WCER Working Paper No. 2012-8
August 2012

Cultural Models of Teaching and Learning: Challenges and Opportunities for Undergraduate Math and Science Education

Joseph J. Ferrare
Associate Researcher
Wisconsin Center for Education Research
University of Wisconsin–Madison
ferrare@wisc.edu

Matthew Tadashi Hora
Researcher
Wisconsin Center for Education Research
University of Wisconsin–Madison
hora@wisc.edu

Wisconsin Center for Education Research
School of Education • University of Wisconsin–Madison • http://www.wcer.wisc.edu/

WCER working papers are available on the Internet at http://www.wcer.wisc.edu/publications/workingPapers/index.php. Recommended citation:

> Ferrare, J. J., & Hora, M. T. (2012). *Cultural Models of Teaching and Learning: Challenges and Opportunities for Undergraduate Math and Science Education* (WCER Working Paper No. 2012-8). Retrieved from University of Wisconsin–Madison, Wisconsin Center for Education Research website: http://www.wcer.wisc.edu/publications/workingPapers/papers.php

The research reported in this working paper was supported by funding from the National Science Foundation (award no. DRL-0814724). Any opinions, findings, or conclusions expressed in this paper are those of the author and do not necessarily reflect the views of the funding agencies, WCER, or cooperating institutions.

Cultural Models of Teaching and Learning: Challenges and Opportunities for Undergraduate Math and Science Education

Joseph J. Ferrare and Matthew Tadashi Hora

As we go about our day-to-day lives we encounter incredible complexity in our relations with others and our surroundings. Yet, more often than not, we move from one situation to the next without feeling the full burden of this complexity because we have constructed models—or "theories"—of how people, events, and objects fit together. Social scientists often refer to these as *cultural models* because they consist of shared information and are internalized through patterns of socialization within and between groups. Consider, for example, that on the first day of a new school term thousands of students filter into lecture halls, find seats, and wait for someone to assume responsibility at the front of the room. This impressive coordination of action occurs without explicit instructions because each student has a cultural model for how people and objects typically fit together in this particular situation. These models perform valuable social and cognitive work with tremendous efficiency, which in turn allows us to take on more complex practices. Of course, the world does not always work so smoothly—sometimes our cultural models conflict with other models, objects, and events. Such conflicts help to remind us that cultural models are often deeply political (Gee, 2004a).

Social scientists from across the disciplinary spectrum have contributed to a rich body of literature focusing on the theoretical and applied aspects of cultural models (for a general introduction see D'Andrade, 1995). In education, researchers have drawn upon cultural models theory to describe and enhance literacy practices (e.g., Curry, 2002; Gee, 2004b), student achievement (e.g., Ogbu & Simons, 1994), and cross-cultural relations (e.g., Fryberg & Markus, 2007), among other topics. However, higher education research—particularly in the area of undergraduate instructional practice in the math and science disciplines—has yet to fully appreciate the utility of cultural models theory. In this paper we argue that cultural models theory is useful to understand and transform instructional practices in these fields, particularly because most math and science instructors have received little, if any, pedagogical training. More specifically, we make the case that math and science faculty[1] espouse and enact (largely tacit) cultural models of teaching and learning with great consequences for the educational experiences of students.

The construction of this argument is built around three specific questions: (1) What cultural models do math and science instructors have for how students best learn the key concepts in their respective fields and for the most effective ways to introduce students to those concepts? (2) To what extent are these models activated and/or restricted by desirable and

[1] By *faculty*, we mean all people who hold undergraduate teaching positions—whether full- or part-time, tenured or untenured—in postsecondary institutions. Throughout this paper we will use the terms "faculty" and "instructor" interchangeably.

undesirable features within instructors' organizational environments? (3) How might our understanding of these cultural models inform the efforts to transform pedagogical practices in the math and science disciplines?

To address these questions we drew upon interview and classroom observation data collected from 41 instructors from math and science disciplines across three research-intensive universities. We began by using cluster analysis and multidimensional scaling to analyze thematic codes derived from the interviews. The results illustrate a "theoretical space" of cultural models that is organized by multiple principles of differentiation.

In the next phase, we drew upon classroom observation data and interview transcripts to explore how the models of three instructors guide their pedagogic decisions and practices. These "case analyses" unpack the thematic codes by quoting extensively from the interview transcripts. In addition, we used graphing techniques from social network analysis to illustrate the different configurations of teaching methods, cognitive engagements, and instructional technology use that constitute each participant's classroom practice. These data are brought into conversation with the interview transcripts to demonstrate how the instructors' cultural models of teaching and learning are activated, mediated, and constrained at the intersections of cognition, social practice, and organizations.

The results from the analysis are suggestive for those interested in undergraduate education, particularly the math and science disciplines. The cultural models of teaching and learning espoused and enacted by math and science faculty are especially salient because these educators typically have not had formal pedagogical training. Indeed, the interviews in this study were highly revealing in that many of the 41 participants reacted to the questions as though they had never been asked to articulate their thoughts on teaching and learning. Of course, some instructors were quite sophisticated in the way they articulated their models. In both cases the results offer researchers, instructional designers, and policymakers insights into how math and science faculty "theorize" student learning and their own role in that process. For example, these insights can be used to help the ongoing (and resource intensive) efforts to design and implement instructional reforms. While it is reasonable to view the "culture of instruction" in these disciplines as constraining such changes, we argue that instructors' cultural models of teaching and learning also represent important opportunities toward this end.

Cultural Models and Education Research

Scholars of education have examined the ways in which cultural models shape a variety of educational practices and outcomes. In general, these researchers have conceptualized cultural models of education as socially constituted meanings about education reflected in individual feelings, thoughts, and actions that are reinforced in publicly available forms (Fryberg & Markus, 2007, p. 215). By far the most common application of cultural models theory in education can be found in the field of literacy studies. Inspired to a great extent by the work of sociolinguist James Gee (1996, 2004b), literacy researchers have used cultural models as a theoretical tool to highlight the challenges faced by educators working at the intersections of

multiple forms of literacy. Examples include studies highlighting the mismatch among cultural models within English as a Second Language classrooms (Curry, 2002), the ways cultural models of quantifying literacy shape early childhood education policies (Gomez, Johnson, & Gisladottir, 2007), and how cultural models mediate family and school literacy practices (Rogers, 2001).

Sociologists, psychologists, and social psychologists have examined racial and ethnic differences in cultural models of education to gain a deeper understanding of disparities in patterns of educational achievement that include and extend beyond literacy. For instance, Ogbu and Simons (1994) found quantitative differences between voluntary and involuntary minorities' (referring to historical patterns of immigration and enslavement) cultural models of education, which the researchers used to help explain persistent differences in school performance. Fryberg and Markus (2007) compared the cultural models of education among American Indian, Asian American, and European American undergraduate students in order to suggest how educational settings might be structured in ways that are more attuned to how these individuals and groups conceptualize "success" in education. In a similar spirit, Gallimore and Goldenberg (2001) argue that analyzing cultural models—in relation to cultural settings—has the potential to provide policymakers and educators with a more concrete understanding of how to "change the culture" of educational organizations through programs and interventions.

While much of the literature has focused on the cultural models of students in relation to schools, some scholars have explored how teachers' cultural models pose challenges for teacher training and educational reform at the K–12 and postsecondary levels. In the context of science teacher education, for example, Bryan and Atwater (2002) argue that teachers' cultural models of how different students learn and the most appropriate responses to such diversity has a profound impact on pre-service teacher training and, ultimately, classroom practices. In this paper we put forward a similar argument but focus on a sample of faculty that primarily teach introductory undergraduate courses in math and science. Although some researchers have paid close attention to the relationship between teaching practices and culture in higher education (e.g., Trowler, 2008; Umbach, 2007), the literature lacks a targeted analysis that connects these practices to instructors' cultural models of teaching practice and student learning. In the next section we delve more deeply into the literature on cultural models and then specify the types of cultural models that will be analyzed.

The Interface of Culture and Cognition: Cultural Models Theory

The development of cultural models theory has been guided by a desire to understand how individuals process and organize cultural knowledge. This "cognitive turn" in cultural theory was initially—and still is to some extent—controversial. While many interpretive anthropologists were claiming that "culture is public" (most notably Geertz [1973]), cognitive anthropologists began looking at the ways in which cultural knowledge is transformed privately in the mind (see D'Andrade, 1995). In particular, the latter researchers sought to understand how cultural knowledge is organized into cognitive structures (often referred to as "schemas") held in long-term memory and activated in specific situations and social environments (e.g., groups or

organizations). Bringing together cognition and culture under a single umbrella thus provided researchers with an opportunity to theoretically unify processes and practices that traditionally have been kept apart by disciplinary boundaries.

Cognitive anthropologists working in this area of research define cultural models as simplified "theories" about relations among people, practices, and/or events that are distributed within and among groups (Quinn & Holland, 1987). The cognitive structures that comprise cultural models are linked to (prototypical) simulations in our minds that help us assemble meanings and act upon them in social transactions. While cultural models generate meanings, explanations, and practices in a similar fashion to any scientific theory, they are often implicitly held and thus difficult to articulate. Although individuals often find it difficult to fully articulate their cultural models at a theoretical level, they can usually offer insights into the workings of their cultural models through judgments, perceptions, and explanations of specific situations (D'Andrade, 1992, p. 34). In this sense, cultural models frequently operate as a form of "practical reason" (Bourdieu, 1990; Sayer, 2011).

Cognitive anthropologists emphasize that many cognitive schemas—including cultural models—are acquired through socialization processes arising out of interactions in specific situations and social environments. The socialization processes through which cultural models are adapted are complex and varied. This is because "(1) public social messages may change, be inconsistent, or hard to read; (2) internalizing these messages does not mean copying them in any straightforward way; and (3) motivation is not automatically acquired when cultural descriptions of reality are learned" (Strauss, 1992, p. 10).[2] Thus, even though the internalization of cultural models is constrained by socialization processes and norms, the way that individuals acquire cultural models remains contingent and, at times, contradictory. Indeed, actors often transform cultural models during acquisition as these models interact with other models and bits of cultural knowledge.

Cultural models have a causal texture in that they allow us to act in the world without having to fully consider all possible actions at the same time. These models assemble situated meanings on the spot, which in turn enable us to make sense of complicated processes without necessarily considering every detail (Gee, 2005). This does not mean that cultural models always generate reliable meanings or that knowing an individual's cultural models makes his or her behavior predictable in every situation. To the contrary, cultural models are often inconsistent, incomplete, and/or exist in conflict with other cultural models. Sometimes the conflicts and ambiguities in cultural models lead people to transform or construct models in the moment, while at other times they generate ambivalence and irony (Shore, 1996, p. 305). Thus, cultural models are not fixed entities that always translate into specific actions. Both actions and cultural models, rather, are mediated through interactions with other models as well as constraints and affordances in the environment (Gibson, 1986; Greeno, 1994).

---

[2] This insight has long been a central tenet among cultural Marxists, too (see, e.g., Gramsci, 1971; Willis, 1977).

In addition to conflicts and ambiguities within and between individual cultural models, these models tend to be distributed unevenly within and between social configurations. That is, there are divisions of labor to cultural knowledge that differentiate who needs to know what. For cognitive anthropologists such as D'Andrade (1984), these social structures are aspects of the organization of cultural meaning systems—"the achievement of systematicity across persons through meanings" (p. 110). Critical theorists are likely to add—or at least clarify—that these social structures are also the means by which certain forms of cultural knowledge are maintained as scarce commodities and legitimate symbolic domination (e.g., Bourdieu, 1984). Thus, just as we rely on our cultural models to perform important cognitive work, we also rely on social structures to perform the consequential social work of dividing the cognitive labor within and among groups. There is, then, a duality between social structure and culture in which the patterning of social interactions and affiliations happens alongside differentiated cultural meanings and strategies (Martin, 2009; Mohr & Duquenne, 1997).[3]

The theoretical understanding of cultural models articulated thus far suggests that the initial "culture as public or private" dichotomy is misleading and empirically inaccurate (Shore, 1996). Rather than perceiving culture as inhering in public information, cognitive structures, or symbolic systems, a more compelling view in the literature locates culture in the interactions among each of these realms (DiMaggio, 1997, p. 274). An examination of cultural models in any context thus involves understanding cultural knowledge as distributed at the individual and group levels, as well as existing at the intersections of organizational contexts, social practices, and cognition. It is at these intersections that we can gain insight into the ways that cultural models are activated and adapted in relation to constraints and affordances in social and organizational environments. In this sense, cultural models—as forms of social cognition—shape individuals' perceptions and judgments pertaining to the qualities of other individuals, groups, and environmental features (Martin, 2011, p. 241).

Specifying Cultural Models of Teaching and Learning

In this paper we examine instructors' cultural models of teaching and learning through the assumptions they make about the ways students best learn the key concepts of their disciplines and the most effective ways to introduce students to those concepts. Thus, while we will use the generic term "teaching and learning" for the sake of brevity, our conceptualization of teaching and learning in this case refers to these more specific assumptions. To this point, though, we have spoken rather generally about cultural models. In order to investigate cultural models of teaching and learning among math and science instructors it will be helpful to identify

[3] Bourdieu (1988) makes a similar argument in the context of higher education in which he links the cultural meanings and strategies of faculty to their social position within academic fields.

the form and functional work that these models perform as distinct from other types of models. For this task we use the typology of cultural models developed by Shore (1996, pp. 46–66).[4]

The types of cultural models investigated below are examples of special-purpose models comprising a combination of expressive/conceptual models and task models (Shore, 1996, pp. 61–66). Expressive/conceptual models designate crucial yet often tacit information and experiences within (and sometimes between) certain communities. Among the different types of expressive/conceptual models, undergraduate instructors' cultural models of teaching and learning can be defined more specifically under the category of theories. This type of expressive/conceptual model helps to simplify complex processes and interactions. While scientific theories are an example of such a model, the models of teaching and learning discussed below are closer to folk theories because they comprise largely tacit knowledge that instructors acquire through a variety of prior experiences. This makes folk theories more resistant to challenges than scientific theories, a point that has implications for pedagogical reform.

Some components of the cultural models of teaching and learning discussed below can also be conceptualized as task models. As the name suggests, task models organize strategies for completing practical tasks. "Scripts" are a type of general performance task model that are commonly drawn upon (often implicitly) in instructional situations.[5] For instance, many mathematics instructors have a script for introducing students to a new theorem. One such script proceeds as follows: The theorem is introduced and proved as an abstract form and then followed up by working through a series of example problems that demonstrate how the theorem works. Students are then assigned problem sets that require them to work through more example problems germane to the theorem. This script is often associated with an expressive/conceptual (theories) model that assumes students learn best outside of the classroom through solitary practice and repetition. The cultural models of teaching and learning explored below each consist of a theory of student learning and a script for facilitating that learning. In practice, the line between expressive/conceptual and task models may not be so clear, but the analytical distinction is important in order to understand the different kinds of work actually done by cultural models of teaching and learning.

Methods: Analyzing Cultural Models of Teaching and Learning in Theory and Practice

Researchers interested in examining cultural models have used a variety of methodological strategies. These strategies include scaling of judged similarities and clustering of folk taxonomies (e.g., see D'Andrade, 1995), consensus modeling (e.g., Atran, Medin, & Ross, 2005; Weller, 2007), as well as a variety of discourse analysis techniques (e.g., see D'Andrade & Strauss, 1992; Gee, 2005). In this paper we draw upon multiple tools from within

[4] As with most conceptual typologies there are substantial gray areas between types of models. Indeed, we found many such areas in Shore's typology. Nonetheless, Shore's conceptual mapping of cultural models is helpful and moves us beyond the generalized definition presented thus far.

[5] Abelson (1981, p. 717) defines a script more generally as "a hypothesized cognitive structure that when activated organizes comprehension of event-based situations."

and outside the cultural models literature to construct the cultural models of teaching and learning among all instructors in the study sample, and to examine how three of the instructors enact and use these models in practice. These tools include thematic analysis of interview transcripts, clustering and multidimensional scaling (MDS) of the interview themes, and social network analysis of classroom observation data. Details concerning this multi-step analytical strategy are described below.

Data Sources

To examine the cultural models of teaching and learning among math and science instructors we draw upon data collected through interviews and observations among undergraduate instructors (*N*=41) in math, physics, chemistry, biology, and geology departments across three large research universities in the United States (see Table 1). A team of three researchers conducted all data collection activities. One researcher observed two class periods of each participant, with interviews typically taking place immediately prior to or after an observed class. For the interviews, a semi-structured protocol ensured that all researchers asked the same general questions, but interviewers were encouraged to explore certain themes if presented an opportunity in the moment.

***Table 1*. Sample characteristics**

	***n* / %**
Sex	
Female	19 / 46.3
Male	22 / 53.7
Discipline	
Math	15 / 36.5
Physics	6 / 14.6
Chemistry	4 / 9.8
Biology	8 / 19.5
Geology	8 / 19.5
Position/Rank	
Lecturer/Instructor	25 / 61.0
Assistant Professor	2 / 4.9
Associate Professor	3 / 7.3
Professor	11 / 26.8

For this specific analysis we focused primarily on the participants' responses to the following two questions: (1) What is your view about how students best learn the key concepts in your field? (2) What are the most effective ways to introduce students to these key concepts? These questions were part of a longer interview with each instructor ranging between 30–60 minutes. While we focused primarily on participants' responses to the two questions above, we

also used a number of utterances from across the entire interview. The interviews were conducted in the privacy of participants' offices, and the audio recordings were later transcribed.

In addition to the interviews, each participant was observed for two full class periods using the Teaching Dimensions Observation Protocol (TDOP) developed by our research team to code the participating instructors' use of teaching methods (e.g., lecture, small group work, demonstration), student/instructor interactions (e.g., forms of Q&A), cognitive engagements (e.g., memorization, problem solving, creating), and instructional technologies (e.g., clickers, chalkboard, slides) at 5-minute intervals throughout the duration of each observed class period. Prior to the observations, the three researchers participated in a 3-day training process in which they verbalized their understanding of each code and then deliberated to reach mutual understanding. In order to test this mutual understanding and establish inter-rater reliability, the analysts coded three videotaped undergraduate classes (two in chemistry and one in mathematics). The following are the results of the inter-rater reliability using Cohen's Kappa for each pair of raters (averaged across the categories): Analyst 1/Analyst 2 (.699), Analyst 1/Analyst 3 (.741), Analyst 2/Analyst 3 (.713).[6]

Constructing Cultural Models of Teaching and Learning

The first phase of the analysis involved two distinct steps: (1) a thematic analysis of the interview transcripts, and (2) clustering/scaling of the derived themes. All interviews were transcribed and entered into NVivo® qualitative analysis software. Two analysts developed a coding scheme in order to segment the data into thematically coherent units. In developing the initial code list, the two analysts conducted an inductive analysis of the data that entailed comparing each successive instance of the code to previous instances in order to confirm or alter the code and its definition (i.e., the constant comparative method) (Glaser & Strauss, 1967). The two codes created during this process that are salient to this paper include "views of student learning" and "introducing new topics." Prior to coding the entire sample, the analysts applied the coding scheme to five transcripts, and inter-rater reliability was assessed by calculating the percentage of agreement between the analysts in applying the codes. The percentage of instances in which both analysts coded the same code relative to all coded instances was 89%.

Next, an in-depth analysis was conducted of all text fragments coded as "views of student learning" and "introducing new topics" in order to identify recurrent themes and patterns (Ryan & Bernard, 2003). This entailed an open coding and constant comparative process as detailed above, and resulted in the identification of 15 "views of student learning" themes and 10 "introducing new topics" themes. In analyzing the "introducing new topics" themes we discovered that, while many participants had the same themes, the sequence in which the themes were reported varied substantially. That is, when asked about the steps they take when introducing students to a new topic, some participants reported that they begin by covering the concept in principle (theme: covering) and then move on to illustrate the principle through

[6] See Hora & Ferrare (in press) for detailed information about the development of the TDOP.

examples (theme: examples). In contrast, other participants reported that they begin by working through many examples and gradually build up to covering the concept in principle. Thus, we took a second step in our thematic analysis in order to derive the underlying sequence through which the themes were connected.

The second step involved creating a participant-by-thematic code matrix in which each cell indicates whether participant *i* expressed thematic code *j* (1) or not (0). We then used cluster analysis and MDS to explore the dimensions underlying the relationships within and between the two sets of themes (i.e., views of learning and new topics sequences). In essence, these techniques ascertain the theoretical space of cultural models espoused by the participants. The term "theoretical space" is meant to qualify that the analysis paints with broad strokes when looking for underlying patterns of themes across all instructors. In practice, however, individual instructors espouse and enact a greater variety of cultural models than the data reduction techniques imply. Nevertheless, constructing this theoretical space provides an insightful point of departure for examining cultural models.

Cluster analysis is a non-statistical procedure for partitioning objects (i.e., themes) into groups based on (dis)similarity as measured through a distance matrix (in this case binary squared Euclidean distance). The particular clustering algorithm used in this analysis is referred to as Ward's Method, which begins with each theme (or theme sequence) as its own cluster and ends with a single cluster that contains all the themes. In between the beginning and end are the stages of clustering that are based on the merging of clusters that result in the least amount of information lost (the smallest increase in the value of the sum of squares index, or variance) by the clustering (Romesburg, 1984). The primary output in cluster analysis is the dendrogram—a diagram that illustrates the clusters and decision-steps the algorithm made to attain them (see Figure 1, p. 14).

As a complement to the cluster analysis we used nonmetric (i.e., ordinal) MDS scaling. Rather than partitioning the themes into mutually exclusive clusters, MDS is a technique for graphically representing the (dis)similarity (i.e., proximities) between themes as distances in a low dimensional space (usually two). In the present application of MDS, distance is conceptualized as Euclidean distance, which is simply the geodesic between two points. In a two-dimensional solution (X) the Euclidean distance (d) between points *i* and *j* can be expressed as:

$$d_{ij}(X) = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2} \qquad (1)$$

Euclidean distance can be re-written more generally to apply to *m*-dimensions:

$$d_{ij}(X) = \left[\sum_{a=1}^{m} (x_{ia} - x_{ja})^2 \right]^{1/2} \qquad (2)$$

One advantage of using MDS in addition to cluster analysis is the ability to measure and report the stress value, which is a non-statistical measure of badness-of-fit.[7]

A Case-Analytic Approach to Analyzing Cultural Models in Action

The second phase of the analysis focuses on three instructors in order to examine individual instantiations of the cultural models of teaching and learning identified in the analysis of themes. In each case the instructor's themes were unpacked in order to examine more specific meanings associated with his or her cultural model. This step involves foregrounding the segments of transcripts that were coded during the thematic analysis. In addition, the classroom observation data were used to provide a description of the teaching methods, cognitive engagements, and use of instructional technologies. Through these practices we assessed the extent to which instructors' cultural models are at work in the activities in which teaching and learning are taking place.

In addition to the narrative accounts of the observed classes, we used graphing techniques from social network analysis to represent the co-occurrences between the different dimensions of practice (i.e., teaching methods, student/teacher interactions, cognitive engagements, and instructional technologies). The raw data for this analysis are in the form of two-mode (or affiliation) matrices that consist of each instructor's 5-minute intervals as rows (mode 1) and observation codes as columns (mode 2). In each matrix a "1" denotes that the particular code was present in the observed interval, and a "0" denotes that the code was not present in that observed interval. Using UCINET (Borgatti, Everett, & Freeman, 2002), each two-mode matrix is then transformed into a one-mode (code-by-code) valued co-occurrence matrix in which each cell corresponds to the number of intervals that observation code *i* is affiliated with code *j*.

Next, we used the program NetDraw (Borgatti, 2002) to graph the co-occurrences between each pair of codes for each instructor. The lines connecting the codes denote a co-occurrence (i.e., codes that were co-coded in the same interval), and the line thickness indicates the relative strength of the co-occurrence (i.e., the number of intervals in which each pair co-occurred relative to the total number of intervals). Thus, for each instructor a network affiliation graph summarizes the co-occurrences of specific instructional practices and serves as a basis for linking the cultural models of teaching and learning to concrete classroom activities.

---

[7] In ordinal MDS the proximities are treated as an *ordering* rather than an actual distance. Therefore, the distances (d_{ij}) are regressed on the proximities (δ_{ij}) by way of a monotonic function. The resulting differences between the monotonic line and the non-monotonic line are referred to as the *disparities* ($\hat{d}_{ij}$), which represent a smoothed version of the distances (d_{ij}). While Kruskal and Wish (1978) place an arbitrary cutoff point for acceptable stress at between 0.0 and 0.2 (for ordinal MDS), Borg and Groenen (2005) suggest that in practice researchers should factor in the ratio of dimensions (*m*) to objects (*n*), error and number of ties in the data, and the point at which increasing dimensionality no longer substantially improves fit.

Cultural Models of Teaching and Learning Among Math and Science Instructors

The presentation of results follows three steps. First, we present the themes derived from the thematic analysis of the interview transcripts. Next, we illustrate the results of the cluster analysis and MDS of the themes, drawing primarily on the dendrogram (shown in Figure 1, p. 14) and the MDS plot (shown in Figure 2, p. 15) to describe the theoretical space of cultural models in which the "views of learning" themes and "introducing new topics" sequences are organized. Finally, we conclude with the three case analyses.

Thematic Analysis

The thematic analysis yielded 15 distinct "views of learning" themes, 10 "new topics" themes, and 3 "new topics" sequences. Table 2 describes the "views of learning" themes in descending order of frequency.

***Table 2*. "Views of learning" themes derived from the thematic analysis**

Views of Learning	*n*	Description
Practice/Perseverance	22	Learning comes from prolonged effort in solving problems (often by oneself).
Application	14	Learning is best facilitated through active, hands-on engagement with the material (e.g., labs, field work).
Outside the classroom	14	The classroom is not the best venue for learning.
Articulating	13	Students learn best when vocally articulating their own thoughts, ideas, and problem-solving processes to others.
Variability	12	Students learn differently (e.g., visual, auditory, hands-on, etc.).
Visualizations	11	Students learn effectively when material is put into visual or physical form.
Construction	10	Students must actively develop their own understandings of the material.
Experiential	9	Learning is best facilitated when course material is explicitly linked to students' own experiences.
Scaffolding	7	Learning is best facilitated when course topics are presented in a sequential fashion from least to most difficult.
Clear Explanations	5	Learning is best facilitated through the clear explanation of topics.
Examples	4	Students learn from concrete examples and illustrations of course material.
Repetition	4	Students learn through repeated exposure to a topic or idea.
Osmosis	2	Students learn by being in the presence of an expert (i.e., an academic).
Individualized	2	Learning is facilitated through one-on-one interaction with an instructor.
Memorizing	1	Learning is accomplished through memorizing facts or computational rules.

By far the most prevalent theme is "practice/perseverance," which was coded in half (53.7%, *n*=22) of the interviews. This theme is predicated on the belief that students learn best through a sustained struggle to solve problems (both computational and conceptual) on their own. The "practice/perseverance" theme is conceptually related to another prevalent theme,

"outside the classroom." One-third (34.1%, *n*=14) of the participants expressed the belief that the classroom is not a good venue to learn the key concepts of their respective disciplines (the "outside the classroom" theme). An equal number (34.1%, *n*=14) of instructors expressed the view that learning the key concepts is done through "application" involving hands-on engagement with the material. Other frequently mentioned views of learning include "articulating" (31.7%, *n*=13), "variability" (29.3%, *n*=12), "visualizations" (26.8%, *n*=11), "construction" (24.4%, *n*=10), "experiential" (22.0%, *n*=9), and "scaffolding" (17.1%, *n*=7). Less frequently mentioned views include "clear explanations" (12.2%, *n*=5), "examples" (9.8%, *n*=4), "repetition" (9.8%, *n*=4), "osmosis" (4.9%, *n*=2), "individualized" (4.9%, *n*=2), and "memorizing" (2.4%, *n*=1).

Table 3 describes the "introducing new topics" themes and sequences in descending order of frequency. Every participant (*n*=41) mentioned "covering," which is simply the idea that the topic is defined in general or abstract terms (e.g., a theorem is presented or "oscillation" is defined). The next most frequently referenced views of how to best introduce students to key concepts is "scaffolding" (51.2%, *n*=21) and "practicing/examples" (48.8%, *n*=20). Other themes include: "assessing" (26.8%, *n*=11), "motivating" (26.8%, *n*=11), "illustrations" (17.1%, *n*=7), "foreshadowing" (12.2%, *n*=5), "outlining" (9.8%, *n*=4), "announcing" (4.9%, *n*=2), and "empathizing" (2.4%, *n*=1).

***Table 3*. "Introducing new topics" themes and sequences derived from the thematic analysis**

Introducing Topics	*n*	Description
Themes		
Covering	41	Defines the topic in general terms (e.g., presents definition or theorem).
Scaffolding	21	Links new topic to previous course material.
Examples	20	Illustrates the concept by working out problems or computations.
Assessing	11	Poses questions to students to check for understanding.
Motivating	11	Makes the case for why the topic is important.
Illustrations	7	Demonstrates the topic through an experiment or real world example.
Foreshadowing	5	Assigns preparatory reading or task that precedes the in-class introduction.
Outlining	4	Highlights the main points of the new topic and/or learning goals.
Announcing	2	Announces that at a new topic is coming in the near future.
Empathizing	1	Puts self in students' shoes to anticipate misconceptions.
Theme Sequences		
Specific→General	18	Begins with scaffolding and/or examples before describing the concept in general (e.g., foreshadowing→scaffolding→covering).
General→Specific	17	Describes the new concept in general before demonstrating through examples (e.g., covering→practicing).
Multi-sequential	6	Sequence of introduction is contingent upon the topic (i.e. uses multiple sequences).

As noted, the "introducing new topics" themes are not independent. Rather, they only make sense in relation to a specific sequence (or script) in which participants reported their views of introducing students to the key concepts in their discipline. For instance, two participants may have mentioned the same themes (say, covering, scaffolding, and practicing) but in the opposite order (covering→practicing→scaffolding vs. scaffolding→practicing→covering). Thus, a secondary thematic analysis classified the theme sequences. The three sets of sequences, shown in Table 3, include "specific→general" (43.9%, *n*=18), "general→specific" (41.5%, *n*=17), and "multi-sequential" (14.6%, *n*=6). The key factor in determining the flow of the sequences was the location of the theme "covering" within the sequences. In the specific→general sequences the participants reported that "covering" was the final step in the sequence. That is, the process of introducing the topic consisted of a series of specific examples, foreshadowing, illustrations, or assessments that build up to a general definition of the concept or theorem (i.e., covering). In contrast, the general→specific sequences were defined by beginning with the general definition of a concept or theorem (i.e., covering) before moving on to specific examples, assessments, illustrations, scaffolding, and so on. Finally, those participants classified as "multi-sequential" reported using both sequence forms depending on the topic and/or students involved.

Clustering and Scaling of Themes and Sequences

The next step of our analysis involved examining the patterning of these first-person accounts of student learning and teaching practice across all instructors. We began with an exploratory cluster analysis of the themes and sequences. The dendrogram in Figure 1 suggests two or three meaningful clusters related to participants' views of how students best learn key concepts and the best ways to introduce students to these concepts. In the two-cluster stage of the analysis the first cluster comprises two sub-groupings: 1A. specific→general sequences and scaffolding, examples, variability, visualizations, and experiential themes; 1B. multi-sequential and osmosis, construction, individualized, memorizing, repetition, clear explanations, and articulating themes. The second cluster comprises general→specific sequences and the application, outside the classroom, and practice/perseverance themes.

While the dendrogram suggests a patterning into two (or possibly three) clusters, it would be a mistake to interpret these clusters as neatly bound types of cultural models of teaching and learning. This caveat becomes clearer when we examine the results of the MDS analysis. Although the horizontal[8] distances between the themes and sequences in Figure 2 follow an ordering consistent with the cluster analysis, the distances do not suggest two or three discrete groupings. Instead, the horizontal dimension of the MDS space illustrates an opposition between the themes in sub-group "A" (from cluster 1) and cluster 2, with the themes in sub-group "B" being more similar (i.e., closer) to the former than the latter. The principle underlying this

[8] In practice, there is no dimensional orientation in this particular application of MDS. That is, notions of horizontal/vertical, left/right, up/down, etc. are completely arbitrary.

opposition approximately follows a distinction between learning as a result of teaching (e.g., scaffolding, osmosis, clear explanations, visualizations, etc.) versus learning that is the result of doing (e.g., application, outside the classroom, and practice). While this finding lends some support to a two-cluster model, it also suggests a great deal of variation in the way that these instructors assemble the themes within cluster 1.

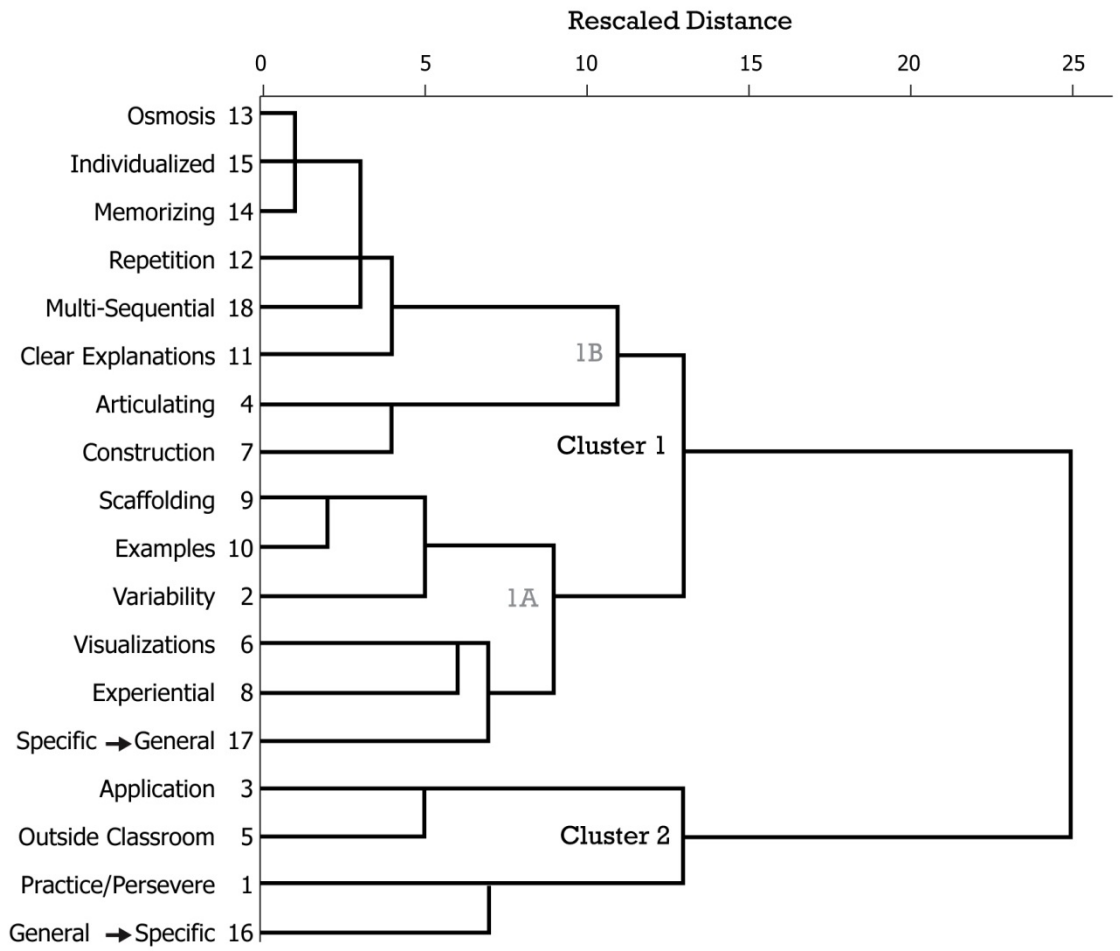

***Figure 1*. Dendrogram (Ward's Method) of "views of learning" themes and "new topics" sequences**

While the horizontal distribution of themes in Figure 2 approximately replicates the pattern of clustering, the results are more nuanced when we integrate the second dimension of the MDS space. This vertical dimension contrasts teacher-constructed views of learning to that of student-constructed views. The teacher-constructed views include themes that emphasize techniques and strategies that the instructor must do to construct knowledge, such as providing visualizations, scaffolding, and examples. In contrast, the student-constructed views include themes suggesting that students must articulate, construct, and apply—particularly outside the classroom. Coinciding with the initial clusters, then, is an additional principle pointing to contrasting views related to *who* is responsible for the construction of knowledge in the

pedagogic relationship. Thus, the MDS results add a dimension to the theoretical space of cultural models of teaching and learning presented thus far.

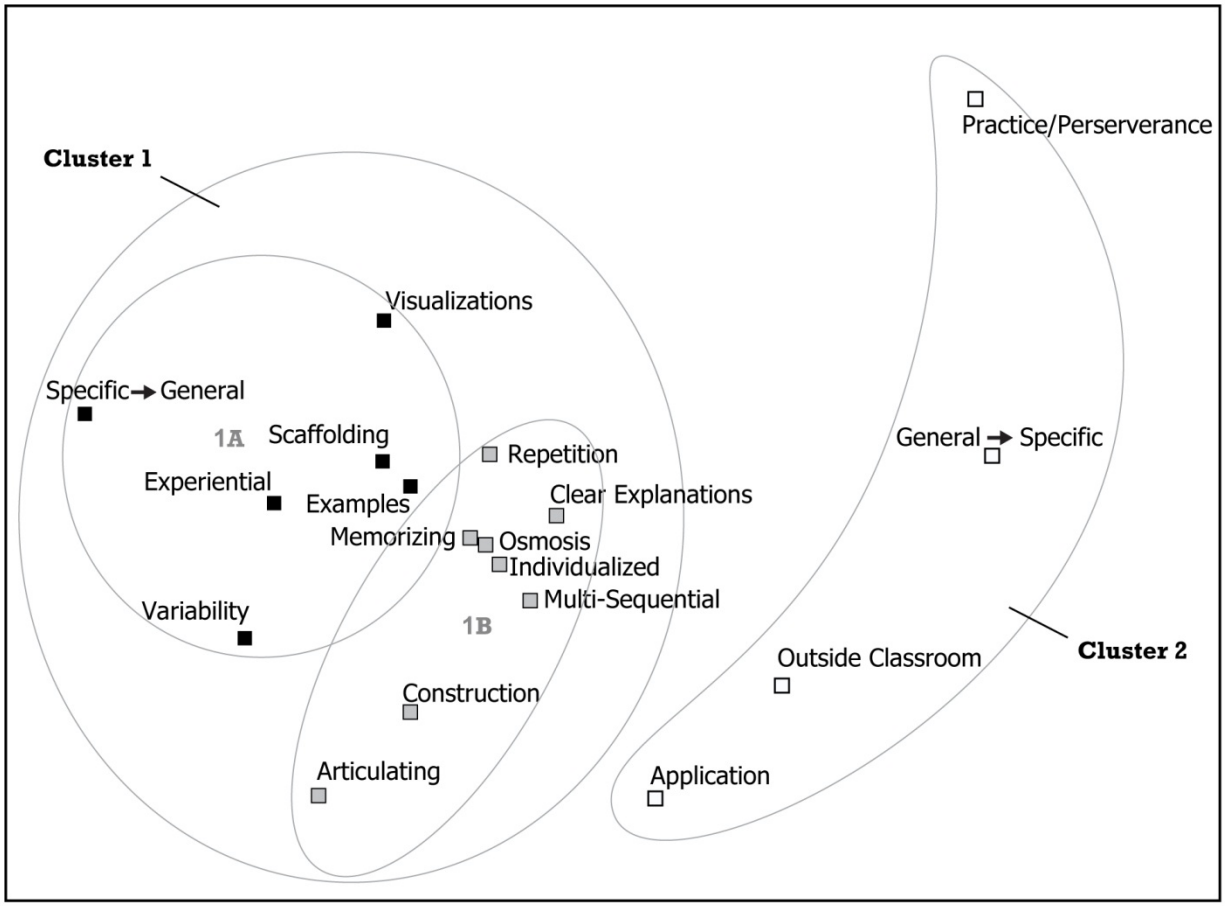

***Figure 2*. Ordinal MDS of "views of learning" themes and "new topics" sequences (Stress=0.104)**

Practically speaking, rather than thinking of these cultural models as discrete types, it is more accurate to conceptualize them as spatially proximal combinations of learning views and new topic sequences. That is, in practice, the boundaries between these cultural models appear to be separated less by rigid "either/or" categories and more by "to what degree" distances.[9] This premise will prove more convincing once we move from examining cultural models on paper (i.e., as theoretical constructs) to an analysis of cultural models in practice.

[9] See Postareff and Lindblom-Ylanne (2008) for a similar argument in the context of the common teacher-centered/student-centered dichotomy that is often used to characterize approaches to teaching.

Case Analyses

While the case analyses below partially reinforce the theoretical boundaries of the cultural models identified heretofore, they also portray a degree of fluidity with which each instructor assembles meanings in relation to their cultural model of teaching and learning in specific instructional situations. The cases also demonstrate that we cannot acquire a deep understanding of cultural models of teaching and learning in language and thought alone. In addition, it is necessary to explore these models at the intersections of cognition, social practice, and organizational life.

"Dr. Spicoli." Dr. Spicoli is a professor of biology who teaches a large (~350 students) introductory-level course in genetics that is required of all biology majors. The two class periods we observed covered gene identification, gene sequencing techniques, embryonic testing, and technologies for measuring DNA. Dr. Spicoli's cultural model of teaching and learning falls primarily in cluster 2, or the "learning by doing" region of the MDS space. This can be seen in his theory that the way students best learn the key principles of genetics is through practice that happens outside the classroom, and his general→specific sequence script (covering→motivating→scaffolding) as the best way to introduce students to these concepts.

Dr. Spicoli does not hesitate when asked about what he thinks is the best way for undergraduate students to learn the key concepts of genetics: "Problem solving," he replies assuredly. "[T]o get 'em proficient in solving genetic problems and understanding concepts," he continues, "is just to do problem solving." It is not surprising, then, that Dr. Spicoli holds that learning primarily occurs outside the classroom where students can engage in problem solving specific to genetics. To this end, Dr. Spicoli assigns weekly problem sets and makes graduate students and proficient undergraduates available for 1 hour per week so that students can ask questions and get feedback on their work.

While Dr. Spicoli's model locates student learning in problem-solving contexts outside of the classroom, he nonetheless is tasked with introducing students to the principles of genetics inside the classroom. When introducing students to new material Dr. Spicoli believes it best to begin by defining the key terms and providing an overall definition of the concept(s). This initial step of covering and outlining is followed by motivating and scaffolding the new material so that, in his words, "it's not just me filling 50 minutes with some technical stuff that they may or may not be interested in, but try to tell them how it's relevant and how it's connected to other parts of the course." Yet Dr. Spicoli's rationale also links back to his model of student learning based on practice through problem solving. As he notes, "[I] try and give 'em the flow of how a geneticist goes through trying to figure out when they have a new mutation or a new phenotype." Thus, Dr. Spicoli's theory of how students best learn key concepts in genetics operates in association with a script for introducing students to those concepts.

By observing Dr. Spicoli's instructional practices we can begin to understand how his cultural model of teaching and learning is activated and adapted to the specific context of his organizational environment. The network-affiliation graph in Figure 3 illustrates that Dr.

Spicoli's primary pedagogical repertoire consists of a didactic style that requires students to frequently receive, follow, and memorize information presented through lecturing with the use of a pointer and PowerPoint slides. At first glance it may appear as though Dr. Spicoli's practice contradicts his cultural model in its espoused form. However, he frequently supplements his didactic style by asking students to solve conceptual genetics problems through the medium of clicker response systems (i.e., real-time polling). These questions are often situated within a specific genetics case study (in the two classes we observed these case studies focused primarily on homologous genes and gene sequencing).

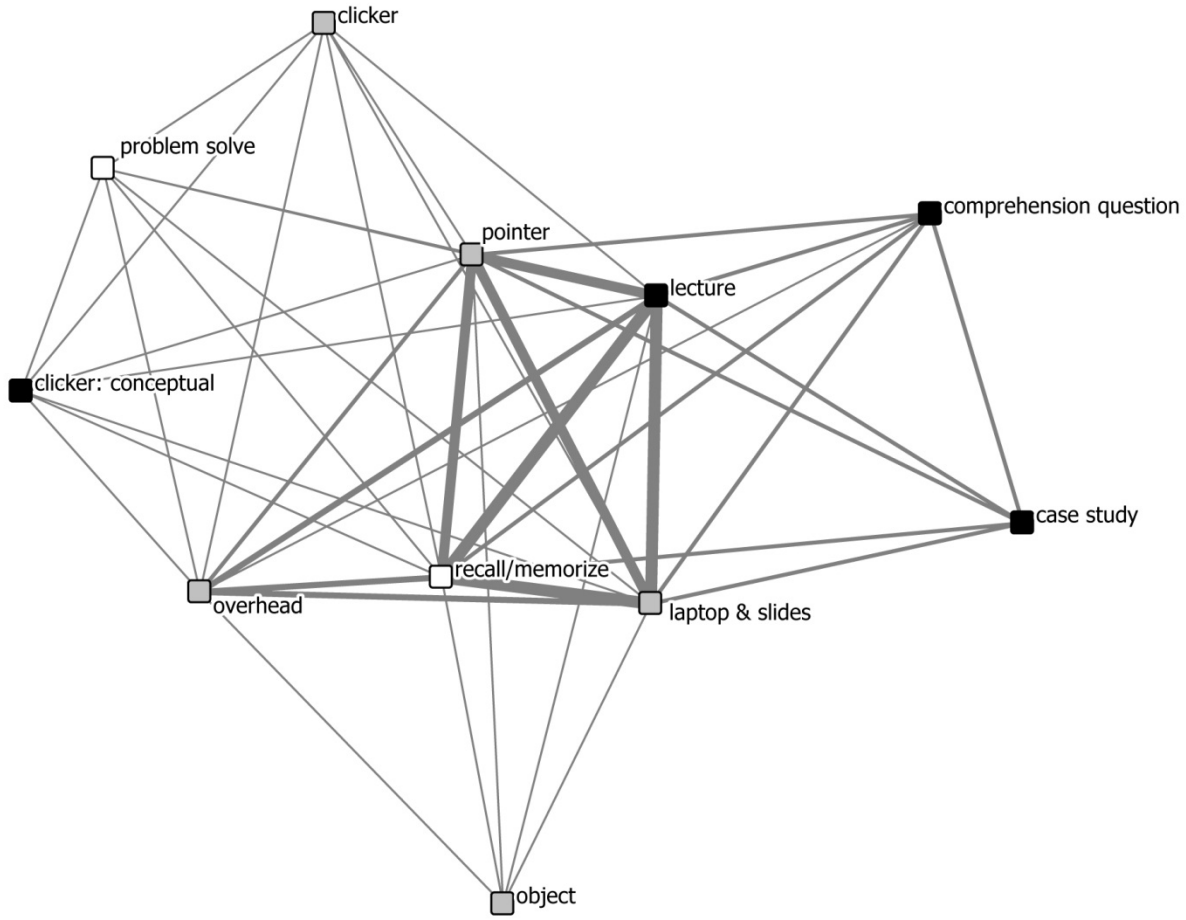

***Figure 3*. Dr. Spicoli's graph of instructional practice**
Note: The black boxes refer to teaching methods, white boxes refer to cognitive engagements, and gray boxes refer to instructional technologies.

Although Dr. Spicoli's cultural model of teaching and learning is clearly at work in his instructional practice, the application of the model is not purely deterministic. Rather, his cultural model is re-contextualized by the constraints and affordances of his organizational environment (Greeno, 1998). Most notably, the high enrollment numbers and varying levels of student ability shape the extent to which he can incorporate problem solving into the classroom. This is particularly evident with the use of clickers. As he notes, "With the size of the class and very different skill levels among the entering students here in biology, I don't do a lot more

sophisticated clicker stuff that some of my colleagues do." Even though Dr. Spicoli's cultural model of teaching and learning represents a relatively coherent theory that he uses to make sense of his environment, this very environment pushes back in a way that requires him to adapt his cultural model (or at least make concessions) to the constraints he perceives in the situation. Even in the face of those constraints, however, instructional technologies such as clickers afford Dr. Spicoli a medium through which to act upon his cultural model.

"Dr. Denny." Dr. Denny is a senior instructor in the mathematics department. At the time of the interview and observation, Dr. Denny was teaching a linear algebra course (~40 students). The week we visited Dr. Denny's class he was covering basic principles in matrix algebra and more complex concepts related to vector spaces. Dr. Denny espouses a cultural model of teaching and learning that is primarily comprised of themes from sub-group A of cluster 1 (i.e., "learning through teaching") and the teacher constructed region of the MDS space. For instance, in addition to "practice," his theory of how students best learn key mathematical concepts is characterized by variability, working through examples, and integrating concepts through scaffolding. Dr. Denny also has a specific→general script for introducing students to key mathematical concepts that begins with numerous examples and gradually builds to a general principle or theorem.

When prompted to think about his views of how students best learn the key concepts in linear algebra, Dr. Denny notes that linear algebra marks a transition from strictly doing computations to more abstract forms of mathematical reasoning. In this context he perceives students to learn at different speeds and through varying styles and thus stresses variability. Regardless of speed or style, though, Dr. Denny contends that in order for students to learn key mathematical concepts they must "grind away" through numerous specific examples and gradually work up to the general principle or theorem. He also holds that students must have a strong foundation (i.e., scaffolding) in the fundamentals of mathematics before they can grasp more advanced and abstract concepts.

Associated with Dr. Denny's theory of how students best learn key concepts in linear algebra is a script for introducing students to those concepts. This script runs counter to what he describes as the "common model" (i.e., general→specific) in mathematics:

> I know a lot of people who come in and will state the theorem … and prove it and then finally do some examples, and I never do that. I do an example, and then I'll do another example, and as I do them I'll point out some feature and I'll say, "Well, we call this thing … Gauss-Jordan elimination…." I do a bunch of examples and then try to lead into the abstract definition.

When asked to say more about the common model (i.e., proving the theorem and then providing examples), Dr. Denny says that most mathematicians teach that way because "[t]hat's the way they're comfortable thinking." He continues:

> But it doesn't seem like the most natural way to learn to me personally. I think you understand it abstractly. [W]hen you learn algebra, that's very abstract. You learn arithmetic—even numbers are abstract, right?… But eventually you learn that numbers are something and then in algebra you have to say let X be a number. So you have this variable, which is an abstraction of a number, and a number is an abstraction of something else … but you don't learn algebra until you've really learned arithmetic, right? Because then you have a bunch of examples of computations that you can imagine you would want to write in this language—and it keeps going like that. [Y]ou always work from the particular to the general.

This quote captures the essence of Dr. Denny's cultural model of teaching and learning, as it illustrates his views that students must work through specific examples and build scaffolds as they proceed to higher levels of abstraction. Thus, the way Dr. Denny believes new topics should be introduced is a microcosm of his broader model of progression in mathematics.

In the classroom it was easy to see Dr. Denny's cultural model of teaching and learning in action. During each class period he meticulously worked through examples, beginning with easy applications and gradually working up to more difficult problems that prompted student questions. This core pedagogical style is evident in Figure 4, which shows that Dr. Denny frequently lectures and works through problems at the chalkboard. The graph also demonstrates that Dr. Denny supplements his primary strategy of working through problems by occasionally posing algorithmic and conceptual questions to the students, and he frequently checks for student understanding. What the graph does not illustrate, however, is that as Dr. Denny progressed through each problem he would periodically stop and point out certain features of the problems that eventually could be assembled into an abstract principle.

For Dr. Denny, the use of the chalkboard provides a medium through which he is able to activate his cultural model of teaching and learning. Since he prefers to provide students with many examples, Dr. Denny's modus operandi is to stand at the board and work out problems. Although the component of Dr. Denny's cultural model related to introducing key mathematical concepts runs counter to what he claims is "the more common model," he is certainly not alone in relying on the chalkboard as an instructional tool. When asked to clarify his use of instructional technology, Dr. Denny notes that while he does believe the students should be using the computer program MATLAB, a programming environment for algorithm development, data analysis, visualization, and numerical computation, he is conflicted about the use of such technology:

> And there is a move to [use MATLAB], but mathematicians are kind of conservative. I'm kind of conservative. We sort of like our discipline to be sort of pure in some sense and so what we really want [students] to see is the beauty of these ideas, and of course … kicking and screaming we admit that these things are actually useful for something, and … we'll teach you how to do it.... But really we want you to be stunned by the loveliness of it.

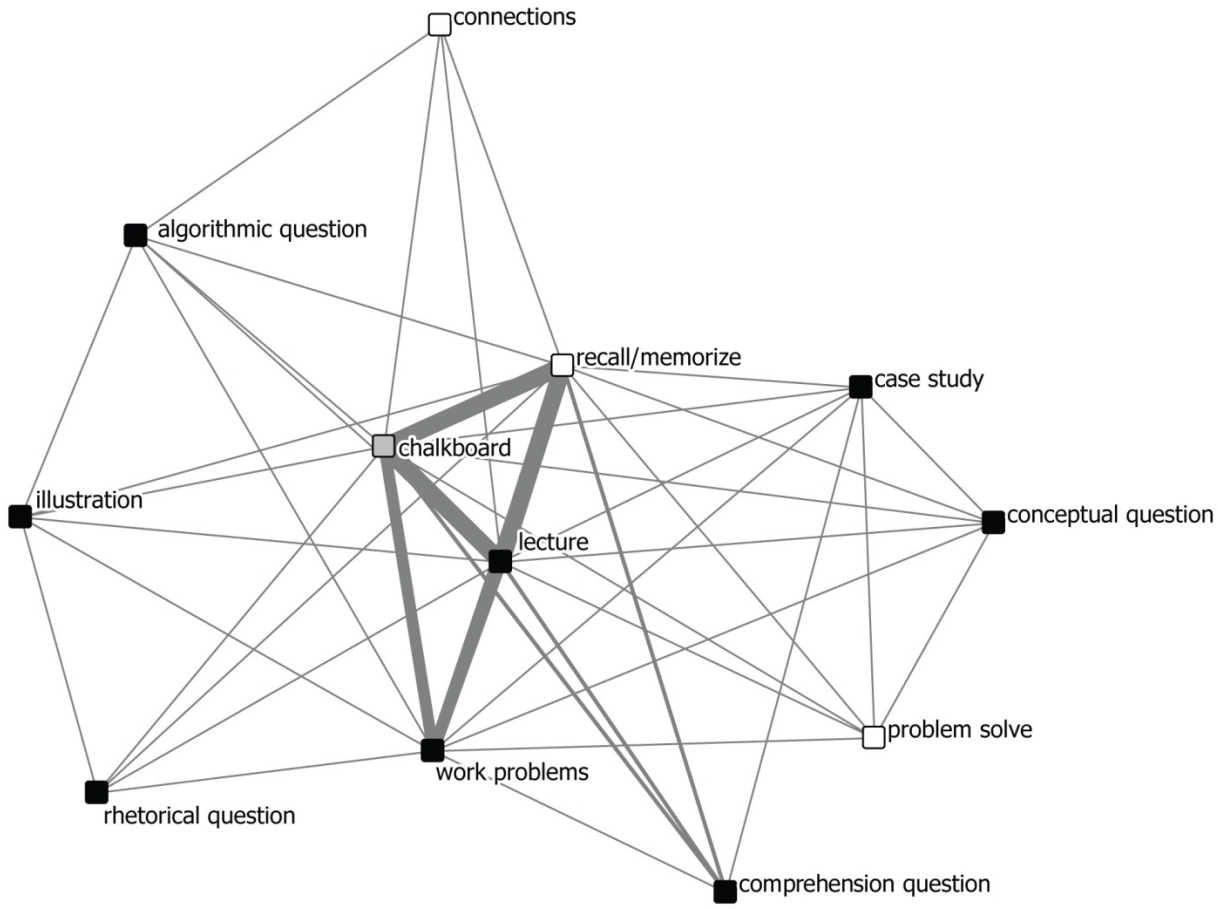

Figure 4. **Dr. Denny's graph of instructional practice**
Note: The black boxes refer to teaching methods, white boxes refer to cognitive engagements, and gray boxes refer to instructional technologies.

This sentiment illustrates the conflicting components of Dr. Denny's cultural model. On the one hand, his model guides him to sequence the material in contrasting style to the more common model in mathematics. On the other hand, he is intent on accommodating the conflicting positions within his model by using the chalkboard to work through examples as opposed to a technological medium that he admits the students "should learn."

"Dr. Bishop." As a senior instructor in biology, Dr. Bishop is primarily responsible for teaching undergraduate courses covering a variety of biological concepts. In addition to her teaching commitments, though, Dr. Bishop is involved in undergraduate science education research projects that have provided her with data to inform her teaching. In this sense her cultural model of teaching and learning extends beyond a "folk theory" and includes features of a "scientific theory." The particular course that was observed in the present case was Developmental Biology, which is an upper division course for biology majors in the department (~100 students). Dr. Bishop's cultural model of teaching and learning cannot easily be characterized. It is considerably more nuanced than the previous two we looked at, and it contains themes from across the entire spectrum of the theoretical space of cultural models. In

total, Dr. Bishop expressed seven distinct thematic views of student learning—variability, construction, articulating, outside the classroom, osmosis, individualized, and application—and espouses multiple scripts for introducing students to the course material.

The complexity of Dr. Bishop's model is captured in her initial response to being queried about the best way students learn key concepts in developmental biology at the undergraduate level. "I guess there [are] two answers to that question," she replies. The first answer, according to her, is that "different people learn the key concepts differently" and that "students have a clear preference for [certain] learning styles." Some students, she claims, are most comfortable coming to class, taking notes, and then going on their own to piece together the key bits of information rather than actively pursuing that knowledge in the classroom. For Dr. Bishop, independent study, reflection, and application outside of the classroom are "critical components" to learning the key concepts.

Despite her belief in variability and acknowledging that some students are not comfortable in an active learning environment, Dr. Bishop's second answer is more definitive in the other direction. "So I guess … there's a student perspective" she says, "but from my own perspective I think that students learn by being active." Dr. Bishop continues:

> So they like that format where they … hear a lot of information, they write it all down, and they go home later and they kind of put it all together. But I don't think that that's actually the best way to figure things out 'cause I think that a lot more is gained from—and there's data to support this too—but there's a lot more to be gained from an active pursuit of the topic in the classroom. Where the things that are confusing you, actually hash it out when you've got the professor there to talk with you about it and you've got your neighbor to go, "Well, I don't think that's the way it works."

Being active, according to Dr. Bishop, thus involves a combination of construction ("active pursuit of the topic in the classroom"), articulation ("hash it out"), and individualized interaction between the instructor and each student. In the process of explaining her cultural model, Dr. Bishop notes that "there is data to support" her model. Here we can see that Dr. Bishop's cultural model of teaching and learning is more explicitly theoretical than what is typical among many scientists and mathematicians.

The complexity of Dr. Bishop's cultural model is also captured by her views of how to best introduce undergraduate students to the key concepts in biology. Dr. Bishop espouses both a general→specific (covering→examples) and specific→general (assessing→covering) script for introducing material. When asked if there is a pattern to her use of the former or latter sequence, she has to think about it for a few seconds:

> I'm trying to think about whether there is a method to my approach…. I guess, all right just being honest, I think I would prefer … to start every class period or every topic with an exploration on their part, culminating with some wrap-up by me. But in practice there

are some number of topics that I don't start that way, and it's just because I haven't developed the right sequence of things that I think will trigger them to really learn it that way.

Similar to her views of student learning, Dr. Bishop's views of how to introduce key concepts are somewhat conflicted. That is, she clearly prefers active over inactive learning and specific→general over general→specific sequences. Yet, rather than expunging these elements from her cultural model, Dr. Bishop has instead adapted them to fit (albeit in conflict) alongside what she believes is the best way to teach and learn.

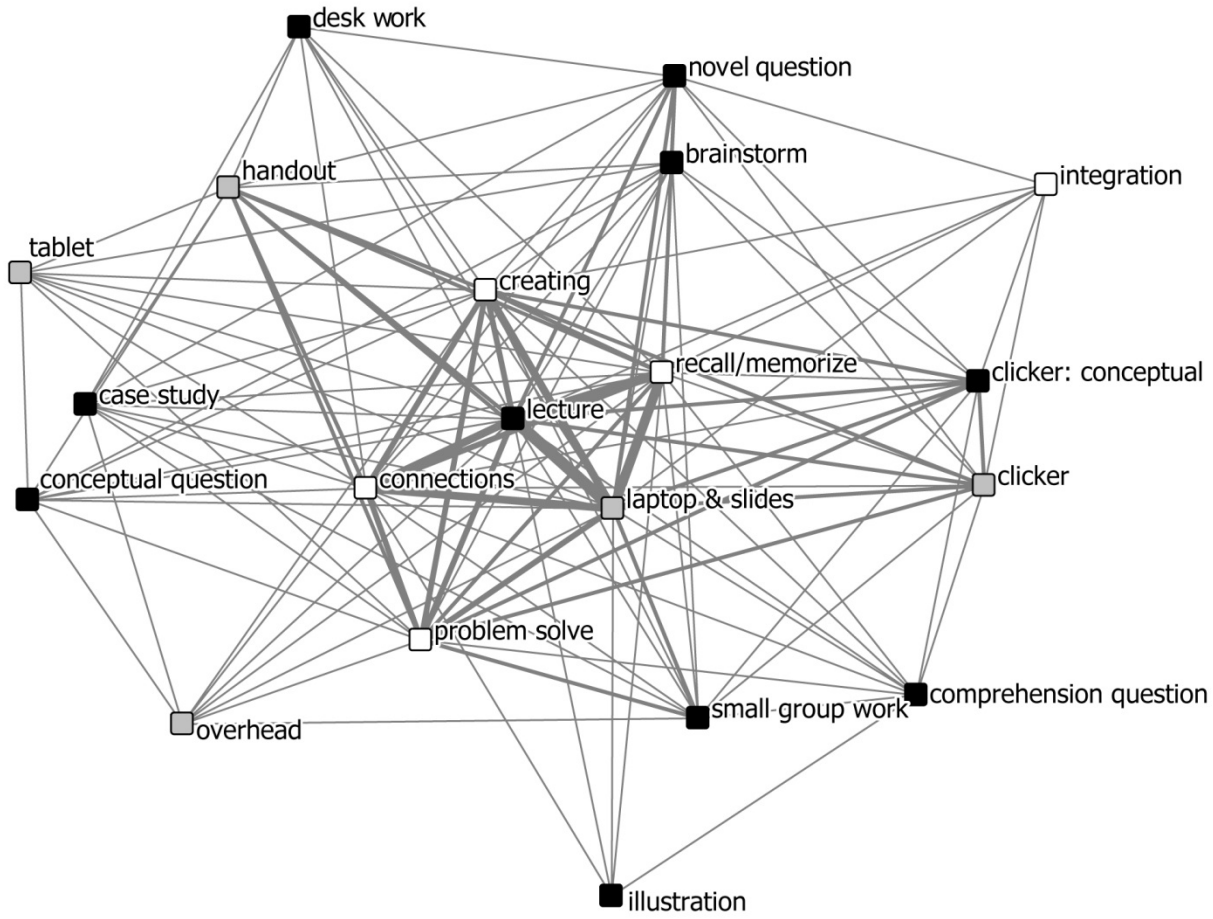

***Figure 5*. Dr. Bishop's graph of instructional practice**
Note: The black boxes refer to teaching methods, white boxes refer to cognitive engagements, and gray boxes refer to instructional technologies.

Given the complexity of Dr. Bishop's cultural model of teaching and learning, it should come as no surprise that her pedagogical style is highly varied. Indeed, the total number of unique nodes (i.e., observation codes) in Dr. Bishop's graph (n=21) is nearly double that of Drs. Spicoli (n=11) and Denny (n=12). In addition, a core/periphery relation of techniques is not as distinct as in the previous graphs; Dr. Bishop's graph is more diffuse. It is in this graph that we can see a multifaceted configuration of educational action that is approximately homologous to

her multifaceted cultural model of teaching and learning. For instance, note that lecturing from a laptop and slides is still a key feature of the graph. During these times both sequences of introducing material were at work. Often when lecturing, for example, Dr. Bishop was introducing a principle or process (e.g., axonal movement) followed by a series of examples. At other times she would instead share very specific pieces of data and ask the students, "What is happening here?"

While lecturing with a laptop and slides is an important feature of the graph, the prevalence of active instructional practices and technologies illustrates the varied aspects of Dr. Bishop's cultural model in action. For example, Dr. Bishop makes regular use of conceptual clicker questions, brainstorm sessions, small group discussions, individual deskwork, and a variety of question styles. In the process she creates the conditions for a variety of active cognitive engagements such as creating, connections, problem solving, and integration. Finally, all of this is accomplished through a mixture of instructional technology that includes an overhead projector, laptop and slides, digital tablet, and clicker-response system.

Discussion and Conclusions: Why Cultural Models?

At the outset of this paper we argued that cultural models are an important theoretical tool that can help us to better understand how instructors make sense of—and act within—their organizational environments. We then suggested looking to the intersections of cognition, social practice, and organizational context to find the most compelling story about instructors' cultural models of teaching practice and student learning. That story began by examining the patterned ways in which the instructors participating in our study assemble cultural meanings and strategies related to how students best learn the key concepts in their fields and the best ways to introduce students to those concepts. At a theoretical level we found these meanings and strategies to be organized into a multidimensional space that provided us a point of departure for looking more closely at how individual faculty assemble and act upon these meanings and strategies in practice.

The three case analyses demonstrate the great variety with which instructors (often implicitly) assemble and mobilize cultural models of teaching and learning in relation to the perceived constraints and affordances in their organizational environments. These constraints and affordances reflect desirable and undesirable qualities of their environments that call out to instructors to act (or not act) in certain ways. At times we saw that the instructors made concessions in response to perceived constraints, while at other times they perceived affordances in their organizational environment (e.g., instructional technologies) in ways that allowed them to remain true to their cultural model. In other instances we saw that conflicts arose between cultural models of teaching and learning and other models. For instance, Dr. Denny's struggle over whether to use MATLAB in class foregrounded the tension between his cultural model of teaching and learning and his more "conservative" cultural model of how mathematics should be appreciated. This example, among others, illustrates that cultural models are relational entities (Gee, 2004) that interact with other models circulating through—and built into—situations and settings.

The variety with which cultural models are assembled and acted upon also points to an important division of labor through which the meanings and strategies that constitute instructors' cultural models of teaching and learning are distributed within and between groups. While this distribution was evident in the cluster analysis and MDS results above, we did not explore the social positions to which these bits and pieces of meanings and strategies are distributed. Some insights did arise from the interviews, however. For example, both Dr. Denny and Dr. Bishop—as non-tenure track senior instructors—referenced their relatively low positions within the academic hierarchy as affording them opportunities to reflect on student learning styles and pedagogical strategies attuned to those styles. Future research might look deeper into the ways in which positions in academic social structures—including disciplinary affiliation—activate and/or constrain cultural models of teaching and learning. Such work may be especially productive for those seeking to find ways to encourage tenure track faculty to pursue pedagogical innovation.

A more pressing question for the present paper is: Why should anyone care about instructors' cultural models of teaching and learning? The answer has multiple facets. First, as we have seen above, cultural models of teaching and learning are important sources of motivation for pedagogical actions, which means that attempts to change those actions must take cultural models seriously. As educators, math and science faculty are generally not hyper-rationalized automatons even though, as scientists, they are conditioned to revise their theoretical models based upon evidence. Yet, for many instructors, teaching is not a theoretical endeavor; it is a practical one, which means their cultural models of teaching and learning may be difficult to revise. The practical nature of their cultural models does not mean that instructors' practices are atheoretical, however. Rather, instructors' cultural models help them make meanings and decisions on the fly in the face of tremendous complexity, and, as a result, theorizing in the moment is simply not constitutive of pedagogical practice (see also Bourdieu, 1990). This suggests that pedagogical reformers might benefit by recognizing—rather than shunning—the practical logic of instructors' cultural models of teaching and learning.

If we stop here, though, the argument can come across as overly rhetorical. What does it mean to recognize the practical logic of instructors' cultural models of teaching and learning? To answer this question let's start by considering how culture is often positioned as the object of change. A commonly referenced step toward transforming the educational experiences of undergraduates is to change the culture of instruction (Kezar & Eckel, 2002; Trowler, 2008). Although the definition of culture can vary widely across researchers and reformers, we believe many proponents of this view would argue that it is necessary to change instructors' preexisting understanding(s) of how students best learn, as well as their understanding(s) of the strategies that create the conditions for this learning to flourish. While this is a laudable goal that has seen some success, the track record of reform efforts points to a Sisyphus scenario in which reformers invest impressive efforts and resources to push reform up the mountain only to watch many faculty rely on the same didactic strategies over and over again.

What if, however, reformers are pushing the stone up the wrong path? Perhaps they see only obstacles when opportunities are on another route up the mountain. Those who are

successful at persuading people to do things they may otherwise resist doing typically begin by appealing to preexisting cultural understandings because these understandings are already persuasive (Gramsci, 1971; Lewontin, Rose, & Kamin, 1984; Quinn & Holland, 1987). Thus, rather than perceiving instructors' preexisting understandings solely as barriers to change, it may be more productive to recognize those understandings as also containing elements of "good sense" (to use Gramsci's phrase) upon which to build (cf. Spillane, Reiser, & Reimer, 2002). That is, just as some instructors perceive affordances in instructional tools to overcome practical constraints, researchers and program designers can perceive affordances in instructors' cultural models to motivate pedagogical innovation. In this sense the "culture of instruction" in an institution is not solely a barrier to change but is also an opportunity to initiate meaningful transformation in the educational experiences of students and educators (Trowler, 2008; Trowler & Cooper, 2002).

Although evidence suggests that instructional transformation in the math and science disciplines has been slow to progress (President's Council of Advisors on Science and Technology, 2012), there are many instructors that have internalized cultural models that are consistent with the pedagogical styles so highly revered by reform advocates. At the same time, these instructors often confront situational constraints (e.g., class sizes, students' own cultural models of teaching and learning, technological resources, etc.) that force them to make concessions and adaptations to their model that they would not otherwise make. This suggests that the burden of responsibility for meaningful transformation is not solely that of instructors, but is distributed throughout the actors, events, and artifacts that constitute educational activities. Recent advances in instructional technology (e.g., clickers, online techniques) illustrate some recognition of this proposition, but the onus of responsibility remains almost entirely with the instructor. Yet, much like the ongoing attempts to demonize teachers in K–12 settings, this view evades the complexity and relational nature of education. A more complete recognition of this perspective might begin with an examination of students' cultural models of teaching and learning and the extent to which these models conflict with instructors' models and other aspects of the organizational environment. These intersections may point to educational opportunities that have yet to be pursued.

References

Abelson, R. P. (1981). Psychological status of the script concept. *American Psychologist*, *36*(7), 715–729.

Atran, S., Medin, D. L., & Ross, N. (2005). The cultural mind: Environmental decision making and cultural modeling within and across populations. *Psychological Review*, *112*(4), 744–776.

Borg, I., & Groenen, P. J. F. (2005). *Modern multidimensional scaling: Theory and applications*. New York, NY: Springer.

Borgatti, S. P. (2002). *NetDraw network visualization*. Harvard, MA: Analytic Technologies.

Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *UCINET for Windows: Software for social network analysis*. Harvard, MA: Analytic Technologies.

Bourdieu, P. (1984). *Distinction: A social critique of the judgment of taste* (R. Nice, trans.). Cambridge, MA: Routledge & Kegan Paul Ltd.

Bourdieu, P. (1988). *Homo academicus*. Stanford, CA: Stanford University Press.

Bourdieu, P. (1990). *The logic of practice*. Stanford, CA: Stanford University Press.

Bryan, L. A., & Atwater, M. M. (2002). Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education*, *86*(6), 821–839.

Curry, M. J. (2002). Cultural models in the U.S. writing classroom: Matches and mismatches. In M. Graal (Ed.), *Writing development in higher education: Changing contexts for teaching and learning* (pp. 45–61). Leicester, UK: University of Leicester.

D'Andrade, R. G. (1984). Cultural meaning systems. In R. A. Shweder & R. A. LeVine (Eds.), *Culture theory: Essays on mind, self, and emotion* (pp. 88–119). New York, NY: Cambridge University Press.

D'Andrade, R. G. (1992). Schemas and motivation. In R. G. D'Andrade & C. Strauss (Eds.), *Human motives and cultural models* (pp. 23–44). New York, NY: Cambridge University Press.

D'Andrade, R. G. (1995). *The development of cognitive anthropology*. New York, NY: Cambridge University Press.

D'Andrade, R. G., & Strauss, C. (Eds.). (1992). *Human motives and cultural models*. New York, NY: Cambridge University Press.

DiMaggio, P. (1997). Culture and cognition. *Annual Review of Sociology*, *23*, 263–287.

Fryberg, S. A., & Markus, H. R. (2007). Cultural models of education in American Indian, Asian American and European American contexts. *Social Psychology of Education*, *10*(2), 213–246.

Gallimore, R., & Goldenberg, C. (2001). Analyzing cultural models and settings to connect minority achievement and school improvement research. *Educational Psychologist*, *36*(1), 45–56.

Gee, J. P. (1996). *Social linguistics and literacies: Ideology in discourses* (2nd ed.). New York, NY: Routledge/Falmer.

Gee, J. P. (2004a). Discourse analysis: What makes it critical? In R. Rogers (Ed.), *An introduction to critical discourse analysis in education* (pp. 19–50). Mahwah, NJ: L. Erlbaum Associates.

Gee, J. P. (2004b). *Situated language and learning: a critique of traditional schooling*. New York, NY: Routledge.

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method* (2nd ed.). New York, NY: Routledge.

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

Gibson, J. J. (1986). *The ecological approach to visual perception*. Hillsdale, NJ: Princeton University Press.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine Publishing Company.

Gomez, M. L., Johnson, A. S., & Gisladottir, K. (2007). Talking about literacy: A cultural model of teaching and learning untangled. *Journal of Early Childhood Literacy*, *7*(1), 27–48.

Gramsci, A. (1971). *Selections from the prison notebooks* (Q. Hoare, trans.). New York, NY: International Publishers.

Greeno, J. G. (1994). Gibson's affordances. *Psychological Review*, *101*(2), 236–342.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist*, *53*(1), 5–26.

Hora, M. T. & Ferrare, J. J. (in press). Instructional systems of practice: A multidimensional analysis of undergraduate math and science course planning and classroom teaching. *Journal of the Learning Sciences*.

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

Kruskal, J. B., & Wish, M. (1978). *Multidimensional scaling* (Vol. 11). London, England: Sage.

Lewontin, R. C., Rose, S., & Kamin, L. J. (1984). *Not in our genes: Biology, ideology, and human nature*. New York, NY: Pantheon Books.

Martin, J. L. (2009). *Social structures*. Princeton, NJ: Princeton University Press.

Martin, J. L. (2011). *The explanation of social action*. Oxford, England: Oxford University Press.

Mohr, J. W., & Duquenne, V. (1997). The duality of culture and practice: Poverty relief in New York City, 1888–1917. *Theory and Society*, *26*, 305–356.

Ogbu, J. U., & Simons, H. D. (1994). Cultural models of school achievement: A quantitative test of Ogbu's theory. Berkeley: Graduate School of Education, National Center for the Study of Writing, University of California, Berkeley.

Postareff, L., & Lindblom-Ylanne, S. (2008). Variation in teachers' description of teaching: Broadening the understanding of teaching in higher education. *Learning and Instruction*, *18*(18), 109–120.

President's Council of Advisors on Science and Technology. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics. Washington, DC: Executive Office of the President.

Quinn, N., & Holland, D. (1987). Culture and cognition. In D. Holland & N. Quinn (Eds.), *Cultural models in language and thought* (pp. 3–42). New York, NY: Cambridge University Press.

Rogers, R. (2001). Family literacy and the mediation of cultural models. In J. V. Hoffman, D. L. Schallert, C. M. Fairbanks, J. Worthy & B. Maloch (Eds.), *50th Yearbook of the National Reading Conference*. Chicago, IL: National Reading Conference.

Romesburg, H. C. (1984). *Cluster analysis for researchers*. Belmont, CA: Lifetime Learning Publications.

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

Sayer, A. (2011). *Why things matter to people: Social science, values and ethical life*. Cambridge, England: Cambridge University Press.

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

Spillane, J. P., Reiser, B. J., & Reimer, T. (2002). Policy implementation and cognition: Reframing and refocusing implementation research. *Review of Educational Research*, *72*(3), 387–431.

Strauss, C. (1992). Models and motives. In R. G. D'Andrade & C. Strauss (Eds.), *Human motives and cultural models* (pp. 1–20). New York, NY: Cambridge University Press.

Trowler, P. (2008). *Culture and change in higher education: Theories and practice*. London, England: Palgrave Macmillan.

Trowler, P., & Cooper, A. (2002). Teaching and learning regimes: Implicit theories and recurrent practices in the enhancement of teaching and learning through educational development programmes. *Higher Education Research & Development*, *21*(3), 221–240.

Umbach, P. D. (2007). Faculty cultures and college teaching. In R. P. Perry & J. C. Smart (Eds.), *The scholarship of teaching and learning in higher education: An evidenced-based perspective* (pp. 263–317). Dordrecht, The Netherlands: Springer.

Weller, S. C. (2007). Cultural consensus theory: Applications and frequently asked questions. *Field Methods*, *19*(4), 339–368.

Willis, P. (1977). *Learning to labor: How working class kids get working class jobs*. New York, NY: Columbia University Press.