identified shifts in the following cultural models, and the specific schema that were addressed and challenged by the intervention.

The cultural model for *teaching undergraduate science*:

- Instruction in a STEM field is based on transmitting facts and direct involvement with lab- or field- based experiences.

The cultural model for *interacting with education faculty:*

- There is some value in the learning sciences but little to no understanding of how people learn;
- COE faculty have the tendency to be impatient, arrogant, and/or unfamiliar with STEM disciplines.

The cultural model for *STEM education reform*:

There is an uncomfortable tension between the needs of education and those of the STEM disciplines.

We note that perspective shifts of these types may alter faculty's cultural models pertaining to teaching and learning, and the potential importance of such changes should not be underestimated. Understanding the rationale for one's teaching practice is an important step in becoming a reflective practitioner (Schon, 1983). Becoming informed in this manner is an important precursor to minimizing the inimical effects of stereotypes and assumptions that people hold for one another and for developing an awareness of one's own tacit assumptions (Spillane, Reimer, Reiser, 2002). At the same time, we are cautious about assuming that attitude shifts of this type automatically translate into changes in classroom practice: the literature on learning indicates that the relationship between teacher thinking and classroom practice is unclear (Kane, Sandretto, and Heath, 2002).

A particularly important outcome of the SCALE project was not that it altered faculty cultural models per se, but that it altered a key contextual factor: professional networks of STEM faculty engaged in pedagogical activities. Prior to the SCALE project, there was

no clearly identified community of science faculty engaged in and conversant with STEM education reform efforts. The only such community of STEM faculty at this IHE was in the Math Department. By forging a community of science faculty who supported one another, exchanged ideas, and continued to communicate after the workshops were over, SCALE successfully created a milieu in which science faculty's cultural models for STEM education could continue to grow and evolve. This would not have been possible without some sort of structural venue in which these groups could meet.

6) Propitious levers for change regarding cultural models at this site

A key question driving this research program is how to apply findings to better understand and possibly re-design the social context of teaching. Based on my analysis of the SCALE project at this comprehensive IHE, it is apparent that some of the cultural models and the specific contextual factors in which they are embedded can be viewed as propitious levers for change. In particular, it is important for program planners and policy makers understand the importance of the faculty workload, the cultural schema of scientific legitimacy and credibility, and the importance of professional networks as support systems for faculty who are "going out on a limb" by participating in STEM education reforms. By acknowledging and addressing these factors, I speculate that reform agents could engage and possibly change the cultural models that are salient to STEM education reform, and thus more likely achieve their goals at the local level. In terms of specific strategies for affecting change in STEM education, the STEM faculty professional development workshops appear to be particularly effective. However, implementing such a program relies heavily on a single factor that may be difficult to replicate: a skilled facilitator who can illuminate, engage, and gently change the existing cultural models of STEM faculty.

Conclusions

This research contributes both scientific and actionable knowledge about how the socio-cultural context of higher education influences change initiatives at the organizational and individual levels. This work builds on current research on the cognitive approach to institutional change by using cultural models as a way to account for variability and individual agency among organizational members, and by linking individual cognitive processes to contextual variables. This analysis demonstrates the resilience of cultural models and how the local context serves to reinforce and reproduce them. This analysis also suggests that "shaping" the culture of an organization that focus on efforts to change or alter the structural, social, and symbolic milieu in which individuals operate, should also pay close attention to the actual cognitive processes that constitute individuals' "habits of mind," which may be much more difficult to change. It is especially important to realize that cultural models operate according to a logic that is most likely inaccessible to leaders and change agents (unless they are insiders to that cultural group) which may require leaders to employ a flexible and multi-faceted toolkit of "frames" through which to analyze their organizations (Bolman & Deal, 2003).

Ultimately, the enduring lesson from SCALE is that efforts to change the cultural and social context of teaching in higher education should integrate attempts to bring together individuals who hold diverse cultural models in an officially sanctioned setting, ideally

with a high-ranking facilitator who understands both groups, to collectively work on a common challenge or task. On a broader scale, I postulate that the enacted theory of change for SCALE was that to bring about improvement that is sustained over time, change must be pursued simultaneously on structural, social, and individual levels. This approach is consistent with research findings on institutional change processes in educational organizations (Seymour, 2001; Gamoran et al, 2003).

While the SCALE program was fortuitously aided by pre-existing conditions at this IHE, such as administrative support for reform and an influx of new faculty due to retirements, SCALE successfully planted the seeds for future changes at each of these critical levels. A particularly important point of support was the formation of a cohort of science faculty who are now interested in STEM education, which is an important social component to reinforcing the observed changes in the cultural model. However, certain factors at this IHE remained unchanged that may provide resistance to diffusing or incorporating these changes at the departmental level. The primary points of resistance are the demanding workload that minimizes faculty engagement in programs such as SCALE, and growing pressure on faculty to focus on research accomplishments. I postulate that this pressure is related to the prevailing cultural model of many STEM faculty and administrators regarding the primacy of research and its role in establishing and reinforcing the scientific credibility of individual faculty, departments, and the institution.

I further speculate that the implicit theory of change of the NSF's Math & Science Partnership program, that educational reform in STEM education is best accomplished through inter-disciplinary and inter-institutional partnerships, is over-simplified with respect to the cultural models at work in each domain. This research provides a way to rectify this oversimplification. To help assure the success of this theory of change as it unfolds at this IHE, I proposed the following recommendations: (a) leaders should ensure the continuation of the professional development workshops for STEM faculty by institutionalizing this activity, guaranteeing funding for faculty release time, and ensuring that a highly skilled facilitator is available to negotiate the socio-cultural divisions between the STEM disciplines and the learning sciences; (b) leaders should target specific departments and clusters of faculty for participation in these workshops in order to achieve critical mass and minimize departmental resistance to pedagogical change; and (c) to nurture change, campus leaders should consider the viability of policy levers such as those afforded by the accountability movement, while simultaneously finding ways (such as the first and second recommendations above) to foster changes in the prevailing cultural model for STEM instruction so that faculty are amenable to such efforts.

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