A situative analysis of postsecondary teaching: Examining the relationships among faculty beliefs about student learning, course planning, and classroom instruction

By

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Acknowledgments

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Abstract

A situative analysis of postsecondary teaching: Examining the relationships among faculty beliefs about student learning, course planning, and classroom instruction

Matthew Tadashi Hora

An abundant literature exists on course planning and classroom instruction at the postsecondary level. However, relatively little is known about how faculty actually plan and then teach their courses, particularly in the science, technology, engineering, and mathematics (STEM) disciplines. Inhibiting the field of higher education's understanding of how and why faculty teach the way that they do is due in part to methodological limitations including the paucity of empirical research that integrates accounts of course planning with classroom instruction, a reliance on self-reported data and statistical analyses that obscures subtle features of decision making and practice, and uni-dimensional notions of instruction (e.g., solely as the teaching methods an instructor uses) that ignores the role of students and instructional technologies. Further, the literature is not guided by a clearly articulated theory of educational practice, and how various factors (e.g., cognitive, organizational) influence faculty work.

A rich body of literature is available on K-12 teacher cognition and situated cognition offers a rich foundation of theory and method that can be used to illuminate features of faculty work. A fundamental argument advanced by this literature is that both planning and classroom teaching cannot be adequately described as simply the enactment or delivery of rote pedagogical techniques, but instead as complex practices that are informed by both conscious and sub-conscious cognitive characteristics of individual teachers and features of the immediate instructional context. Pedagogical beliefs, particularly those regarding how students learn, play a unique and influential role in this process by filtering new information, framing problems, and

guiding action in concert with other mental representations. Importantly, teacher thinking and planning does not take place in a cultural or organizational vaccum, but is deeply embedded in the routines, norms, and physical features of organizations. Situative theories of cognition and activity can be particularly useful in integrating accounts of individual cognitive activity with the socially organized systems in which they take place. In particular, situative views of cognition and practice emphasize how problem spaces (i.e., representation of a situation, goals, and strategies for reaching goals) emerge in activity, how understanding is shaped through individuals' interactions with one another and their environments, and how learning includes participation in the patterned behaviors of communities of practice.

Research on faculty thinking suggests that the pedagogical thoughts of postsecondary teachers can be characterized as existing on a continuum from student-centered to teaching-centered orientations, the latter of which are viewed as more pedagogically effective than the former. Additionally, these orientations are widely seen as unilaterally determining classroom instruction and even student learning outcomes, such that some scholars claim a clear and causal chain of relations among these elements. However, this body of literature has been critiqued for insufficient conceptualization of psychological constructs, lack of attention to the influence of organizational contexts, and the tendency of researchers to rely exclusively on self-report data without observing actual classroom practice. Importantly, higher education researchers tend to do not draw upon research on K-12 teacher cognition, cognitive psychology, or theories of situated cognition.

In this thesis I advance a multi-dimensional account of faculty practice based on situative theories of cognition and behavior that address these gaps in the postsecondary literature. However, my goal is not to propose yet another conceptual framework containing all possible factors that influence faculty work, but instead to ground an account of practice in the actual processes whereby faculty plan and then teach their courses. Such an approach necessitates choosing an entry point into the panoply of factors that do shape these complex processes, and in this study I focus on the role of pedagogical beliefs and how they interact with features of individual faculty and the organizational environment as part of course planning. To this account of planning I add a similarly multi-dimensional analysis of classroom teaching that captures interactions among teaching methods, student cognitive engagements, and the use of instructional technology. Using thematic, data reduction (i.e., cluster analysis and multidimensional scaling), social network, and thematic network analysis techniques, I examine interviews and classroom observations from 56 faculty from three public research universities in the U.S. Study respondents were teaching undergraduate courses in math, physics, chemistry, biology, and geology at the time of data collection.

Results indicated that 15 types of beliefs could be discerned from the data, with the most widely held being that students best learn through practice and persistence. These beliefs can be grouped into two clusters that appear to have an underlying dimensionality characterized by which agent (teacher or student) is seen as primarily responsible for constructing meaning. Additionally, two beliefs (i.e., that students best learn through practice and perseverance, and that people learn according to different styles) appear to be stand-alone beliefs unrelated to this dimension. Further, 37 faculty in the study reported beliefs that cut across the two clusters and stand-alone beliefs, thereby indicating that most faculty cannot be characterized as holding a particular "type" of belief. Analyses of classroom observation data using social network analysis resulted in five distinct configurations of teaching dimensions (i.e., teaching methods, cognitive engagement of students, use of instructional technology) across the five disciplinary groups in the study. These configurations can be seen as the cultural regularities of classroom practice for these groups, which represents the tacit and habituated teaching practices that group members enact on a regular basis. Case studies of three faculty demonstrate how beliefs, goals, prior knowledge, and perceived affordances within the organizational context all interact to shape planning and teaching. The case studies also suggest that beliefs play a role in framing or defining the parameters for teaching, or the problem space in which teaching a particular class then unfolds. That is, the data indicate that instead of unilaterally dictating what types of teaching practices an instructor uses in the classroom, beliefs instead interact with other elements to determine how a teaching task will be viewed and then enacted.

Results from this study suggest that: (a) a multi-dimensional account of course planning and classroom teaching that focuses on tracing a single element throughout the instructional process provides a rich and detailed account of faculty teaching, (b) efforts to label individual faculty as holding a particular "type" of belief, and corresponding assumptions regarding the subsequent efficacy of their teaching, should be avoided, and, (c) beliefs alone do not directly and causally determine teaching practice, but they interact with other features to help define problem spaces for teaching. These conclusions are important considering the significant resources and policymakers attention being directed towards educational improvement at the undergraduate level in general, and in the science, technology, engineering, and mathematics (STEM) disciplines in particular. Many efforts single out faculty beliefs and skills (or lack thereof) as a primary determinant of poor student learning outcomes, and thus aim to impart new beliefs (e.g., student-centered) or skills (e.g., inquiry-based teaching) to faculty in order to improve teaching and learning. However, changes to faculty teaching are slow and spotty, and increasing evidence suggests that the alignment between reform initiatives and local practices is a key factor that shapes how well a new innovation or policy is adopted or adapted. Further, supporting teacher development entails affecting changes in the organizational contexts in which teacher's daily work, as well as facilitating growth in their pedagogical skill sets and conceptual understandings of teaching and learning, such that a singular focus on changing an instructor's beliefs and/or teaching repertoire may be too narrowly focused. The field should adopt a more comprehensive view of teacher learning that views existing practices, especially entrenched beliefs and configurations of classroom teaching, not solely as barriers to progress but as opportunities for designing new programs that build upon them while also adding new elements.

CHAPTER 1: INTRODUCTION

Problem statement

An abundant literature exists on course planning and classroom instruction at the postsecondary level (e.g., Lattuca & Stark, 2009; Menges & Austin, 2001). However, relatively little is known about how faculty actually plan and then teach their courses, particularly in the science, technology, engineering, and mathematics (STEM) disciplines. This situation is due in part to the abundance of research that is either conceptual in nature or relies on statistical analyses of questionnaire data, neither of which do not illuminate the subtle features of instructional decision-making as it happens in academic settings. I suggest that another reason that the field of higher education has a relatively limited understanding of faculty decision-making is that teaching itself is often conceptualized as being comprised primarily of the overt pedagogical methods or techniques used in the classroom (e.g., Deslauriers, Schelew & Weiman, 2011), with little attention paid to either course planning or other critical dimensions of classroom practice such as the role of students or instructional technology. Further, the literature on faculty teaching is not guided by a clearly articulated theory of educational practice, and how various factors (e.g., cognitive, organizational) influence faculty work (Lattuca, 2005).

In this dissertation I argue that this narrowly conceived view of teaching in higher education is insufficient for two reasons: (1) such a view obfuscates the roles that pre-existing features of individual faculty (e.g., beliefs about teaching and learning) and organizational contexts plays during the planning process; and, (2) reducing classroom instruction to a single variable (i.e., teaching methods) ignores other important features of instructional practice (Cohen & Ball, 1999). Given the substantial resources invested in educational improvement in STEM education, more nuanced and multi-dimensional insights into the specific factors that both shape and constitute planning and teaching behaviors are necessary so that policymakers and researchers can obtain more accurate perspectives on faculty practice with which to design, implement, and evaluate professional development initiatives.

A rich body of literature is available on K-12 teacher cognition and situated cognition offers a rich foundation of theory and method that can be used to illuminate features of faculty work. A fundamental argument advanced by this literature is that both planning and classroom teaching cannot be adequately described as simply the enactment or delivery of rote pedagogical techniques, but instead as complex practices that are informed by both conscious and sub-conscious cognitive characteristics of individual teachers and features of the immediate instructional context (Borko, Roberts, & Shavelson, 2008; Feldon, 2007; Schoenfeld, 2000). Pedagogical beliefs, particularly those regarding how students learn, play a unique and influential role in this process by filtering new information, framing problems, and guiding action (Fives & Buehl, 2012; Nespor, 1987). Importantly, beliefs do not singularly determine action but act in concert with other mental representations such as teaching-related goals, knowledge, and perceptions regarding the physical and socio-cultural features of a particular organization that may de-limit for an individual which behaviors are permissible and feasible (Carayon, 2008; Greeno, 1998; Schoenfeld, 2000). Insights into the importance of the role of the context on educational practice is also apparent in research on teaching that uses a situative perspective that integrates accounts of individual cognition with the socially organized systems in which they take place. In particular, situative views of cognition and practice emphasize how problem spaces (i.e., representation of a situation, goals, and strategies for reaching goals) emerge in activity, how understanding is shaped through individuals' interactions with one another and their environments, and how learning includes participation in the patterned behaviors of communities of practice (Greeno, 1998).

While promising work exists that accounts for the wide array of factors as they impinge upon course planning (e.g., Stark, 2000) and classroom teaching (e.g, McAlpine, Weston, Timmermans, Berthiaume, & Fairbank-Roch, 2006), the field is plagued by several methodological limitations including the inadequate conceptualization of constructs, lack of attention to context, and limited empirical work linking thought and action (Kane, Sandretto, & Heath, 2002), as well as the aforementioned uni-dimensional view of classroom teaching as the delivery of pedagogical techniques. Additionally, higher education researchers tend to do not draw upon the K-12 literature, or research in cognitive psychology upon which much of this research is based, thereby bypassing a rich body of theory and method from which to draw upon (Entwistle, Skinner, Entwistle, & Orr, 2000; Lattuca, 2005). However, a promising line of inquiry on faculty practice draws on situated cognition theory, which emphasizes how cognitive processes are embedded in particular settings, to explore the problem of how and why faculty make particular teaching-related decisions (Norton, Richardson, Hartley, Newstead, & Mayes, 2005).

In this dissertation I elaborate upon this approach by drawing on the situative perspective of Greeno (1998) to investigate the beliefs regarding student learning held by faculty, and how these beliefs interact with other factors to shape the emergent problem space of instruction for individual instructors (Greeno, 1998). A core idea underlying this approach is a multi-dimensional view of practice that accounts for the influence of cognitive, cultural, and organizational influences on course planning as well as multiple dimensions that constitute actual classroom instruction. Through in-depth interviews with 56 STEM faculty regarding specific features of their course planning processes, and classroom observations using the newly developed Teaching Dimensions Observation Protocol (TDOP) that captures three critical elements of instructional practice (i.e., teaching methods, student cognitive engagement, and use of instructional technology), a rich and varied depiction of faculty practice is made possible. Within the broad problem of improving the field of higher educations understanding of how and why faculty teach the way they do, I then focus on the specific role that faculty beliefs about student learning play in instructional decision-making.

I suggest that a productive approach to understanding and unraveling the complexity of decision-making and practice is not to develop conceptual models replete with numerous boxes and arrows denoting hypothetical relations, but instead to select one element and trace its chain of influence from the beginning of course planning to actual classroom teaching as it happens to faculty in the field. In this study I hone in on the role of pedagogical beliefs as part of such an effort, and analyze the interview and classroom observation data using a variety of analytic approaches including inductive and thematic network analysis, data reduction techniques (i.e., cluster analysis and multidimensional scaling), and social network analysis. Results from these analyses for the entire sample are reported regarding the types of beliefs faculty have about student learning, any underlying dimensionality to these beliefs, and classroom observations. Then, in order to ground these analyses in the actual practices of faculty in the field, three case studies are presented that integrate each of these datasets and analyses in order to provide a comprehensive portrayal of faculty work.

Research questions

The research questions that guide the study are: (1) What beliefs do faculty have for how undergraduate students learn in their discipline? (2) What, if any, underlying dimensionality exists for these beliefs? (3) What are the unique configurations of classroom practices for faculty in different disciplines? And (4) How, if at all, do beliefs interact with other factors to influence how three faculty plan and teach their classes?

Background

A long-standing question in education is to what degree teachers' planning and classroom practice is influenced by an individual's pedagogical thoughts in general and their beliefs about teaching and learning in particular (Pajares, 1992; Shavelson & Stern, 1981). Beliefs play an important role in guiding a variety of human activity such as health behaviors (Armitage & Connor, 2000), persistence in difficult situations (Bandura, 1997), and ethical decision-making (Trevino,1986) to name but a few. Beliefs also play a critical role in the cultural life of a community, particularly in cases such as organized religion where shared beliefs can increase intragroup cohesion and cooperation (Radcliffe-Brown, 1952; Rappaport, 1979). In educational settings, beliefs, particularly those regarding how students learn, play a unique and influential role in teachers' decision-making processes by filtering new information, framing problems, and guiding action in concert with other mental representations as well as features of the immediate task environment (Fives & Buehl, 2012; Nespor, 1987). Research on school leadership using a distributed view of cognitive activity also contributes important insights into the subtle interactions between individual agency and organizational contexts. According to this view, an organization's context is not simply the backdrop to task performance, but instead, activity is conceptualized as being distributed among individual actors, artifacts, and features of the situation (Spillane, Halverson & Diamond, 2001).

Research at the postsecondary level has identified several characteristics of faculty decision-making in regards to course planning (Conrad & Pratt, 1983; Hativa & Goodyear, 2001;

Lattuca & Stark, 2009) and the multi-faceted nature of classroom instruction (Perry & Smart, 1997), yet the literature is limited in important ways. First, research on faculty thinking has been critiqued for insufficient conceptualization of psychological constructs and the lack of attention to the influence of organizational contexts on decision-making, such that findings may represent de-contextualized thoughts that bear no resemblance to the decisions made by faculty in specific situations (Kane, Sandretto, & Heath, 2002; Norton, Richardson, Hartley, Newstead, & Mayes, 2005). Further inhibiting research on faculty thinking is that little is known about a particularly influential factor – that of beliefs regarding student learning. Researchers have also found that the pedagogical thoughts of postsecondary teachers can be characterized as existing on a continuum from student-centered to teaching-centered orientations, though some critique a view of faculty thinking as an "either/or" proposition whereby individuals must be linked to specific points on a single continuum as over-simplifying a complex phenomenon (Postareff & Lindblom-Ylanne, 2008).

Second, the precise nature governing the relationships among the various forces thought to influence both planning and teaching (e.g., factors external to institutions, individual characteristics, disciplinary cultures, etc.) is poorly understood. This is due in part to the fact that much of the research on faculty planning is either conceptual in nature (i.e., model development), or relies on self-reported data without actual observations of planning, such that Stark noted that little is known about "the actual decisions teachers make about course plans and curriculum" (Stark, 2000, p. 435). Similarly, researchers of faculty thinking regularly make claims regarding the causal links between thought and action, yet few actually observe classroom practice and instead rely on faculty self-reports and/or correlational analyses with which to make their claims (Kane, Sandretto, & Heath, 2002). For example, Trigwell, Prosser, and Waterhouse

(1999) argue that "a chain of relations" from teacher thinking to classroom instruction and even student learning (p. 67), and Kember (1997) stated that "a lecturer who holds an information transmission conception is likely to rely almost exclusively on a unidirectional lecture approach" (p. 270). Yet few studies exist that integrate accounts of course planning with actual observations of classroom instruction, such that relationships between the two can be established. Instead, researchers use statistical analyses of survey data to identify associations between an instructors' beliefs or approaches with self-reported teaching practices (e.g., Trigwell, Prosser, & Waterhouse, 1999). As Kane, Sandretto, and Heath (2002) observed in their critical review of the literature, such analyses do not provide adequate evidence to warrant claims of causality between thought and action, and so the gap in the literature noted by Stark (2000) over 12 years ago remains.

Finally, a significant amount of research has demonstrated that teaching is a multi-dimensional practice that encompasses behaviors beyond the use of particular teaching methods, such as instructor enthusiasm, clarity, preparation and organization, each of which have been empirically demonstrated to be components of instruction linked to student learning (Feldman, 1989; Murray, 1983; Perry, 1997).[1] Similarly, classroom instruction can be viewed as a multi-faceted practice that encompasses the teacher, students and features of the instructional task (Cohen & Ball, 1999), instead of the common practice of focusing solely on oft-used pedagogical techniques (e.g., lecturing, small-group work, etc.). Without taking the multiplicity of instructional behaviors into account as they occur in specific, observable situations, a coarsely grained and inaccurate portrayal of classroom behavior is the result.

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[1] This body of research provides perhaps the most robust and detailed descriptive accounts of classroom instruction at the postsecondary level. Unfortunately, the research programs of these scholars in this area did not continue past the late 1990s.

The view of teaching as solely comprised of observable teaching methods is partially an artifact of the instruments researchers commonly use to study teaching at the postsecondary level. While a variety of measures exist for studying teaching, including self-report data, student ratings, peer ratings, video-tapes of classroom practice, observations, and student outcomes (Berk, 2005), the study of faculty teaching is frequently conducted using questionnaires of self-reported practice that necessarily must reduce teaching behaviors to individual items. For example, the widely used national surveys of faculty such as the Higher Education Research Institute (HERI) Faculty Survey (e.g., DeAngelo et al, 2009) and the Faculty Survey of Student Engagement (FSSE, 2010) conceptualize and measure teaching as a collection of discrete methods used by faculty. In the case of the FSSE, teaching practice is operationalized as the percentage of class time allocated to particular methods.

While these accounts of teaching have provided some important insights into the different types of teaching methods used by faculty, this perspective necessarily results in one-dimensional accounts of teaching that are limited. Self-reported data elicited in surveys have been critiqued on various grounds, including limited internal and ecological validity (Mayer, 1999; Desimone, Smith & Frisvold, 2009) and the fact that self-reported data capture espoused theories but not the theories-in-use which are actually enacted in the classroom (Argyris & Schon, 1974; Kane, Sandretto & Heath, 2002). In particular, the technique commonly called "lecture" is particularly subject to this reductionist approach, as what is generally meant by the term – a discourse given before an audience – actually masks a myriad of specific pedagogical behaviors such as distinct rhetorical strategies and the use of different instructional technologies (e.g., Hativa, 1995). Further, the lecture method is often determined a priori by researchers to be an undesirable pedagogical technique, yet as Saroyan and Snell (1997) argue, "A lecture can be as effective as any other instructional strategy so long as it is appropriately suited to the intended learning outcomes and is pedagogically planned and delivered" (p. 102).

Thus, the results of these methodological limitations have resulted in not only a paucity of robust accounts of faculty planning and classroom teaching, but also over-simplified notions of precisely what teaching is, and how to determine whether or not it is effective or high-quality. For example, I argue that the widespread conception of teaching in reductionist terms contributes to the assumption that teaching quality can be inferred from the methods a teacher uses. Indeed, national policy focused on STEM education makes this very assumption in its targeting of "lecturing" as an instructional approach to avoid in favor of more interactive teaching techniques (President's Council of Advisors on Science and Technology, 2012). One of the motivations behind this dissertation and the research program of which it is a part[2], is to add some nuance to this discussion of teaching and learning at the postsecondary level by conducting descriptive research that sheds light on what a group of people do in their workplaces. In this way, I am inspired in part by the field of applied anthropology in which a primary aim is to describe the social and cultural lives of communities in ways that can aid in the analysis and solution of real-world problems (Kedia & Willigen, 2005).

Theoretical Framework

Obtaining robust accounts of faculty practice requires not only improved instruments, but also theoretical frameworks with which to frame, interpret and analyze the resulting data. As previously noted, much of the research on faculty teaching is atheoretical, with little explanation provided for the processes that characterize faculty decision-making. In this dissertation study, I draw on the situative perspective as articulated by James Greeno and colleagues to investigate

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[2] The data reported in this dissertation was collected as part of a National Science Foundation funded study, the Culture, Cognition, and Evaluation of STEM Higher Education Reform (CCHER) project (Award # DRL – 0814724), for which I served as the Project Director and co-Principal Investigator.

these complex phenomena. A fundamental premise of the situative approach is that the individual agent, and his/her own cognitive activity and learning processes, take place in relation to the task environment in which the agent functions. Put another way, advocates of cognitive activity as situated emphasize that cognition involves task-relevant inputs (e.g., perceived environmental features) and outputs (e.g., subsequent actions that influence the situation) (Wilson, 2002). As Greeno (1998) observes, this notion is not new and has been promulgated by learning theorists (e.g., Dewey, 1929/1958; Vygotsky, 1934/1987) and scholars for many decades. What is novel in recent formulations of situated cognition and activity is that two bodies of research came onto the scene: cognitive science, and what Greeno (1998) calls "interactional studies" that focused on the dynamic interactions among actors, artifacts, and tasks. [3]

First, research in cognitive science revealed the structure and processes of human problem-solving and reasoning that represented a quantum leap in the scientific understanding of how humans think and make decisions. Advances made by early cognitive scientists resulted in more in-depth understanding of the nature and limitations of memory (Miller, 1956), the structure of problem solving (Rumelhart & McClelland, 1986; Simon, 1979), the nature of mental models and their influence on perception (Brewer & Trevens, 1981; Johnson-Laird, 1989), and differences between the cognitive schemata and problem-solving strategies of novices and experts (Chi, Feltovich, & Glaser, 1981; Ericcson & Simon, 1985), to name but a few. Such advances, and more recent research on neuroscience and its implications for educational

[3] In framing the literature in this way, in the interests of brevity I am necessarily passing over other influences on the situated cognition research program, as well as research from fields such as sociology and cultural anthropology that focus on social action. Additionally, this review is not intended to be a thorough analysis of the history of cognitive science or interactionist studies, but instead provides a short introduction to situated cognition theory as it pertains to this dissertation study.

applications (e.g., Ansari & Coch, 2006), make it impossible for researchers interested in social action to ignore these important insights into individual-level cognitive activity.

Second, research on the nature of learning, activity, and decision-making within specific socio-cultural settings sheds light on the influence of the situation on human cognitive activity. Research in this area shed light on the importance of the development of intersubjective knowledge (e.g., Steffe & Thompson, 2000), how individuals create idiosyncratic mental maps of physical settings (Lave, Murtaugh, & de la Rocha, 1984), and the importance of participation in discrete communities of practice in the learning process (Lave & Wenger, 1991). This body of research highlighted the importance of situating the individual decision-maker within a particular historical and socio-cultural context, such that cognitive activity could no longer be viewed as occurring in isolation from the environment.

The situative perspective builds on these traditions, and Greeno (1998) in particular argues that an important next step in advancing scientific inquiry into cognition should focus on activity within multi-dimensional systems.[4] This approach is particularly salient for educational research given that the problem spaces relevant to teaching situations are unstable and poorly defined, in contrast to the goals and strategies for discrete and bounded tasks such as the famous Tower of Hanoi problem often used in experimental studies. Instead, features of the problem space "emerge" during the activity of planning a lesson or interacting with students in the classroom. As a result, Greeno (1998) argues that researchers should focus on the processes whereby problem spaces are constructed and modified. In this dissertation I focus on the role of pedagogical beliefs in this process, given prior evidence that teachers' beliefs will frame how

[4] In a similarly integrative fashion, Shavelson & Stern (1981, p.461) argue that to adequately understand teaching practices, we need to understand "(a) their goals, (b) the nature of the task environment confronting them, (c) their information processing capabilities, and (d) the relationship between these elements."

new situations or problems are perceived and conceptualized (Fives & Buehl, 2012; Nespor, 1987).

Another important feature that shapes this process is how an individual perceives their socio-cultural and organizational environment to pose constraints or affordances to their actions. mental representations actually "index" aspects of the situation such that the representation (e.g., knowledge of thermal dynamics) is inextricably linked to the physical and socio-cultural environment in which that knowledge was conveyed and encoded (Brown, Collins & Duguid, 1989). For instance, Lave (1988) found that the layout of a supermarket's aisles and product selections led to particular shopping habits and purchasing decisions. This is because individuals perceive objects and situations to have particular properties and possibilities or affordances for interaction (Norman, 1988). According to this view, when engaged in planning and instructional activities, faculty will "read" their environments and determine how local policies, procedures and the curriculum affords or constrains particular pedagogical choices (Hora, 2012; Lattuca & Stark, 2009). This is important in postsecondary settings because faculty operate in relation to the socio-cultural and structural contexts of their departments and institutions, as they are "embedded in an organizational matrix" of influences including their discipline, profession and institution, and so the broader milieu of practice should be taken into account when examining faculty teaching practices (Umbach, 2007, p.263).

A situative view also has implications for the study of classroom teaching itself. The dominant view of teaching, as solely the overt teaching methods (e.g., lecturing) used by instructors in the classroom, is based on the notion that teaching is reducible to a de-contextualized, single behavior of an individual, or the lone hero premise of organizational practice (Spillane, 2006). Instead, activity itself can be thought of not solely as the physical actions of an individual but in broader terms of the context itself in which activity occurs (Cole, 1996; Engestrom, 1996). Teaching can thus be viewed in terms of participation in local networks or systems which, necessitates an account that moves beyond solely capturing the methods that teachers use in the classroom (Barab, Barnett, Yamagata-Lynch, Squire & Keating, 2002). According to this view, teaching is a multi-faceted practice that encompasses the teacher, students, and features of the instructional task (Cohen & Ball, 1999). Thus, classroom instruction not only includes the use of specific teaching methods by faculty (e.g., lecture, small-group discussion), but also the types of cognitive engagement that students experience in class, and the use of instructional technology (e.g., clicker response systems, chalkboards).[5] Each of these categories represents the core actors (i.e., teachers and students) and artifacts that comprise instructional systems-of-practice within the classroom.

The configurations that form through the collective use of these teaching methods, cognitive engagements, and technologies can be thought of as "repertoires of practice" for individual instructors, departments, disciplines, and even institutions (Gutierrez & Rogoff, 2003). In this dissertation I focus specifically on these configurations at the disciplinary level since disciplines play a considerable role in shaping faculty identities, institutional structures, and approaches to teaching and learning. These configurations can be empirically discerned through techniques from social network analysis, which are increasingly being used to study complex interactions and affiliations in educational contexts (see, e.g., Daly, 2010; Schaeffer et al., 2009; and Zhang, Scardmalia, Reeve & Messina, 2009). These patterned behaviors of communities of practice thus represent the groups cultural practice as it pertains to instruction, and new members are socialized into this habituated approach to teaching and learning.

[5] This conceptualization is specific to my target sample for the study reported below, which consists primarily of large undergraduate courses in science and mathematics at three research universities. Other teaching contexts (e.g., a high school math course) will likely include different activities.

In using the situative perspective to investigate the nature of faculty planning and classroom instruction, I build upon the research program of Alan Schoenfeld (2000) and McAlpine and colleagues (McAlpine, Weston, Berthiaume, & Fairbank-Roch, 2006). In one of the few active research programs on teacher decision-making, Schoenfeld (2000) pays considerable attention to the interactions among three distinct types of schemata: knowledge, goals, and beliefs. In his model of "teaching-in-context," Schoenfeld (2000) posits that pre-existing teacher knowledge, beliefs and goals are activated in relation to specific instructional tasks, which then inform subsequent decisions about lesson planning and in-class teaching. Then, after a class period is completed the instructor may engage in reflection or other post-class practices that then recursively feed back into the planning process for the next class.[6] In their exploratory analysis of how two instructors draw on pedagogical knowledge and goals to construct problem spaces for teaching, McAlpine and colleagues (2006) represent a rare case of postsecondary researchers who draw upon concepts from cognitive science, while also examining instructional decision-making in specific contexts. The study reported in this dissertation represents the beginning of a research program focusing on instructional-decision making at the postsecondary level that extends these efforts as a way to understand how and why faculty teach the way that they do.

Significance of the study

Answers to the questions posed in this dissertation are important considering the significant resources and policymakers attention being directed towards educational improvement at the undergraduate level in general, and in the STEM disciplines in particular

[6] This work is similar to research on course planning in higher education that accounts for the role of human cognition in specific contexts and the non-linear process of curriculum design (Conrad & Pratt, 1983; Stark, 2000), though postsecondary researchers have not yet conducted fine-grained analyses of planning practices in the same manner as Schoenfeld.

(e.g., National Research Council, 2010; PCAST, 2012). In recent decades a growing number of critics have assailed colleges and universities in the U.S. for providing inadequately rigorous and engaging instruction to undergraduate students (Arum & Roksa, 2011; Bok, 2005; Boyer, 1990). In particular, while math and science fields produce a prodigious amount of cutting-edge research, policymakers and educators are increasingly expressing concerns that these fields are failing to offer meaningful educational experiences to students. Additional concerns about the underrepresentation of women and students of color, the number of students entering these disciplines from high school and persisting until graduation, and the quality of learning taking place at the undergraduate level contribute to a rising chorus of critiques of how these disciplines are taught (NRC, 2010). These critiques are centered on the persistence of the "sage on the stage" model of instruction, where faculty primarily present facts, concepts and/or procedural knowledge in a way that relegates the student to a passive observer (Handelsman et al., 2004). Thus, reform efforts tend to focus on encouraging faculty to reduce the time they spend lecturing (i.e. verbal discourses provided to an audience [Merriam-Webster, 2011]), and to engage students more directly in the learning process by adopting methods such as problem-based learning (Hmelo-Silver, 2004), peer learning (Mazur, 1997) and digital technologies (Garrison & Akyol, 2009).

Despite these efforts, evidence suggests that faculty are slow to adopt these "research-based" teaching methods, and that the considerable investments made in pedagogical reform are having marginal impacts (Fairweather, 2008). Possible reasons for this state of affairs include organizational structures that are slow or difficult to change, entrenched cultural norms that run counter to these innovations, or recalcitrant faculty who resist changing their teaching practices (Henderson & Dancy, 2007; Kezar, 2001; Woodbury & Gess-Newsome, 2002). Another explanation is the nature of reform itself – research indicates that the mismatch between new tools or innovations, and the realities of practice within local settings in which they are introduced, is a common reason for unsuccessful reforms (Fishman, 2005).[7] This raises questions regarding whether or not education reformers are adequately informed about the cultural realities of teachers' daily experiences, and if their calls for change are responsive to these practices.

Regardless of the cause for the slow rate of curricular and pedagogical change in higher education, policymakers, instructional designers and other agents advocating change can benefit from detailed descriptions of the specific practices that teachers use in order to design, manage, and implement behavior change initiatives (Cobb, Zhao & Dean, 2009). Once identified, the situated practices of a group can be used as a foundation for designing new interventions that are more closely aligned with the realities and constraints of existing practice or as a road map to identify specific factors that can be maintained or altered to change task performance (Halverson, 2003). Given recent research outlining the deleterious effects of top-down pedagogical reforms that fail to engage faculty in the actual design and implementation of new curriculum, developing more locally attuned interventions has become a national priority (Henderson & Dancy, 2008). This stance can be contrasted with a "deficit model" approach to teacher growth and development, where poor student outcomes are seen as largely due to teachers' lack of skills and knowledge such that educational improvement depends on increasing the training and professional development provided to instructors (Putnam & Borko, 1997). This approach is not only endemic in K-12 schools, but at the postsecondary level the pedagogical acumen of faculty

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[7] This is also a basic premise in fields long involved in behavior change efforts such as public health - a key problem is the misalignment between the socio-cultural context of the "target population" and the underlying assumptions regarding behavior that inform particular interventions (Rogers, 1995; Helman, 2007).

(PCAST, 2012) and even their lack of reflection on diversity-related issues (Bensimon, 2005) are seen as a primary cause of student failure and educational inequality.

Further, supporting teacher development entails affecting changes in the organizational contexts in which teacher's daily work, as well as facilitating growth in their pedagogical skill sets and conceptual understandings of teaching and learning (Clarke & Hollingsworth, 2002; Putnam & Borko, 1997), such that a focus on single factor (e.g., changing an instructor's beliefs) may be too narrowly focused. Thus, researchers who suggest that a causal relationship exists among faculty thinking, classroom practice, and student outcomes, and that efforts to improve educational outcomes should support faculty in obtaining the more sophisticated student-centered perspectives, may be advocating an over-simplified prescription for educational improvement (Gibbs & Coffey, 2004; Ho, Watkins, & Kelly, 2001; Saroyan & Amundsen, 2001; Kane, Sandretto, & Heath, 2002).

CHAPTER 2: LITERATURE REVIEW

In this section I briefly review the literature on faculty planning and classroom instruction, followed by an in-depth analysis of research on teacher beliefs at the postsecondary level. Then, I turn to research on K-12 teacher beliefs and aspects of cognitive psychology upon which this literature is based that can be fruitfully applied to research on faculty beliefs and teaching decisions. Finally, a brief discussion of reform implementation situates the analysis within the broader context of educational improvement in general, and in math and science instruction at the undergraduate level in particular.

Research on faculty planning and classroom instruction

Planning. A substantial body of research exists on curricular design at the postsecondary level that ranges from conceptual model development to empirical studies on instructional decision-making in the field. Several researchers have developed models of curriculum planning largely to aid designers in the development of degree programs (Conrad & Pratt, 1983; Dressel, 1971; Mayhew & Ford, 1971). For example, Dressel's (1980) model posited six continua upon which course programs can be characterized (e.g., continuity to fragmentation) and that administrators and curriculum designers should consider. Conrad and Pratt (1983) critiqued this and other approaches to modeling curricular design for not sufficiently articulating the relationship among model components (especially those including environmental features) and for setting forth an overly rational, linear depiction of curriculum development that likely did not reflect how curricula were designed in actual postsecondary settings. Instead, their model is comprised of a recursive and non-linear process whereby a wide range of factors shape how curricular decision-making unfolds, including environmental inputs (e.g., professions, community), the nature of the material, instructional traditions, and resource allocations, to name but a few. This shift from abstracted model development to more grounded, descriptive accounts of how faculty and administrators actually design course curricula was also the hallmark of the research program initiated by Joan Stark and colleagues. According to their perspective, research on this topic was important given widespread calls at the time to improve teaching and learning at the undergraduate level by encouraging a more structured and "coherent" curriculum, which ultimately depended on how instructors decided to implement the curriculum at the course level (Stark & Lowther, 1986). This led researchers to question whether or not courses were designed in ways to facilitate learning, and the degree to which faculty were intentional when they planned their courses (Stark, Lowther, Ryan & Genthon, 1988).[8]

A prescient feature of the research program of Joan Stark and colleagues was the attention paid to the influence of pre-existing faculty beliefs and how these were influenced or "filtered" by features of the organizational context to ultimately shape how courses were planned and taught. Stark hypothesized that faculty beliefs and assumptions about education would drive decisions about the structure and content of a course, and that these beliefs were in turn influenced by characteristics of the discipline and contextual factors such as student characteristics and goals, external influences (e.g., accreditation agencies), departmental goals, and facilities and resources (Stark, 2000). Based on this line of inquiry, Stark developed the "Contextual Filters Model" as a way to explain how structural, socio-cultural, and psychological features of academic life influenced course planning and classroom instruction. Importantly, this model integrated accounts of planning and its myriad of influences, with classroom instruction

[8] Interestingly, this focus on how faculty "enacted" the curriculum is remarkably similar to a significant body of research on K-12 curriculum design and implementation, yet no higher education researchers cite the seminal works in this area including early work by Tyler (1949), and Apple (1978). More recent research on the transformative nature of curriculum enactment by researchers including Bernstein (2000) and Remillard (2005) offer ways of examining curricular decision-making that have gone largely unnoticed by the higher education community. In a current paper for the CCHER project I am hoping to remedy this situation by drawing on this literature to examine the specific processes whereby faculty translate the curriculum for specific classes.

itself (e.g., selection of course materials, use of particular teaching methods) in a way that depicted the clear chain of relations from one component of the model to the other. Thus, Stark and colleagues provided an account of instructional decision-making that spanned course planning and classroom instruction that clearly demonstrated that accounts of one were incomplete without the other.

While this model set forth an integrative account of faculty practice and posited specific features that shape instructional decision-making, it has not been empirically tested beyond survey validation studies. Consequently, the precise relationships among components of the model have not yet been explored. As Stark (2000, p. 435) explains, "Our work fell short of exploring in depth the actual decisions teachers make about course plans and curriculum, and only used information about how teachers prefer to arrange content and monitor student progress." [9] Despite this sentiment, little descriptive work has been conducted in the years since, with most research in this area revolving around continued model development and prescriptions for how instructional designers and administrators can improve how their institutions design and implement course curriculum (e.g., Lattuca & Stark, 2009).

Classroom instruction. An abundant literature also exists on classroom instruction at the postsecondary level, with many scholars focusing on topics such as student assessment, the use of specific teaching strategies, and discipline-based approaches, to name but a few (see Menges & Austin, 2001 for a review). In a review of the literature, Murray (1997) makes a distinction between research focusing on "low-inference" and "high-inference" behaviors. Low-inference behaviors are easily observable, concrete actions that would require little inference on behalf of

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[9] Another limitation to this and other postsecondary research in this area is the lack of any reference to cognitive psychology or other disciplines that actively study decision-making. Thus, even if Stark and colleagues had conducted more empirical work in this area, I suggest that without drawing on theory and method from fields such as naturalistic decision-making or K-12 teacher cognition, the results would have been hindered by their lack of grounding in these important bodies of research.

the observer (e.g., gesturing with arms), while high-inference behaviors requires a great deal of observer judgment and interpretation (e.g., clarity of lesson)(see also Rosenshine & Furst, 1971). Murray (1997) suggests that besides being easier for analysts to code low-inference behaviors, another advantage of focusing on these easily observed teaching practices is that teachers are more receptive to concrete feedback regarding specific behaviors, as opposed to their performance on more abstract, high-inference categories. Much of the research in this area was designed to identify whether or not teachers make a difference in student learning, and if so, what specific behaviors most contributed to superior outcomes. Another line of inquiry focused on determining whether or not student ratings were reliable and valid measures of faculty teaching (see Marsh, 1984). Essentially, work in this area is comprised of either observational studies of classroom practice or experimental studies where a particular teaching behavior is manipulated to ascertain its effect on a particular dependent measure (e.g., student outcomes). In this review, I focus on observational studies of faculty classroom practice.

Early observational studies of postsecondary teaching focused on low-inference behaviors using a combination of data collection techniques including audiotape recordings, teacher surveys, student ratings, and in-person observations (Solomon, Rosenberg, & Bezdek, 1964). Of the 169 variables identified in this study, eight factors were identified including control vs. permissiveness, vagueness vs. clarity, and encouragement of student expressiveness. The researchers conducted a correlational analysis with these variables and mean student gain in factual knowledge as well as student ratings of teacher quality, finding that factors such as clarity (e.g., speaking clearly and understandably) were correlated with both knowledge gains and high student ratings (Solomon, Rosenberg, & Bezdek, 1964). Another early study used videotapes of classes to document faculty teaching practices at 5-second intervals across 15 categories of behaviors, some of which were low-inference and others high-inference (e.g., management behaviors) (Cranton & Hillgartner, 1981). This study was novel in its recording of data at regular intervals throughout the class period, whereas most researchers summarize teaching practices at the conclusion of a lesson into a single score or data point.

Perhaps the most influential and robust body of research on faculty teaching using an observational approach was led by Harry Murray, who developed the widely used Teachers Behavior Inventory (TBI) protocol. While a primary goal of Murray's research program was to determine the nature of effective teaching practices, his observations of classroom teaching led to the identification of six factors that describe a wide range of both high- and low-inference behaviors. These factors include enthusiasm (e.g., speaks expressively), clarity (e.g., uses concrete examples), interaction (e.g., addresses students by name), task orientation (e.g., states course objectives), rapport (e.g., easy to talk to), and organization (e.g., uses headings and subheadings) (Erdle & Murray, 1986; Murray, 1983, 1985). Over time, Murray reduced the TBI from 100-items to 60-items, and this version of the TBI remains in use to this day. Additionally, research using the TBI consistently found that three dimensions of practice predicted instructional outcomes, including enthusiasm/expressiveness, clarity of explanation, and rapport/interaction (Murray, 1997). These findings were considered during the development of the classroom observation instrument used in this dissertation.

Another widely used observation instrument in higher education is the Reformed Teaching Observation Protocol (RTOP), which aims to capture the degree to which instructors are using "reformed" teaching practices or not (MacIssac & Falconer, 2002). Since the RTOP is based on underlying scales of instructional practice (e.g., classroom culture) and a priori determinations of instructional quality, however, the resulting data do not provide descriptive accounts of teaching but instead pre-judge which practices are effective and which are not. Given findings that research-based techniques can be implemented poorly and traditional lectures delivered in a pedagogically rich manner (Saroyan & Snell, 1997; Turpen & Finkelstein, 2009), such judgments call into question the validity of instruments that determine instructional quality prior to actually observing an instructor's practice. Despite these limitations, observation-based approaches represent an advance in the empirical analysis of postsecondary instruction as they typically capture multiple dimensions of practice as opposed to solely focusing on the self-reported use of particular teaching methods.

Research on faculty beliefs

A substantial amount of research exists on faculty thinking and beliefs (see Hativa & Goodyear, 2001 for a review), but the research program is considerably smaller and arguably less conceptually and methodologically robust as research on K-12 teacher cognition[10]. Surprisingly, few higher education researchers in this area reference the K-12 literature on teacher cognition in general, and cognitive psychology in particular (Entwistle, Skinner, Entwistle, & Orr, 2000; Lattuca, 2005). Instead, a parallel yet distinct line of inquiry developed on faculty thinking in the early 1990s. Researchers in this area have investigated many different types of faculty thinking, and scholars focused on beliefs have studied topics such as the beliefs of exemplary teachers (Dunkin & Precians, 1992; Hativa, Barak & Simhi, 2001), faculty self-concept beliefs (Roche & Marsh, 2002), faculty self-efficacy beliefs (Bailey, 1999; Hora & Ferrare, under

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[10] A related line of inquiry investigates how faculty and administrator "cognitive frames" influence the degree to which organizational learning occurs, particularly in relation to student equity (e.g., Bensimon, 2005). Interestingly, this research cites neither the research on faculty thinking described in this chapter or work on K-12 teacher cognition. Not surprisingly, the account of faculty cognition is mostly conceptual as the construct of "cognitive frame" is not clearly specified or linked to any specific empirical research on the nature of human cognition, thinking, or decision making.

review; Landino & Owen, 1988), conceptions about student problem-solving (Trigwell, Prosser, Martin & Runesson, 2002), and beliefs about effective teaching (Samuelowicz & Bain, 1992).

Much of the literature focuses on college faculty beliefs about teaching and learning writ large, such that little is known specifically about beliefs pertaining to student learning. Interestingly, several researchers who study faculty thinking trace the lineage of their scholarship to early work on student beliefs about their own learning (e.g., Prosser, Trigwel, & Taylor, 1996), but over time the scope of analysis has widened to more broadly defined constructs that either subsume or supersede beliefs (e.g., approaches to teaching). In one of the earliest studies on this topic, Saljo (1979) interviewed 90 Swedish teenagers and adults of varying educational backgrounds regarding their beliefs about learning, finding that students held five distinct beliefs such as learning as memorization and learning as the quantitative increase in knowledge. Later, first year students at the Open University in Britain were interviewed to identify their conceptions of learning which largely confirmed earlier work (Marton, Dall'Alba, & Beaty, 1993). These studies are examples of a large body of work focused on student beliefs about their own learning (e.g., Biggs 1988; Entwistle and Ramsden 1983), which led to the research program on faculty beliefs.

In early studies on faculty beliefs about teaching and learning, researchers found that they ranged from teaching as transmitting content on the one hand, or facilitating student learning on the other hand (e.g., Samuelowicz & Bain, 1992). In their seminal study on faculty beliefs about teaching and learning, Prosser, Trigwell, and Taylor (1996) speculated that while beliefs about learning may underlie beliefs about teaching, or that they were closely related, it was still important to disentangle the two (Prosser, Trigwell, & Taylor, 1996). This particular study was also focused on eliciting faculty beliefs in a specific instructional environment – that of first year chemistry and physics in a large university – based on research indicating that faculty beliefs are "relational" or context dependent (e.g., Ramsden, 1987). In their study Prosser, Trigwell, and Taylor (1996) adopted a phenomenographic approach that emphasized eliciting the experiences and perceptions of respondents. The researchers interviewed 24 chemistry and physics faculty, asking them "What do you mean by teaching and learning in this subject?" and "How do you know if a student had learned something in this course?" They identified five conceptions of learning, six conceptions of teaching, and examined how the two sets of data inter-relate. The five conceptions of learning included: (a) learning as accumulating more information to satisfy external demands, (b) learning as acquiring concepts to satisfy external demands, (c) learning as acquiring concepts to satisfy internal demands, (d) learning as conceptual development to satisfy internal demands, and (e) learning as conceptual change to satisfy internal demands.

Importantly, 21 of the respondents in this early study could be linked to one of the five conceptions, whereas three held beliefs that could not be distinguished between two different conceptions. This study led to additional work on more broadly construed aspects of faculty thinking, particularly "approaches" to teaching that integrate teachers' intentions and strategies. While later studies did address beliefs about student learning, none have focused exclusively on this particular belief. Instead, these beliefs have been elicited in conjunction with beliefs about teaching and other issues, and then aggregated into more generalized beliefs about teaching and learning (Samuelowicz & Bain, 2001).

*Attributes of faculty beliefs***.** Much like the literature on teacher cognition in K-12 schools, one of the defining characteristics of the higher education literature is the profusion of terms used by scholars to describe and study aspects of instructional thinking. For example, in his review of 13 studies on faculty thinking, Kember (1997, p.256) noted that researchers had used the following terms: “orientations, conceptions, beliefs, approaches, and intentions” and that few definitions had been offered for these constructs. In research pertaining to the construct of beliefs, Kember (1997) found that the term “beliefs” was less commonly used in the 13 studies he reviewed, but that in practice they were consistent with the term “conceptions”. Other widely used constructs appeared to focus on collections of beliefs (i.e., orientations to teaching) or higher-order types of thinking such as “approaches” to teaching (Kember, 1997). [11] Contributing to the sense of conceptual ambiguity, some researchers use such terms interchangeably within individual papers (e.g., Samuelowicz & Bain, 1991). Kane, Sandretto and Heath (2002) argued that this situation was contributing to terminological confusion, echoing the sentiments of Pajares (1992) in his assessment of the early literature on teacher cognition. In response, Kane, Sandretto, & Heath (2002) call on higher education researchers to “agree upon a common terminology and definitions” (p.204), and to generally pay more attention to methodological issues than was evident in the literature. More recently, researchers have more carefully articulated the constructs used in their studies (McAlpine, Weston, Timmermans, Berthiaume, & Fairbank-Roch, 2006; Norton, Richardson, Hartley, Newstead, & Mayes, 2005).

As previously noted, the most in-depth analysis of faculty beliefs about student learning was conducted by Prosser, Trigwell and Taylor (1996), who not only identified five types of beliefs but also argued that the beliefs varied along two dimensions. First, the beliefs contained a “structural” dimension that referred to whether or not the belief was responsive to external (e.g., disciplinary, departmental, or instructors) or internal (e.g., the learners) demands regarding the purpose of learning. One aspect of this dimension pertains to the manner by which meaning and understanding is acquired. For conceptions (a) and (b) it is through acquiring objective

[11] The “approaches” construct is perhaps the most widely cited and influential body of literature in regards to faculty thinking, yet the term and its attendant conceptual and technical assumptions have come under increased criticism (Meyer & Eley, 2006; Norton et al., 2005; Postareff & Linblom-Ylanne, 2008).

knowledge and facts from textbooks or through course lectures. Judgments regarding whether or not learning has occurred is subsequently based on performance on tests and homework that are created by and evaluated according to the expectations of the teacher. In contrast, for conceptions (c), (d), and (e) learning involves the student developing their own meaning of the material that elaborates upon their prior knowledge and experience. In terms of verifying the quality of their knowledge, tests play an important role but faculty holding these beliefs also reported that it is the student who knows “when they have learned something because it will have personal meaning for them” (Prosser, Trigwell, & Taylor, 1996, p.221). The authors also suggested that faculty beliefs varied along a “referential” continuum that referred to the topic or activity that the belief itself referred to. These included accumulating information, acquiring concepts, and conceptual change or development (Prosser, Trigwell, & Taylor, 1996).

As part of this study the authors also identified six categories of faculty beliefs for teaching, which could also be characterized along referential and structural dimensions, such that beliefs about teaching appeared to vary based on who is the focus of teaching, the student or the teacher (Prosser, Trigwel, & Taylor, 1996). The authors then argue that these two sets of beliefs (i.e., teaching and learning) are logically related, largely due to the fact that respondents often do not differentiate between the two. Further, these beliefs could be logically ordered into a hierarchy such that Conception E encompasses all other conceptions (a), (b), (c), and (d) whereas conception (a) reflects an individuals’ sole belief about teaching and learning. This hierarchy is also presumed to reflect varying degrees of pedagogical sophistication, with conception (e) being the most sophisticated, with subsequent implications for the quality of classroom instruction and student outcomes.

These characteristics underlying these two sets of beliefs served as the conceptual basis for the development of the "approaches" to teaching research program, which has been the primary focus of the research program of the authors since this early study. Essentially, a teaching approach includes both teachers' intentions and strategies that vary from conceptual change/student-focused to information-transmission/teacher-focused approaches, and evidence suggests that faculty can be characterized as holding one of five distinct approaches (Trigwell & Prosser, 1996, 2004). In the teacher-centered category, instructors tend to view teaching as the delivery of content to passive students, whereas in the student-centered category, instructors view teaching as the active facilitation of student learning. This work led to the development of a 16-item survey called the Approaches to Teaching Instrument (ATI) that is widely used to diagnose faculty thinking, and its relationship to a variety of outcomes including classroom teaching, student approaches to learning, and student learning outcomes (see Trigwell & Prosser, 2004).

The notion that faculty thinking in general varies along these approaches is widely shared in the literature (Kember 1997; Kember & Kwan, 2000). In one of the seminal studies on this point, Samuelowicz and Bain (1992) independently identified a five-level classification system regarding orientations to teaching and learning that varied from knowledge transmission (teacher-centric) to learning facilitation (learning-centric), with an intermediary category of facilitating learning (Samuelowicz & Bain, 1992). The three types of orientations also exhibited variation along five "dimensions," one of which was beliefs about who should be responsible for organizing and/or transforming knowledge. Other researchers have similarly found that one of the principal features distinguishing between different types of faculty thinking pertains to the agent who is seen as responsible for transforming knowledge (e.g., Martin & Balla, 1991; Pratt, 1992).

The literature is also consistent in arguing that the different types of approaches or orientations have two key characteristics. First, the different categories within framework (e.g., teacher- or student-centered) are seen as mutually exclusive points on a single continuum, such that individual faculty can be identified as holding a particular type of approach. That is, using an instrument such as the ATI it becomes possible to determine the teaching approach, and thus the underlying cognitive characteristics of a single instructor. Second, many researchers argue that a direct and causal relationship exists between these approaches and an instructor's classroom practice (Gibbs & Coffey, 2004; Kane, Sandretto, & Heath, 2002; Samuelowicz & Bain, 2001; Martin, Prosser, Trigwell, Ramsden, & Benjamin, 2000). Based on the presumed relationship between faculty thinking and classroom instruction, some researchers argue that college faculty development programs should focus on the underlying beliefs, intentions, and approaches that are associated with both desirable and undesirable practices (Devlin, 2006; Kane, Sandretto, & Heath, 2002; Prosser, Trigwell, & Taylor, 1996).

However, the research program on faculty thinking in general, and assumptions regarding the functional relationship between thought and practice in particular, have come under considerable criticism in recent years. Some researchers suggest that higher-order constructs such as "approaches" to teaching represent de-contextualized thoughts that bear little resemblance to the actual plans and decisions made by faculty in specific teaching situations (Eley 2006; Kane, Sandretto, & Heath, 2002; Norton, Richardson, Hartley, Newstead, & Mayes, 2005). Other critiques center on the validity of the ATI instrument (Meyer & Eley, 2006) and the assumption that the underlying dimensionality of faculty thinking represents an "either/or" proposition whereby individuals must be linked to specific points on a single continuum. In an analysis of faculty approaches to teaching, Postareff and Lindblom-Ylanne (2008) found that several respondents in their study exhibited multiple beliefs representing both student- and teacher-centered perspectives, which led to the suggestion that research on approaches to teaching should go beyond the student/teacher-centered dichotomy and that "a strong opposite 'either/or' positioning of the approaches does not do justice to the nature of the phenomenon." (p.120). Similarly, Gibbs and Coffey (2004) suggested that instead of teacher-centered and student-centered perspectives representing end points on a single scale, they might instead be independent dimensions such that an individual could "score" highly on both of them. A promising line of work suggests that instead of viewing distinct approaches to teaching in "either/or" terms, it may be the case that some faculty will indeed exhibit tendencies related to a single approach whereas others will hold elements of both (Akerlind, 2003; Postareff, Lindblom-Ylanne, & Nevgi, 2008).

Another critique of the literature is that prior research has overlooked the nature of the instructional situation, or the context of teaching and learning (Devlin, 2006; Eley, 2006; Norton et al., 2006). These criticisms highlight the prospect that higher education researchers have tended towards overly reductionist accounts of faculty cognition that obscure the complexity of both cognitive processes and the reality of instructional decision-making in specific settings. For example, McAlpine and colleagues (2006) argue that constructs such as "approaches" to teaching do not "fully explain the complex range of ways in which thinking appears to be enacted" (p. 601). In an attempt to capture more subtle variations in faculty descriptions of their own teaching, distinct "zones" of thinking are theorized to more accurately capture the types of thinking faculty engage in as they move towards the planning and teaching of an actual class (McAlpine et al, 2006).

*Relationship between faculty beliefs and classroom instruction***.** One of the dominant themes in research on faculty thinking is the assumption that beliefs are directly correlated with faculty teaching practices, such that individuals with teacher-centered/content-oriented beliefs will tend to engage in teaching that exhibits little attention to engaging students in their own learning process (Gibbs & Coffey, 2004). Kember (1997, p.270) states that “a lecturer who holds an information transmission conception is likely to rely almost exclusively on a unidirectional lecture approach” and Pratt stated that teacher self-reports should be viewed as “surrogate evidence for their actions” (1992, p.206). Using the ATI, Trigwell, Prosser, and Waterhouse (1999) argue that a “clear chain of relations from teacher thinking to the outcomes of student learning.”

Despite these claims, few researchers have actually observed faculty teaching and instead rely on self-reported behaviors with which to compare to their articulated beliefs or approaches. In a 2002 review of the literature on the relationship between faculty thinking and classroom practice, Kane, Sandretto & Heath argued that “research that examines only what university teachers say about their practice and does not directly observe what they do is at risk of telling only half the story” (2002, p.177). This argument is based on the notion that faculty have both idealized and working conceptions about teaching and learning which are similar to Argyris and Schon’s (1974) distinction between espoused theories and theories-in-use. Espoused theories are those accounts of activity that individuals’ are able to articulate to others and that represent their own idealized views of their behavior. In contrast, theories-in-use are more implicit guides for activity that actually shape decision-making and practice (Argyris & Schon, 1974). In educational research, this framework can be used to distinguish between accounts of faculty thinking and practice elicited through interviews and surveys (i.e., self-reports of behavior) and those based on actual observations of classroom practice (Kane, Sandretto, & Heath, 2002).

Some researchers also suggest that the relationship between faculty thinking and actual teaching practice is far more complex, and perhaps even tenuous, than some claim. For example, different types of thoughts such as goals, knowledge, and beliefs may interact with one another within specific teaching situations as faculty engage in planning and classroom teaching (McAlpine, Weston, Berthiaume & Fairbank-Roch , 2006), a finding that is consistent with research on K-12 teacher cognition (e.g., Schoenfeld, 2000). Indeed, researchers using the approaches to teaching construct also argue that these approaches are context-specific, such that a teacher's approach may vary from one situation to the next (e.g., Samuelowicz & Bain, 2001). In one of the few studies examining the relational nature of approaches to teaching, Lindblom-Ylanne, Trigwell, Nevgi and Ashwin (2006) found variation in faculty approaches by discipline and institution, yet this study did not examine why this variation exists, or the influence of other contextual factors such as departmental leadership, resource availability, or even the layout of classrooms. In a study on how physics faculty in particular are influenced by their organizational contexts, Henderson and Dancy (2007) found that perceptions regarding student abilities, time constraints, and organizational policies exert considerable influence on faculty teaching. Again, research from the K-12 sector supports the notion that taking into account the relationship between teacher cognition and the context in which teaching occurs is of critical importance (e.g., Spillane, Halverson, & Diamond, 2001). Thus, while some promising examples of research exist that have investigated faculty practice by drawing on both self-reported data as well as classroom observations (e.g., Eley, 2006; Hativa, Barak, & Simhi, 2001), relatively little is known about the interactions among faculty thinking, organizational contexts, and teaching practice (Kane, Sandretto, & Heath, 2002).

However, one study does exist in the postsecondary literature that both draws on the situative perspective while also addressing the concept of faculty problem spaces for teaching. In this study, the authors explicitly draw on a cognitive framework to explore how faculty create problem spaces for instruction that represents an internal mental model of the instructional situation (McAlpine, Weston, Berthiaume, & Fairbank-Roch, 2006). This perspective is consistent with the role that beliefs play in framing new situations or tasks, such that beliefs may be one of the more salient constructs at play in determining these problem spaces (Nespor, 1987). The authors draw on a situative perspective to ground faculty planning in specific instructional settings, arguing that the relationship between faculty thinking and practice is best understood in relation to specific situations. The specific role that beliefs play in this process of defining problem spaces is not extensively discussed, with the focus instead on goal and knowledge statements. Two instructors were interviewed before and after teaching, with statements about pedagogical goals and knowledge related to planning both overall courses and specific classes inductively identified in interview transcripts. The authors found that faculty held complex "repertoires of knowledge" that were context-dependent (e.g., features of the course under consideration, knowledge of students at the institution), which suggested that the context exerts a strong influence on shaping the nature of the problem space of teaching. This led McAlpine and colleagues (2006) to recommend that future analyses of faculty thinking investigate how problem spaces are constructed in specific contexts, and how cognitive resources such as beliefs are activated in these unique settings. This dissertation study aims to build upon this work and to extend it through studying a larger sample of faculty and utilizing a range of analytic techniques in which to address this issue.

Faculty beliefs and professional development. Faculty development initiatives have a long history in higher education, and have included a variety of strategies to improve the quality of faculty work including the provision of sabbaticals, skills-oriented workshops, and peer mentoring programs (Lewis, 1996). Increasingly, researchers and faculty developers have focused on the pedagogical thoughts of faculty as a key leverage point for instructional improvement (Kane, Sandretto, & Heath, 2002). This is not necessarily a recent development as faculty developers have long recognized that supporting the personal growth of faculty is as important as curricular improvement and enhancing the pedagogical skills of the academic workforce. For example, largely in response to faculty development initiatives that were viewed as cosmetic or piece-meal in nature, Berquist and Phillips (1975) proposed a comprehensive model of faculty development that addressed three elements: (a) faculty members' attitudes about teaching and learning, (b) instructional processes, and (c) organizational structures. The focus on attitudes was due to the view that resistance to new pedagogical methods or improvements are largely based on belief systems that often emphasize research over teaching, and the status quo over innovation. Thus, addressing the beliefs and other aspects of faculty thinking is seen as an important component, in conjunction with the providing new instructional skills and altering organizational structures, of an effective faculty development initiative (Bergquist & Phillips, 1975).

With the growth in interest in faculty thinking as represented in the literature previously reviewed, a new focus on the pedagogical thoughts of faculty became apparent in both the scholarly and practitioner literatures. In some cases, beliefs about teaching and learning came to be seen as indispensable to any efforts towards instructional reform. As McAlpine and Weston (2000) argued, “Fundamental changes to the quality of university teaching…are unlikely to happen without changes to professors’ conceptions of teaching (p. 377).” In some cases, researchers built on findings that faculty beliefs vary according to their degree of sophistication, and argued that faculty developers should design their programs to encourage more sophisticated, student-centered beliefs about teaching and learning (Entwistle & Walker, 2000). For example, Lindblom-Ylanne, Trigwell, Nevgi and Ashwin (2006) suggest that student learning can be enhanced by helping faculty develop more student-centered approaches to teaching.

In response to these claims about the causal link between faculty thinking and student learning, some professional developers have designed programs explicitly to encourage the development of student-centered beliefs and approaches. These efforts are also inspired in part by the view that traditional faculty development efforts tend to be more about providing faculty with “prescribed skills and teaching recipes” rather than on developing an individual’s pedagogical identity and expertise (Ho, Watkins, & Kelly, 2001, p. 144). Trigwell (1995) designed a workshop that aimed to encourage the development of student-centered approaches to teaching by making faculty more aware of their implicit beliefs about teaching and learning. Another examples includes faculty development programs at the University of Helsinki, which offers three levels of pedagogical training to faculty, one of which is focused on supporting the acquisition and development of student-centered conceptions of teaching and learning (Postareff, Lindblom-Ylanne, Nevgi, 2008). Indeed, Postareff, Lindblom-Ylanne, and Nevgi (2008) report that the University of Helsinki adopted as official curricular policy that faculty thinking should be changed to become more student-centered and less teacher-centered. Other efforts have attempted such conceptual change by eliciting the existing beliefs of faculty, providing exposure to alternative views, and assisting faculty in developing new lesson or course plans in light of these new beliefs (Ho, Watkins, & Kelly, 2001; Saroyan & Amundsen, 2001). A similar feature across these programs is that the pedagogical thoughts of faculty are elicited in some fashion, challenged through the presentation of evidence from the learning sciences, and opportunities to practice these new approaches. In following this model of conceptual change, some of these initiatives are similar to existing theories of personal growth and development (e.g., Argyris & Schon, 1974), and mirror efforts underway in the K-12 sector (Clarke & Hollingsworth, 2002).

The focus on faculty beliefs as a principal locus for affecting instructional improvement is not without its critics. Devlin (2006) argues that the empirical evidence is lacking in regards to the assumption that changes in beliefs will necessarily lead to changes in teaching practice. Another critique is that no single type of belief or practice is inherently superior to another, and that "different conceptions of teaching and teaching methods or styles are appropriate in different contexts (Kane, Sandretto, & Heath, 2002, p. 202)." Given evidence that some science faculty feel that the rhetoric and strategy for instructional improvement of faculty developers and educational researchers is ineffective largely due to a top-down approach whereby innovations are handed down to instructors (Henderson & Dancy, 2008), it may be important to first identify the nature of faculty work in specific contexts prior to designing and implementing programs. Such an approach not only increases the likelihood that a program will be aligned with local goals and needs, but lays a foundation of trust and goodwill (Neal & Peed-Neal, 2009).

In any case, faculty developers must account for a variety of changing circumstances facing the academic workforce when designing and implementing professional development programs in the future. These circumstances include the changing nature of the professoriate (e.g., increasing numbers of non tenure-track faculty), changing student demographics, and institutional emphases on high-quality instruction in addition to research accomplishments (Sorcinelli, Austin, Eddy, & Beach, 2006).

Research on K-12 Teacher Beliefs

An extensive literature exists on K-12 teacher cognition in general, and on their pedagogical beliefs in particular (see Kagan, 1992; Pajares, 1992; Fives & Buehl, 2012 for reviews). Indeed, since the 1950s over 700 research papers have been published on teacher beliefs, mostly at the elementary and secondary levels (Fives & Beuhl, 2012), one of the goals of which was to use insights into the determinants and characteristics of teaching practice to establish predictive models for explaining differences in teaching and student outcomes (Calderhead, 1996; Schoenfeld, 2000). One of the hallmarks of the teacher cognition research program is that it is strongly grounded in cognitive psychology, and tends to view instructional decision-making as a complex process involving various schemata, or cognitive structures stored in long-term memory, that are activated in particular situations (Shavelson & Stern, 1981).[12] One of the schemata thought to influence teaching practice is pedagogical beliefs, particularly in how they influence the specification of problem-solving situations and subsequent strategies in unstructured or ill-defined situations such as those that are commonly encountered in the classroom. Nespor (1987) described this process in terms of the nature of perception and how individuals unconsciously bring to bear various cognitive resources or "tools" when perceiving new situations or information, including facts, memories, decision heuristics, or whichever resources are available. In cognitive science this process of drawing upon representations of

[12] In their seminal review of the literature, Shavelson and Stern (1981) provide cognitively informed accounts of teacher work that integrates planning and classroom instruction, though they indicate that distinct cognitive processes are at play in each setting. For example, classroom teaching requires rapid decision-making that draws on implicit decision heuristics and scripts for activity, whereas planning may take place in a quieter setting where more deliberate thinking and decision-making can be used.

situations, initial and desired goal states related to a given situation, and possible actions or strategies for satisfying these goals is known as searching through a "problem space" (Newell & Simon, 1972). Beliefs are thought to play an important role in shaping these problem spaces because they can be held in memory for long periods, be easily retrieved due to their association with notable episodes, and have an affective saliency that guides action (Abelson, 1979; Nespor, 1987). In addition, evidence indicates that beliefs can shape perceptions about which features of a problem will be noticed and responded to as well as guiding the selection of particular problem-solving strategies (Bandura, 1977). For example, human cognition is limited in the amount of information that can be perceived at any given moment, given constraints in our perceptual systems; thus, visual, aural, and haptic inputs are perceived and encoded in selective fashion, in ways both conscious and unconscious. Beliefs are thought to play a role in determining what types of information is perceived as actionable in a given situation. A core idea underlying these perspectives is that when making decisions people do not necessarily follow the rules of logic or reason when weighing alternatives and considering courses of action, but instead, act on their beliefs (Kahnemann, 2012; Cheng, Holyoak, Nisbett, & Oliver, 1986).

Many researchers have examined the role of specific types of beliefs in human cognition and behavior. Bandura's research on self-efficacy beliefs, for example, reflect an individual's assessment about personal capacity to successfully perform tasks. He found that self-efficacy beliefs shape perceptions about which features of a problem will be noticed and subsequently responded to, how much energy is expended during task performance, and how long individuals will persist at challenging tasks (Bandura, 1977). Fishbein and Ajzen (1975) posited that a person's beliefs about the consequences of performing an action, and how they perceive their peers would judge them if they performed the behavior, will predict subsequent action. As these two examples demonstrate, beliefs represent not only knowledge about a situation or entity, but also contain an affective component that rouses emotion, and a behavioral component that can directly lead to action (Rokeach, 1968). This affective component is thought to also influence how events and information is encoded and retrieved, which makes them a particularly potent factor in regards to retrieval and decision-making (Abelson, 1979; Nisbett & Ross, 1980).

Beliefs also do not exist as isolated cognitive constructs, but instead are part of larger associative networks of cognitive structures. In particular, beliefs are thought to exist as part of organized structures or scripts that comprised of a model of reality (Block & Hazelip, 1995; Rokeach, 1968). Further evidence that beliefs do not act alone in determining behavior is that particular types of beliefs such as self-efficacy interact with other constructs (e.g., causal attributions) during problem-solving (Stajkovic & Sommer, 2000). Further, beliefs interact with experience, cultural norms and social practice to influence action. Beliefs influence problem solving through compliance with cultural conventions, which represents a form of beliefs about appropriate social practice. In Fishbein and Ajzen's (1975) theory of reasoned action, perceptions about the normative expectations a group has for appropriate behaviors interact with beliefs to determine behavior. Beliefs can also influence decision-making through individual perceptions of how particular structures or objects in their environment, which are the result of cultural norms and values of a group, act to constrain or afford particular actions (Norman, 1988; Greeno, 1994). For example, Aarts and Dijksterhuis (2003) found that when surreptitiously shown a picture of a library, study respondents then spoke softly and acted more discreetly when performing experimental tasks. Perceptions of appropriate behaviors in one's environment may prime pre-existing beliefs or expectations about behavior that subconsciously influence behavior (Bargh, 2005). Thus, "in-the-head" accounts of belief can ignore the situated nature of cognition and behavior (Brown, Collins, & Duguid, 1989). Actors try out, and eventually adopt, prevailing beliefs in their communities of practice (Lave & Wenger, 1991) or affinity groups (Gee, 2004). The cultural context in which beliefs are developed and enacted plays a major role in the reproduction of belief systems from generation to generation (Bourdieu, 1990; Van Fleet, 1979).

Finally, beliefs have a substantial, but not determinate, relation to behavior. General beliefs turn out to be unreliable predictors of behavior in specific settings. Bandura argues that self-efficacy beliefs about task performance in general (e.g., teaching) are less predictive than beliefs about performing specific tasks (e.g., teaching an undergraduate calculus class) (Bandura, 1977). Thus, Bandura advocates that researchers focus on specific types of self-efficacy beliefs (SSE) (Stajkovic & Luthans, 2003). Another approach is to compare higher-level constructs with outcome measures that aggregate across behaviors (Ajzen, 1991). In any case, the literature suggests that researchers pay close attention to ensuring that the grain-size of any psychological construct should be aligned with the grain-size of the outcome measure.

In summary, the psychological literature on beliefs highlights their importance in framing situations and guiding action, their cognitive, cultural, and social dimensions, and that beliefs alone do not determine behavior. This literature provides a foundation upon which educational beliefs should be examined, such that these important features of beliefs are not ignored. Research on K-12 teacher cognition and beliefs generally acknowledges this literature and the basic ideas briefly reviewed in this section, whereas the postsecondary literature does not.

Attributes of K-12 teacher beliefs. Early research on teachers' pedagogical thoughts and decisions was also strongly grounded in cognitive science and psychology, and focused on discerning the underlying mechanisms of instructional decision-making based on principles of human cognition including schema theory (Shavelson & Stern, 1981), decision heuristics (Borko

& Shavelson, 1978), and bounded rationality (Lee & Porter, 1990). Such inquiries took as a starting point the notion that teaching is a rational activity requiring planning and spontaneous decisions in complex settings (Shavelson & Stern, 1981). Both consciously held schemata such as goals and beliefs, as well as more automatized or subconscious cognitive processes, play a considerable role in dictating how teachers plan and teach (Feldon, 2007; Schoenfeld, 2000).

Researchers have considered the role of beliefs in shaping decisions about curriculum, instruction, and assessment. Research indicates the influence of beliefs such as teacher self-efficacy beliefs (Tschannen-Moran), epistemological beliefs (Hofer, 2001; Woolfolk-Hoy & Murphy, 2001), and attribution beliefs regarding student performance (Borko & Shavelson, 1978) on different facets of teaching practice, to name but a few types of beliefs studied in the past four decades. In mathematics education researchers found that teachers' implementation of math curriculum is strongly influenced by their beliefs and knowledge about teaching and learning (Ball, 1988; Borko et al., 1992; Nathan & Koedinger, 2000). For example, Nathan and Koedinger (2000) found that high school math teachers' beliefs about student learning cause them to misjudge students' symbolic and verbal reasoning abilities, which could lead to poor decisions about instruction and assessment. While work on teacher beliefs reached a peak in the 1990s and has given way to a focus on teacher knowledge (Borko, Roberts, & Shavelson, 2008), teacher beliefs remains an active area of inquiry for K-12 researchers (Fives & Buehl, 2012).

One of the key attributes of teachers' pedagogical beliefs is the role of beliefs play in defining problems in unstructured or ill-defined situations, such as those that are commonly encountered in the classroom. Nespor (1987) described this process in terms of the nature of perception and how individuals unconsciously bring to bear various cognitive resources or "tools" when perceiving new situations or information, including facts, memories, decision heuristics, or whichever resources are available. Since beliefs are often encoded in memory in relation to a vivid episode or emotion, they are easily recalled in association with other memories in ways that act as a sort of "filter" when perceiving a new situation (Pajares, 1992). In a more recent study, Yadav and Koehler (2007) showed videotaped clips of teaching to teachers with different beliefs about teaching and learning. Teachers holding a traditional view of learning (i.e., acquisition of teacher-delivered knowledge) reported that examples of effective teaching by the videotaped teacher included pointing out student mistakes and correcting their errors. In contrast, teachers with a more constructivist view of learning noticed the teacher discussing the nature of students errors with them after providing the correct answers. These results suggest that the teachers' beliefs framed how they viewed the problem of student learning in the video clip, as well as appropriate courses of action regarding teaching.

There has been some confusion about how teacher researchers define the construct of "belief." Pajares (1992) noted that researchers had been "messy" with the construct and often used the term as a synonym for values, opinions, attitudes, personal theories, or conceptions, often without offering a clear and consistent definition within a given study. Examples of specific definitions for beliefs include "an individual judgment of the truth or falsity of a proposition" (Pajares, 1992, p.316) and "the implicit and explicit stable and dynamic systems of propositions held as 'true' by individuals" (Fives & Buehl, 2012). Some researchers have questioned whether knowledge and belief can be empirically distinguished (Nespor, 1987; Pajares, 1992). Some suggest that beliefs underlay all types of knowledge structures (Pajares, 1992), while others argue that beliefs are more static types of structures than the more flexible and changeable knowledge schema (Roehler, Duffy, Hermann, Conley & Johnson, 1988). This is due to the perseverance phenomena, as beliefs incorporated into one's cognitive structures early in life and subsequently reinforced through experience, can be difficult to change (Nisbett & Ross, 1980; Pajares, 1992).

Researchers have also noted the importance of studying the domain specificity and grain-size of beliefs, and their role in larger psychological and socio-cultural networks. A teacher's beliefs can be about broadly defined domains (e.g., teaching in general) or more specific domains (e.g., teaching undergraduate physics majors). Fives and Buehl (2012) argued that research on teachers' beliefs should focus on beliefs related to specific teaching situations (e.g., reading instruction), disciplines, or educational contexts. Since teacher beliefs exist within larger networks, it would be more accurate to talk about beliefs in relation to other cognitive structures including types of knowledge, other beliefs, and perceptions of environmental cues (Rokeach, 1968; Nespor, 1987; Schoenfeld, 2000). Research on situated and embodied cognition emphasizes the important role that perceptions of constraints and affordances plays in decision-making, whereby teachers become attuned to what behaviors are feasible and desirable within particular settings (Greeno, 1998; Van es & Sherin, 2002). Thus, in a given teaching situation the initial perception of that situation may activate a series of beliefs and knowledge that ultimately lead to a decision regarding how to plan and teach (Schoenfeld, 2000). Importantly, perceptions of student abilities and aptitude are known to influence decisions such as how to group students for reading instruction (Shavelson, & Stern, 1981) and the degree of difficulty for particular types of assessments (Nathan & Koedinger, 2000).

This body of literature underscores the importance of pedagogical beliefs in shaping teaching practice, how these beliefs exist in relation to other psychological constructs and situations, as well as challenges that research in this area has encountered in the past. I suggest that these studies should inform how higher education researchers analyze of faculty thinking and teaching practice.

*Relationship between K-12 teacher beliefs and classroom instruction***.** The precise mechanisms governing the relationship between teacher beliefs and practice are not well understood (Schoenfeld, 2000). Given the range of pedagogical situations, belief systems are thought to fill in gaps in knowledge and to help organize and make sense of the dynamic demands of classrooms (Eisenhart, Shrum, Harding, & Cuthbert, 1988). Fives and Buehl (2012) argue that beliefs act in three different ways, from distal to proximal relationship to actual instruction: to filter (i.e., interpret events and information as salient), frame (i.e., define tasks or problems at hand), and guide (i.e., affect immediate action, such as self-efficacy beliefs for engaging students). The nature of the belief is not reliably correlated with the types of instructional decisions made by the teacher. For example, Stipek, Givvin, Salmon, and MacGyvers (2001) found that teachers who believed that effective instruction focused on procedural fluency subsequently taught in a way that emphasized students' abilities to solve problems and follow mathematical procedures. Similarly, Kagan (1992) found that teacher beliefs are associated with congruent styles of teaching across diverse situations. In other cases however, considerable evidence exists indicating incongruities between expressed beliefs and practice (Raymond, 1997). In particular, research suggests that teachers with reform-based beliefs often do not translate these beliefs into reformed classroom practice (Borko et al, 1992). Explanations for the lack of alignment between beliefs and practice include insufficient pedagogical content knowledge (Fennema, Carpenter, Franke, & Carey, 1992; Thompson, 1992), and content knowledge (Borko et al, 1992).

Teachers' beliefs play an important, if inconclusive, role in shaping instructional decisions. Shulman (1986) suggested that researchers could address the uncertain relation between belief and knowledge that the focus of inquiry should be on another construct altogether – that of teacher knowledge – which had the effect of re-orienting the trajectory of research on teacher cognition for the 1990s and beyond (Borko, Roberts, & Shavelson, 2008). Similarly, Schoenfeld (2000) argued that much of the literature lacks "explanatory power" and thus he examines the interactions among beliefs, goals, and knowledge in specific situations, represents a line of inquiry that combines rigorous analyses of teacher thinking with classroom observations in order to establish links between the two. Despite promising research such as this, a recent review of the literature found that the precise role that beliefs play in shaping practice remains unclear (Fives & Buehl, 2012). Given the early goals of the program on teacher beliefs to establish "explanatory and predictive mechanisms" for explaining differences in teacher practice and learning, it appears that the state of research indicates that such a goal was overly ambitious and perhaps unachievable.

K-12 teacher beliefs and professional development. Traditional models of K-12 teacher growth and professional development have focused on conveying technical skills to pre- and in-service teachers (Borko, Roberts, & Shavelson, 2008). This approach follows a deficit model of teacher development where teacher growth is viewed as providing individuals with the knowledge and skills that they currently lack, which were then assumed to lead to corresponding changes in classroom behaviors. In recent decades a view of teacher growth and development argued for a focus on teacher change and growth over time, and that changes in knowledge and beliefs may not result in changes in student outcomes for a considerable period of time (Clarke & Hollingsworth, 2002; Fullan, 2001). As research on teacher cognition grew over time, professional developers began to emphasize the importance of targeting teacher beliefs and different types of knowledge (e.g., content, pedagogical, and pedagogical content knowledge) as key leverage points for change. As Cuban argued, “educational change depends on what teachers do and think – it’s as simple and as complex as that” (Fullan, 2001, p.117). Along similar lines Putnam and Borko (2000) argued that teaching improvement is contingent upon helping teachers to incorporate new information into their existing belief systems. Researchers and professional developers also argued that more attention should be paid to situating teacher practice in specific classroom contexts, and thus designing professional development initiatives that address local practices and constraints (Cobb, Zhao, & Dean, 2009).

Summary of the literature

While a substantive literature exists on teacher cognition in general, and pedagogical beliefs in particular, at both the K-12 and postsecondary levels, the bodies of work vary based on their utilization of theory and method from cognitive psychology. Given the lack of grounding in research from the cognitive sciences, particularly from a situative perspective, the postsecondary literature fails do draw upon important insights into the nature of human cognition as it unfolds in complex, naturalistic settings (for an exception see McAlpine, Weston, Berthiaume, & Fairbank-Roch, 2006). In particular, the role that pedagogical beliefs play in framing new situations and the problem space for tasks suggests that future research should investigate this phenomenon at the postsecondary level (Nespor, 1987; Pajares, 1992).

In addition, the roles that *instructional goals*, *prior experience*, and *perceived affordances* in the social and organizational environment play in instructional decision-making should be considered as factors that may influence the relationship between beliefs and teaching (Schoenfeld, 2000; Stark, 2000). Research on faculty teaching must also address the well-known methodological problems facing the field, including terminological confusion and the paucity of empirical work linking thought to practice (Kane, Sandretto, & Heath, 2002; Pajares, 1992). Further, questions persist regarding the finding that faculty can be associated with a single "type" of thinking (e.g., student- or teacher-centered), or whether pedagogical thinking varies by individual and context (Postareff, Lindblom-Ylanne, & Nevgi, 2008). Finally, while integrative accounts of the inter-relationship between course planning and classroom instruction have been advanced conceptually (e.g., Conrad & Pratt, 1983; Stark, 2000), to date little empirical research has been conducted that has examined how these two facets of faculty work are related, if at all.

Addressing these gaps in the literature is important given that assumptions regarding faculty thinking are influencing how institutions and faculty developers design and implement educational improvement programs (e.g., Ho, Watkins, & Kelly, 2001). In this dissertation I attempt to address these limitations while also advancing the literature on faculty pedagogical beliefs and approaches to teaching by adopting a situative perspective of both course planning and classroom instruction.

CHAPTER THREE: METHODS

The design for the study is a qualitative case study in which an in-depth analysis of instructional decision-making and practice is conducted. Case studies are intensive analyses of a single bounded unit (e.g., an incident or an organization) that can be conducted using a variety of methodological approaches (Merriam, 1998; Stake, 1995; Yin, 2008). The case focuses on 56 math and science instructors at three large research universities who taught undergraduate courses in the spring of 2010. After examining the beliefs, their underlying dimensionality, and classroom teaching practices for all 56 faculty, I then conducted case studies of three individual faculty in order to examine the relationship between beliefs and teaching practices in greater detail. It is important to note that this study is an exploratory analysis of how faculty cognition can unfold within specific situations, and is not an experimental study that can provide warrants for generalizable claims. Instead, this study is exploratory in that it draws on a small sample to examine a new line of inquiry, which then may be used to develop more specific hypotheses and subsequent research in the future.

In this study I adopt an interpretivist approach in order to identify local meaning systems, and how individual faculty think about and approach their teaching. In emphasizing the unique lived experiences of my research subjects, I adopt the position of Geertz whose view of scientific inquiry is widely quoted: “Believing, with Max Weber, that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs, and the analysis of it to be therefore not an experimental science in search of law but an interpretive one in search of meaning” (1973, p. 5). However, I do not subscribe to the view that reality is completely dependent on an individual’s unique perspective and experience, but argue that some aspects of behavior and practice can be measured and described in “objective” terms. While this is not a positivist approach in a strict sense, the view that objective measures of social action are possible is frowned upon by some interpretivist researchers (Bernard, 2002). In this dissertation I argue that classroom instruction is a type of observable behavior that is amenable to an approach that relies exclusively on the use of structured measures, whereas course planning is more appropriately studied using an interpretive approach. Thus, in this dissertation I advance the position that in studying faculty teaching both the individuals' intent and meaning should be integrated with external descriptions to provide a robust and multi-faceted view of teaching. As Kagan (1990) argued, "the use of multimethod approaches appears to be superior, not simply because they allow triangulation of data but because they are more likely to capture the complex, multifaceted aspects of teaching and learning (p. 459). Towards this goal of integrating both approaches, the study also adopts a concurrent mixed design in drawing on both interviews and classroom observations, and assigning them equal weight in addressing the research questions (Tashakorri & Teddlie, 2002).

Research sites and sampling procedures

This study is part of a National Science Foundation funded study focused on the cognitive, cultural, and contextual factors that shape faculty planning and teaching. The research sites for this study are three public research institutions with large undergraduate populations and active pedagogical reform initiatives underway at the time of data collection. Research universities (R1) were selected because of the interest in both undergraduate education and pedagogical reform, both of which are present in large R1s. I selected the sites specifically because they share the following characteristics: (a) public research-intensive institutions as defined by the Carnegie Foundation for the Advancement of Teaching (2007); (b) institutions with undergraduate enrollments of similar size based on figures from fall 2006; and (c) institutions with similar 4-year averages of NSF Division of Undergraduate Education (DUE) funding, which indicates the level of pedagogical reform activities at a given institution. Based on these criteria, we selected Institution A located on the West Coast, Institution B located in the Mountain West, and Institution C located in the Midwest. At these institutions five disciplines selected, each of which have strong traditions in pedagogical reforms: math, physics, chemistry, biology and geology. Finally, a variety of pedagogical reform initiatives were active during the time of data collection. The course component of interest for this study was the classroom component (i.e., the lecture) instead of discussion, laboratory or tutorial sessions.

The sampling frame for the study included 263 individuals listed in the spring 2010 timetable as the instructor of record for undergraduate courses in math, physics, chemistry, biology, and geology departments. Individuals were contacted up to two times via email for participation in the study, and 57 faculty (22% of the initial sample frame) participated in the study (see Table 1, below for details on the study sample). While 57 faculty participated in this study, one respondent requested that his interview not be recorded. Thus, the number of faculty observed teaching was 57, while the study sample for the interview component is 56.

Table 1

Description of sample

	n	Percentage
Sex		
Female	22	39%
Male	35	61%
Institution		
A	18	32%
B	21	46%
C	18	32%
Discipline		
Math	18	32%

Physics	11	19%
Chemistry	9	16%
Biology	11	19%
Earth/space science	8	14%
Level of course		
Lower division	39	68%
Upper division	18	32%
Size of Course		
50 or less	10	18%
51-100	18	31%
101-150	9	16%
151 or more	20	35%
Participation in Teaching Program		
Yes	28	49%
No	29	51%
Position type		
Lecturer/Instructor (non tenure-track)	29	51%
Assistant Professor	6	11%
Associate Professor	4	7%
Professor	18	31%

Limitations to the study include self-selection bias and the lack of data regarding tacit or subconscious beliefs of respondents. Thus, study respondents likely represent a non-representative sampling of faculty within the study institutions, especially in regards to their interests in teaching and learning. However, given that approximately half of the study sample had not recently participated in teaching-related professional development, it is likely that the beliefs and practices of faculty with less interest in these activities were captures. That being said, all conclusions should be considered in light of the fact that respondents self-selected into the study. In addition, the respondents who are profiled in the case studies were selected solely on the basis of their observed teaching practices. Ideally, an analysis of whether or not distinct "types" of beliefs and observed teaching practices could be conducted to identify prototypical instructors who exhibit particular patterns in how they think and act in regards to teaching. Another limitation to the study is that no data regarding the subconscious or implicit beliefs of respondents are elicited. This is due to the descriptive and non-experimental design of the study. In the future, researchers should consider using techniques from experimental psychology such as priming to examine the role that implicit beliefs and/or automaticity plays in instructional practice (e.g., Bargh, 2005). Finally, it is important to note that the analysis of problem spaces in this dissertation differs from that of traditional research in cognitive science on this topic, which entails a highly structured analysis of the goals, action steps, and operations problem solvers utilize to perform a specific and well-defined task (Newell & Simon, 1972). In this dissertation, the idea of problem spaces is used metaphorically to conceptualize how faculty represent their teaching situations and subsequently perform planning and teaching-related tasks within those settings. Thus, instead of closely tracking the specific decision steps individuals take to solve tasks such as the Tower of Hanoi puzzle, this study examines faculty thinking about problem-solving in relation to ill-defined tasks and situations.

Data collection

The data collected in this study includes an interview and two classroom observations with each respondent, all of whom were faculty in math or science departments at the three study sites. All data were collected by three researchers, including myself and two graduate assistants.[13]

Interviews. The interview protocol was designed to elicit each respondent's beliefs about student learning, and how these beliefs influenced planning and teaching activities for a specific class (see Appendix A). The interview protocol utilized a semi-structured approach, where all

[13] The other two researchers who assisted with data collection include Joe Ferrare (then a doctoral candidate in the department of Curriculum & Instruction at UW-Madison) and Craig Anderson (then a doctoral candidate in the department of Educational Psychology at UW-Madison).

respondents were encouraged to explore new ideas tangential to the questions posed to them (Spradley, 1979). Thus, while each respondent was asked all of the questions in the protocol, the length and depth of answers varied considerably. The interviews lasted approximately 45 minutes. Questions in the protocol salient to this study include:

- What is your view about how people best learn key concepts in your field at the undergraduate level?
- Is this view evident in how you plan and teach this course? If not, why not?
- Do you have any goals for students in this course?
- What is your overall plan for the class I will be observing?
- What specific teaching techniques and/or approaches do you plan to use in this class, and what factors did you take into account as you planned?

Responses to these questions generally included a wide range of statements regarding respondents' instructional goals, prior experiences, knowledge about teaching and learning, and perceptions of how their organizational and socio-cultural environments provided constraints or affordances to their own practice. In addition, responses included clear statements of the lesson plan that respondents had developed for the class that was subsequently observed.

Classroom observations. An important complement to the interviews was observations of classroom practices, in order to explore the relationship between stated beliefs and plans on the one hand, and observed practices on the other. Thus, the primary goal of the observations was to describe classroom practices in as detailed manner as possible. While available observation protocols were limited by the use of pre-existing scales that were not salient to the study, or the prevalence of open-ended response items that would not allow for comparisons across observations, an instrument designed to study inquiry-based science instruction in middle schools did represent a viable starting point for the construction of a systems-of-practice based protocol (see Osthoff, Clune, Ferrare, Kretchmar & White, 2009). The core features of this instrument included three categories (teaching methods, student cognitive engagement, and use of instructional technology) with several codes describing specific instances of each category. The instrument allowed the researcher to circle a code when it was observed during the lesson at five-minute intervals, thereby resulting in a rich and temporally organized dataset.

I adapted the substance of this instrument to develop the Teaching Dimensions Observation Protocol (TDOP) (See Appendix A)[14]. The original protocol was changed by reducing the number of categories to include only teaching methods and cognitive demand, which would capture both faculty pedagogical behaviors and teacher-student interactions, and adding a category for instructional technology. I also included a section for open-ended notes to be taken about the specific activities taking place in the classroom. Several of the specific codes used in the original instrument suited more for a middle school classroom (e.g., reading work) were eliminated, while others relevant to a university setting were added (e.g., clicker response-systems). To identify the most appropriate codes for the entire instrument, as well as to ensure content validity, I informally surveyed education researchers active in math and science education and math and science faculty to review a proposed list of codes for each of the three categories in the Fall of 2009. This group of faculty also confirmed that the list of codes included in the instrument were consistent with their own understanding of their teaching practice, thus providing face validity for the TDOP.

Prior to data collection the three researchers participated in an extensive three-day training process. During these sessions researchers verbalized their understanding of each code,

[14] The version of the TDOP included in Appendix A has been revised to include new dimensions of practice (e.g., pedagogical strategies such as organizational skills) and new codes for existing dimensions.

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 results of the inter-rater reliability using Cohen's Kappa are shown in Table 2.

Table 2

Inter-rater reliability results from TDOP training

	Teaching Methods	Cognitive Engagement	Instructional Technology
Analyst 1/Analyst 2	0.707	0.625	0.655
Analyst 1/Analyst 3	0.745	0.659	0.781
Analyst 2/Analyst 3	0.732	0.578	0.728

The inter-rater reliability fluctuated according to the dimension of practice being observed. For this reason I provide the Kappa scores in disaggregated form. Note that 'cognitive engagement' has the lowest Kappa scores overall, further suggesting the highly inferential nature of assessing this dimension of practice. One possible explanation for the low reliability on the cognitive engagement dimension could be that the research team did not have disciplinary training in the observed classes. In an effort to increase reliability with this dimension, additional training was conducted prior to the data collection phase, though no data are available to assess the effectiveness of this additional training.

I describe each category and examples of the specific codes contained in the TDOP in greater detail below.

Teaching methods. The teaching methods category refers to overt and observable pedagogical techniques. The observed teaching techniques include both specific teaching methods and types of question-posing strategies. For examples of each code see Table 3.

While these codes provide a fine-grained description of faculty members' classroom behaviors, they remain a relatively blunt measure of instruction. That is, each of these codes represents a middle-range of specificity in regards to a particular pedagogical technique, such

Table 3

TDOP Codes for Teaching Methods

Teaching Methods	Example
Lecture (LEC)	Instructor verbally presents facts or concepts.
Illustration (IL)	Instructor uses story or anecdote to describe a fact or concept.
Demonstration (DEM)	Instructor uses a physical demonstration of a phenomena using experimental or other equipment.
Problem-solving (PS)	Instructor engages in active solving of a numerical problem.
Small group work (SGW)	Instructor directs students to work in pairs or small groups.
Desk work (DW)	Instructor directs students to work alone at their desks.
Case study (CS)	Instructor presents a case for detailed elaboration and analysis.
Online techniques (OT)	Instructor actively draws on course website.
Rhetorical question (RQ)	Instructor poses question as a figure of speech for illustrative or persuasive reasons.
Display conceptual questions (DCQ)*	Instructor poses question to obtain information about student comprehension about concepts.
Display algorithmic questions (DAQ)*	Instructor poses question to obtain information about student comprehension about algorithms or computations.
Comprehension question (CQ)	Instructor poses question to assess students generalized understanding of previous topic.
Novel question (NQ)	Instructor poses question to which he/she does not know the answer.
Whole class discussion (CD)	Instructor and students engage in back and forth discussion.

* These types of questions are frequently posed using clicker response systems. As a result, each of these questions are also coded in conjunction with clickers (i.e., DCQ-CL and DAQ-CL).

that many codes could be further broken down into more nuanced sub-codes. For example, working out problems or computations (WP) here simply refers to whether or not the faculty member is actively solving a numerical problem in front of the class, a measure which necessarily obscures subtleties of problem solving such as specific types of problem-solving procedures. However, these details can be captured in analyst note-taking if this level of nuance is desired.

Cognitive engagement. The cognitive engagement category refers to the types of cognitive activity that students *potentially* experience in the classroom. This category is based on research demonstrating that the type and degree of student cognitive engagement in the classroom is a key feature of learning (Blank, Porter & Smithson, 2001; Blumenfeld, Kempler, & Krajcik, 2006; Porter, 2002). Measuring cognitive engagement is inherently difficult, and strategies include inferring student engagement from observations of student-teacher interactions, or of student task performance. For example, Nystrand and Gamoran (1991) distinguished between substantive (i.e., sustained and deep engagement with material) and procedural (i.e., compliance with classroom rules) types of cognitive engagement, which were inferred from the type and quality of classroom discourse. Despite challenges associated with inferring student cognitive engagement, I felt it an important dimension of instructional practice to attempt to capture. To develop these codes, I adapted the category of "cognitive demand" from the Osthoff et al. (2009) instrument and adapted them to fit the undergraduate classroom. For examples of each code see Table 4, below.

Table 4

TDOP Codes for Cognitive Engagement

Cognitive Engagement	Example
Receive/memorize information (RM)	Students hear facts and information with expectations only that students will internalize and recall information.
Understanding problem solving (PS)	Students follow solution paths or other analytic processes.
Creating ideas (CR)	Students engage in brainstorm activity at their desks and report back to the class with their ideas.
Integrating ideas (IN)	Students actively reflect on prior knowledge and its relationship to new information.
Connecting to real world (CN)	Students relate course material to common experiences or aspects of their daily lives.

Because this category is what Murray (1999) calls high-inference, this category received significant attention during the instrument-training phase to ensure that all analysts coded cognitive engagement in a similar fashion. Towards this end, I developed coding rules that could be followed during data collection. For example, the “connecting to the real-world” code was only applied when the instructor linked the course material to events, place, objects or persons associated with popular culture or the state or city where the institution was located, through anecdotes or extended illustrations. Another example involves the problem-solving category, which was applied in cases when instructors verbally directed students to participate in a computation or other problem solving activity, usually at their own desks or in small groups.

Instructional technology. Finally, the instructional technology dimension refers to instructional materials or technologies used by the instructor. As the observations are necessarily limited to what is directly observable in the classroom, many critical artifacts related to instructional decision-making and classroom practice such as course syllabus, textbooks, departmental policies governing teaching and so on are not captured by the TDOP. This point applies particularly to the role of textbooks, as it is not possible to discern if an instructor is following the book's organization or using text-based problems in class based solely on an observation. Instead, textbook use is only coded when the instructor explicitly referred to or physically picked up and used a book during the class, which likely underestimates this pedagogical resource.[15]

Table 5

TDOP Codes for Instructional Technology

Instructional Technology	Examples
Demonstration equipment (D)	Ball suspended from ceiling, or laboratory equipment such as beakers.
Laptop and slides (LC)	Laptop computer connected to a digital projector that displays slides on a screen.
Posters (PO)	Posters on the wall such as the Periodic Table.
Book (B)	A textbook or other book physically used by faculty member.
Pointers (P)	Laser pointers used to shine a focused light on a screen.
Clicker response systems (CL)	Hand-held devices where students indicate answers to multiple-choice questions projected onto a screen.
Overhead projector (OP)	Projector that displays images or writing on transparent sheets of plastic.
Digital tablet (T)	A computer that displays images or writing directly onto a screen.
Black/white board (BB)	A blackboard or white-board (i.e., dry-erase board) hung on walls at the front of a classroom.
Misc object (OB)	Miscellaneous instructional artifact not captured by other codes.

The technology included in the TDOP were identified first by a review of the disciplinary literature in math and physics, and then through a pilot study in the Fall of 2009, where the actual

[15] Given the limitations of observation-based data in discerning pedagogical intentions or instructional decision-making that may be informing classroom behaviors, it is especially important to pair observations with interviews with instructors. This is particularly important in regards to the role of artifacts in systems-of-practice, as task analysis on its own will not illuminate all of the artifacts (and their features) that inform practice.

materials and technologies used by respondents were included in the final instrument. The instructional technology category is limited to those materials or technologies used by teachers alone, such that any student-based technology (e.g., a laptop used for taking notes) is obscured. The only exception is clicker response systems that typically involve instructors' generating and posting questions while students answer them using a handheld device.

Data analysis

The data for this study were analyzed in four stages. First, all 56 interview transcripts were analyzed to identify belief types using an inductive technique known as the constant comparative method (Glaser & Strauss, 1967). This step involved analyzing the data to identify mutually exclusive belief types or categories. Second, these belief types were analyzed using exploratory data reduction techniques in order to explore their underlying dimensionality. Importantly, these techniques (cluster analysis and multidimensional scaling) are used as heuristic devices with which to explore relationships in the data, which was followed by further analysis of interview data based on these preliminary groupings. Third, the classroom observation data were analyzed using social network analysis that identified affiliations between pairs of codes in the TDOP. This analysis took place for respondents in each of the five disciplinary groups. Fourth, the interview and observation data for three individuals were analyzed using thematic analysis (Miles & Huberman, 1994), which is an inductive method for identifying relationships between pairs of codes, themes, or events. Once identified, these relationships are graphically depicted in order to tease out specific chains of associations from complex datasets.

Stage 1: Identifying belief types. The analysis for this stage of the study followed the verbal analysis technique of Chi (1997), which is a structured approach to discerning the structure of cognition through inductive analyses of verbal data. All interviews were transcribed and entered into NVivo® qualitative analysis software. The first step in the analysis involved segmenting the data into manageable units using a coding scheme with which to code all transcripts. The coding scheme was created inductively, using an open-coding process where terms or phrases from the text were used to name a new code. For this phase of the analysis I worked with another researcher, where each independently developed our own code lists. In developing the code lists we used the constant comparative method, which entailed comparing each successive instance of a newly created code to previous instances in order to confirm or alter the code and its definition (Glaser & Strauss, 1967). After creating the initial code list, the analysts met to discuss the coding scheme, and then analyzed another five randomly selected transcripts. Upon two additional meetings to revise and refine the codes, a final coding scheme comprised of 10 categories and 135 individual codes were developed. Examples of categories includes "classroom practices" and "organizational factors", and examples of individual codes included "beliefs about student learning" and "instructional goals."

The next step in the data segmentation process was to ascertain inter-coder reliability, and as part of this process the analysts applied the coding scheme to five newly selected transcripts. The unit of analysis for this application of codes to the interview transcripts was an utterance, which was defined as a series of sentences or phrases pertaining to a specific subject (e.g., the course syllabus). After applying the coding scheme to the five transcripts, inter-rater reliability was assessed by calculating the percentage of agreement between the analysts in applying the codes. The proportion of instances in which both analysts coded the same code relative to all coded instances was 89%. The analysts then applied the coding scheme to all 56 transcripts, which resulted in an extensive NVivo® library of coded text.

Next, I took all text fragments coded as faculty beliefs and analyzed them using the same approach (i.e., constant comparative method) until a set of mutually exclusive categories was identified. This process continued throughout the entire dataset until a “saturation” point was reached where new data did not offer new or contradictory insights beyond the list of categories already identified (Glaser & Strauss, 1967). This process resulted in the identification of 15 unique types of beliefs. As a reliability check another researcher (not the same one assisting with the data segmentation procedure) then reviewed 25% of the raw data coded as “views of learning” and conducted a similar analysis. The two analysts then met to discuss our respective results that ended up confirming the initial finding of 15 belief types. The results are reported for the entire study sample and then by disciplinary group.

Stage 2: Identifying the underlying dimensionality of belief types. In order to examine the degree to which the 15 beliefs exhibited dissimilarity or similarity (i.e., underlying dimensionality), I followed Samuelowicz and Bain (2001) in using a combination of descriptive data reduction techniques (cluster analysis and multidimensional scaling) and inductive analyses of interview data. It is important to note that the data reduction techniques used in this dissertation are intended to serve as a heuristic device for interpreting the data. Indeed, Bernard (2002) characterizes methods such as cluster analysis and multidimensional scaling as a preliminary step in the analysis of multivariate data, where the analyst must “stare at the output and decide what the meaning is (p.653).”

Cluster analysis is a non-statistical procedure for partitioning objects into groups based on (dis)similarity as measured through a distance matrix (in this case binary squared Euclidian distance). The matrix used in this analysis included respondents as rows and belief types as columns, with a “1” indicating the presence of a belief type and “0” indicating its absence. In this analysis I used an agglomerative form of hierarchical clustering. The particular clustering algorithm used in this analysis is referred to as Ward's Method. This algorithm examines all pairs of objects in the distance matrix and clusters pairs based on the least amount of information (sum of squared distance) that is lost by the clustering. The primary output in cluster analysis is the dendrogram; a diagram that illustrates the clusters and the decisions the algorithm made to attain them. At a certain stage of the analysis the algorithm organized the belief themes into two distinct clusters, with the most widely reported belief not falling within either group. Additional analyses such as the "furthest neighbor" method of clustering were conducted and provided similar results. All cluster analyses were conducted using SPSS.

Next, as a complement to the cluster analysis I used a nonmetric multidimensional scaling procedure to analyze the data. Instead of locating belief types into mutually exclusive groups as is done in cluster analysis, multidimensional scaling graphically represents the similarity (or dissimilarity) between themes as distances in a two-dimensional space. In this analysis I used Euclidean distance to identify theme proximities. Multidimensional scaling also provides a measure of the degree to which the resulting graph is consistent with a perfectly proportional graph of code relationships, known as the "stress" value. Kruskal and Wish (1978) suggest that a cutoff for acceptable stress exists between 0.0 and 0.2, and the stress value for the analysis performed for this thesis was .018.

Then, in order to interpret the meaning behind these results I organized the original text fragments coded as "views of learning," which had been labeled as referring to one or more of the 15 belief types, into the three groups indicated by the cluster analysis. Then, I conducted an inductive analysis of these data with an eye towards detecting the nature of the similarity among data within each cluster. This approach is similar to Corbin and Strauss' (2007) structured approach to grounded theory, where external theory or an a priori research question dictates the coding and subsequent interpretation of the data. In this case, the grouping of the data represented the imposition of an external framework on the data. This procedure entailed grouping the raw data and associated belief type codes identified earlier in the analysis into three distinct groups (i.e., the two clusters and the widely reported individual belief), and examining the data to identify whether or not each group varied according to a discernable theme or underlying dimensionality (i.e., selective coding in the grounded theory methodology). A new set of open codes were derived while reviewing the data and ultimately a single theme emerged that best described the grouping of the belief types.

Stage 3: Analyzing classroom observation data using network affiliation. I use techniques from social network analysis to analyze the observation data, as it is well suited to capturing configurations within and between the dimensions of practice. The raw data for this analysis are in the form of a two-mode (or "affiliation") matrix that consists of instructors' five-minute intervals as rows (mode 1) and TDOP codes as columns (mode 2).[16] In the matrix a '1' denotes that the particular TDOP code was present in the interval, and a '0' denotes that the code was not present in that interval. Using UCINET (Borgatti, Everett, & Freeman, 2002), the two-mode data matrix was transformed into a one-mode (code-by-code) matrix through matrix multiplication. This transformation results in a valued co-occurrence matrix in which each cell corresponds to the number of intervals that TDOP code *i* is affiliated with code *j*. For example, the intersection of Code 1 (e.g., small group work) and Code 3 (e.g., problem-solving) could have a value of three, which means these two dimensions of instruction were co-coded in three five-minute intervals across all instructors in the matrix. Next, the program Netdraw (Borgatti,

16 This means that, at least initially, each instructor has multiple rows of data, one for each five-minute interval that was observed.

2002) was used to graph the co-occurrences between each pair of codes across all instructor-intervals. 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, thicker lines correspond to stronger co-occurrences, which can be interpreted as more frequently co-coded in the same five-minute interval (than those lines that are thinner).

Configurations of co-occurring codes within each graph are used to identify patterns of practice at the disciplinary level. That is, I construct code-by-code co-occurrence (or "affiliation") graphs in order to identify the TDOP codes that most frequently co-occur (i.e. coded in the same five-minute interval) in each discipline. Within the systems-of-practice framework, capturing the co-occurrence of teaching methods, cognitive demand, and instructional technology provides a direct measure of the configurations within and between the different dimensions of the activity system.

Next, I use the concept of graph density (Δ) to measure the breadth of each discipline's repertoire. The density describes the proportion of ties in a graph relative to all possible ties. In the context of this study, the density refers to the proportion of co-occurrences between TDOP codes relative to all possible co-occurrences. Thus, in calculating the density I temporarily ignore the strength of the co-occurrences by dichotomizing the matrix. In this case a '1' indicates that code i and j appeared in the same five-minute interval at least once, and a '0' indicates that the codes never co-occurred. The result is a value ranging from 0 (if there are no lines present in the graph [L=0]), up to 1, in which all possible lines are present ($L=g(g-1)/2$) (Wasserman & Faust, 1994). In graph-theoretic terms, a '0' corresponds to a null (or "empty") graph and a '1' corresponds to a complete graph.

Finally, using the raw (two-mode) dataset I identified the prevalence of “practice triads” by calculating the simple proportion of five-minute intervals in which particular codes from each dimension of teaching were affiliated. A practice triad represents the affiliation of codes from each of the three dimensions of observed practice. For example, among the physics faculty in this study, the practice triad of “lecture-receive/memorize-laptop/slides” was observed in 50.7 percent of the five-minute intervals. This means that in half of the observed intervals the teaching technique of ‘lecturing’ was co-coded with the cognitive engagement of ‘receive-memorize’ and the technology ‘laptop-slides’ (e.g. PowerPoint) in the same five-minute interval. I report some of the most common triads for each discipline in order to provide snapshots of how the three dimensions of instruction co-occur within each disciplinary repertoire of practice. In addition, I report those triads that were observed less frequently overall but were nonetheless distinctive of a particular group’s graph. For example, the ‘small group work-problem solving-laptop/slides’ triad was only observed in 7.1% of biologists’ intervals, but this exceeded all the other disciplines.

Stage 4: Case studies of three individual instructors. The next stage of the analysis entailed conducting in-depth case studies of three instructors. The goal of these case studies was to discern the role of beliefs and other psychological constructs (e.g., goals) in the decision-making processes related to planning and then teaching a particular class. Given widespread interest in encouraging “interactive” teaching techniques, and whether or not beliefs and/or situational constraints are related to the use of these techniques, an instructor who utilized an interactive approach as evidenced in their TDOP data was selected from our sample. While no objective standard exists to determine the degree of an instructor’s “interactivity,” I used three criteria from the literature that are considered to be an indicator or more engaged and effective teaching styles. These include *a high-degree of question asking* (Chin & Osborne, 2008; Pedrosa-de-Jesus, da Silva Lopes, Moreira & Watts, 2012*), diverse types of student cognitive engagements in the classroom* (Blank, Porter & Smithson, 2001; Blumenfeld, Kempler, & Krajcik, 2006), and *the pacing of lessons that avoids extensive stretches of the same activity* (Johnstone & Percival, 1976; Burns, 1985). Based on these criteria I identified one instructor each from biology, mathematics, and physics.

Once three individuals that met these criteria were identified, their interview transcripts were analyzed using thematic network analysis.[17] I used thematic network analysis to identify relationships between concepts or events in a graphic and time-ordered fashion (Miles & Huberman, 1994). The primary aim of this analysis was to illuminate the role of psychological and cultural factors in faculty planning and teaching. Data included in this analysis include codes identified through an inductive analytic process, and the analysis of TDOP data for each instructor which included calculating how often particular codes were observed as a proportion of all observed codes. Besides utilizing the belief codes identified earlier, I identified the following additional codes: text that included clearly stated instructional goals were coded as *goals*, text that referred to previous experiences salient to the topic at hand were coded as *prior experiences*, and text that included references to how specific factors constrained or afforded teaching practice were coded as *perceived affordances*. Then, each transcript was analyzed to identify explicit statements regarding relationships among each of these codes as well as observed teaching practice. These relationships were identified through two types of criteria: (1) respondents' statements that clearly indicated a causal relationship, and (2) analyst interpretation

[17] Miles and Huberman (1994) call their technique "causal network analysis" and offer a robust defense of ascertaining causal relations from qualitative data using these techniques. However, I was uncomfortable in claiming causality among faculty beliefs, other factors, planning, and teaching given the nature of the data (i.e., self-reported accounts of practice) and thus decided to call the technique used in this thesis "thematic" network analysis.

of associations between elements. As an example of respondent-based claims regarding associations between factors, one of the faculty included in this analysis clearly stated that the layout of the classroom (i.e., a perceived affordance) precluded the use of the chalkboard and thus led to the planned use of PowerPoint slides instead. Associations reliant on the analyst interpretations are limited to positing links between beliefs and observed teaching practices – relationships that could not be directly made by respondents.

CHAPTER FOUR: RESULTS – BELIEF TYPES AND DIMENSIONALITY

In this section I report the results of the analysis that address the first two research questions motivating this study. First, the beliefs that faculty have for how undergraduate students learn in their discipline are reported for the entire sample and then by disciplinary group. Second, the underlying dimensionality of these beliefs are examined using data reduction techniques and a re-analysis of the interview data.

Belief types

The analysis of interview data resulted in the identification of 15 distinct themes for student learning. The median number of references to beliefs per individual was three, and the range varied from zero references to seven references. This variation among respondents underscores the potential role of volubility in the elicitation of belief data using interview techniques, as some individuals by nature spoke more extensively during interviews than others. However, 84% (47) of respondents reported between one and four beliefs, thus indicating that most faculty in the study sample consciously held a similar number of beliefs.[18] The analysis of interview fragments codes as "views of learning" revealed 15 distinct belief types (see Table 6, below). Each belief type is briefly described in the following section.

Table 6

STEM faculty beliefs about student learning (n=56)

	Belief Type	Number of References	Belief Description
1	Practice and perseverance	27	Learning comes through prolonged effort on solving conceptual and computational problems by self.
2	Variability	20	All people learn differently (e.g., visual,

[18] Interestingly, four respondents responded to the question regarding beliefs by saying that they had no formal training in education. For example, one respondent stated that "I have not done a whole lot of learning about how people learn," thereby indicating that some felt that beliefs about learning themselves should be grounded in some form of formal training.

			auditory, hands-on, etc.).
3	Hands-on/ Application	18	Learning is best facilitated through active, hands-on engagement with the material (e.g., labs, field-work).
4	Articulating	16	Students learn best when vocally articulating their own thoughts, ideas, and problem-solving processes to others.
5	Not in the classroom	16	The classroom (i.e., the lecture) is not the best venue for learning.
6	Visualizations	13	Students learn effectively when material is put into visual or other physical form.
7	Active construction	12	Students must actively develop their own understandings of the material.
8	Connection to experience	10	Learning is facilitated when course material is explicitly linked to students' own experiences.
9	Scaffolding	8	Learning is facilitated when course topics are presented in a sequential fashion from least to most difficult.
10	Examples	5	Students learn from concrete examples and illustrations of course material.
11	Explication	5	Learning is facilitated through the clear explanation of topics or problems.
12	Repetition	4	Students learn through repeated exposure to a topic or idea.
13	Osmosis	3	Students learn by being in the presence of an expert (i.e., an academic).
14	Memorizing	2	Learning is accomplished through memorizing facts or computational rules.
15	Individualized instruction	2	Learning is facilitated through one-on-one interaction with an instructor.

*Practice and perseverance***.** 27 respondents reported the belief that student learning is best achieved when the student works diligently on their own to engage in problem-solving practice. A core feature of this belief is that learning occurs over time and through sustained engagement with the material. The level of engagement that faculty reported was very high, thus indicating a view of practice as one requiring many hours of hard work. As one respondent stated, students "will not learn until they do it a thousand times." Thus, 48% of the faculty in the study sample expressed the belief that prolonged study, particularly in solving computational problems, is a key prerequisite for learning course material.

Interestingly, several faculty described this belief in physical or even violent terms, such as “banging one’s head against the table,” “mental weight lifting,” and “grinding away at it.” The use of physical imagery such as this suggests two things: that faculty view learning as something akin to athletic training, and that faculty view learning as taking place only through struggle and pain. Finally, several respondents described their beliefs about practice and perseverance in terms of homework assignments and other out-of-class student work. Thus, embedded within this belief was an assumption about the role of classroom-based instruction – that it was secondary to the work that students did on their own. For some faculty then, the class becomes a staging ground for introducing problems and computations that students then take home (or to the lab) to probe more deeply. Another math faculty who was teaching an introductory course at the time of data collection stated that in her class no “deep content” is discussed, as students are viewed as needing first to grasp basic techniques that they then take home and practice in homework, discussion sections and on quizzes.

***Variability*.** The next most regularly cited belief was that the fundamental nature of learning varies from person to person (20 respondents). One respondent characterized this belief as “the eyes, ears, and handwriting” theory of learning styles, or that some people are auditory learners while others rely on visual or text-based methods. As such, no single type of instruction or learning milieu is adequate for all students, but instead, different people will gravitate to the type of learning they find most effective. For some faculty this belief is grounded in personal experience. One geology professor explained that her colleagues all have very distinct styles of thinking and approaching their research, which was evidence that different people have different ways of problem-solving and learning. Interestingly, no respondents who cited this belief referenced the literature on learning styles (e.g., Kolb & Kolb, 2005). One of the implications of this belief is the subsequent attempt by some faculty to provide different learners in their classrooms with correspondingly diverse types of learning opportunities. A physicist in the study stated that given the range of student learning styles, he deliberately planned his classes to include lectures, hands-on exercises, readings, and web-based modules. Another respondent linked this belief to the current generation of students, whom she perceived as having limited attention spans due to being raised in a digitized world.

Hands-on/application. 18 respondents reported the belief that learning takes place when students are actively engaged with the material in a hands-on manner. This type of learning was frequently associated with venues such as laboratories or field-work sites. In this case, optimal learning does not occur through the passive reception of information (i.e., sitting in a lecture hall, reading a book, etc.) but through the active involvement with the subject matter. For example, a physics faculty member stated that students should take the principles of physics gleaned from their classes or readings and "apply them to real things." In this case, the respondent explicitly drew on research from the learning sciences (e.g., NRC, 2000) to explain how abstract ideas are best retained when the learner actively applies the idea on their own through physical or computational manipulations. This belief is similar to the belief regarding student's practice and perseverance in that a focus is on the student being directly engaged with the material, though the data supporting the hands-on/application belief did not reference hard work or diligence. Additionally, this belief is similar to the active construction belief reported later in this section, and the distinction here is that the hands-on/application belief included references to actually applying knowledge in real-world situations whereas the active construction belief refers more to students constructing their own understanding of the material.

Student Articulation. 16 respondents expressed the belief that learning occurs when students are forced to articulate their own understanding of the material to their peers or the instructors. That is, an especially effective way to learn something is to be forced to teach it, because through the act of verbalizing one's level of comprehension for a given topic it becomes clear to the audience whether or not the interlocutor genuinely understands the material. Additionally, through the act of expressing their ideas to peers or instructors, students put themselves in a position to receive valuable feedback in the form of confirmation or critique. This social aspect to learning is viewed by some faculty as providing an especially powerful and influential learning environment, particularly in creating opportunities for students to confront and address misconceptions about the material. Given the perception that many students dislike speaking in front of large classrooms, but are more comfortable speaking privately with their neighbor, encouraging small group work or peer interactions is a common pedagogical technique some faculty use to facilitate student articulation.

Learning outside the classroom. 16 respondents reported that learning takes place outside of the classroom. In other words, faculty expressing this belief felt that of all possible learning environments (e.g., laboratories, discussion sections, field-work, etc.) the classroom format, particularly large "lecture" style classes, was the least amenable to facilitating student learning. In disciplines such as geology and biology, where research experiences in the field are a core part of advanced undergraduate and graduate training, faculty stated that students only really understand how to "do science" when they are forced to design studies or collect and analyze data in the field. Thus, the classroom is viewed as an important venue in which basic principle of a discipline are conveyed and discussed, but only as one component of a students overall educational experience.

In some cases this belief was closely related to beliefs about effective modes of teaching. For example, a physics faculty observed that if students simply “show up to take notes” then it is not a productive use of their time, since passively watching the instructor write on the chalkboard or recite from slides is not an effective way to learn. In this case, the instructor then observed that good teaching did not encourage students to take such a passive role in the classroom.

*Visualizations***.** 13 respondents expressed the belief that students learn most effectively when the course content is put into visual or other physical form. This belief is based on the assumption that learning abstract, de-contextualized topics is harder for students than learning about topics through their physical manifestation. For several faculty this simply entailed projecting PowerPoint slides of images that illustrated the material (e.g., RNA sequences, volcanic eruptions, hydrologic cycles), whereas others used more complex demonstrations or models. In each case, the respondent suggested that the nature of the material lent itself to visualization. For example, one chemistry professor stated that “chemistry is a colorful world of molecules” that could be shared with students through physical models, PowerPoint slides, or drawings of molecular structures on the chalkboard. Other faculty saw visualizations as acting as an aid for retention, such as providing chocolate for students when talking about chocolate tree pollination. As with the belief about learning styles, no respondents referenced the extensive literature on the role of artifacts and visualizations in facilitating student learning.

*Active construction***.** 12 respondents reported the belief that learning is dependent on students actively constructing their own unique understanding of the course material. In several cases the term “construct” was used to describe the learning process, and three faculty specifically reference constructivist learning theories. An important idea underpinning these references was that retention and comprehension is enhanced when students come to appreciate the course material on their own terms. That is, students do not rely on the instructor's formulation of a concept or idea, nor do they rely on the textbook or other expert's opinions. As one chemistry faculty noted, "successful students reformulate it (course material) in their own terms." As such, this belief is closely related to other beliefs that emphasize student effort in developing expertise in a topic (e.g., practice and perseverance, hands-on/application).

*Connection to experience***.** 10 respondents expressed the belief that students learn best when the connection between the material and their own lives is made explicit. Five respondents used the word "motivate" to explain this phenomena, as they felt that students should not be expected to be excited about the material on their own, and that instructors had to clearly explain why the topic was important and relevant to their lives and future careers. For example, a chemistry faculty teaching a course with mostly pre-med students felt that the relevance of chemistry to health science was often "not clear," and so he included topics such as the history of penicillin to make the connection explicit. Thus, the faculty reporting this belief think that students will become more engaged when instructors connect the material to their own experiences, which in turn enhances learning.

Scaffolding. Eight respondents expressed the belief that student learning is best achieved when instructors effectively sequence course material. This scaffolding of material can take place in a variety of ways, from introducing basic concepts first followed by more complex material, or by providing concrete illustrations before delving into more abstract principles. For example, one chemistry faculty stated that students learn about chemical reactions by first being introduced to element combinations, molecular structure, and polarity. Another chemistry faculty elaborated on this point by stating that before students can learn about the causal mechanisms of chemistry, they first must be introduced to more descriptive, basic concepts of the field. Interestingly, these views of scaffolding represent an elementary understanding of the concept as it is used in educational psychology and instructional design (e.g., Puntambekar & Hubschner, 2005), thus indicating the prospect for some faculty to further develop their understanding of scaffolding and how it can be used in the classroom.

*Examples***.** Five respondents expressed the belief that students best learn when given content-rich and real-world examples of course material. That is, providing abstract principles or theorems with little or no concrete illustrations regarding how they either can be used to solve actual problems, or how they appear in the natural world, does not adequately engage students or provide them with ways to envision applying these ideas in their own problem-solving. These examples can take many forms, including anecdotes, analogies, or even multi-media. For example, one chemistry faculty stated that anthropomorphizing chemistry (e.g., likening chemical bonding to friends being attracted to one another at a party) is an especially effective way to reach undergraduate students. In this way, this belief is focused on using various types of concrete examples to engage students while also providing them with key insights about more abstract ideas and principles.

Explication. Five respondents reported the belief that students require explicit, step-by-step descriptions of course material, particularly at the early undergraduate level (e.g., lower-division courses). For these respondents a key antecedent to learning is simply the instructor explaining the material. For example, one math faculty reported spending time focusing on certain aspects of the day's topic and highlighting potential problem areas and how students can best approach them. Another answered the question regarding beliefs about student learning with the short reply, "You explain the principles and then they have to practice it – that's it." Thus, this belief is based on the assumption that learning is achieved largely through the instructor's ability to clearly explain the course material to students.

*Repetition***.** Four respondents stated that effective learning requires repetition, particularly for students with limited background or aptitude. That is, by reviewing topics regularly and focusing on particularly important or challenging concepts several times throughout a semester, instructors create an environment in which students can learn effectively. As one chemistry faculty reported, going over key concepts "repeatedly" is the key to learning.

Osmosis. Three respondents expressed the belief that students learn by being exposed to high-quality researchers. As one biology faculty stated, all students should take courses from active researchers who can share cutting-edge ideas with their classes. One reason that the presence of these faculty in the classroom is viewed as a key component of learning is because they have access to information, opportunities, and skills that other instructors do not. Thus, this belief does not pertain to the specific pedagogical methods being used in the classroom but instead speaks to instructor attributes as being a considerable factor in the quality and efficacy of student learning.

*Memorizing***.** Two respondents reported the belief that memorization was a key facet of learning, particularly in math and science. As one biology faculty stated, biology is a "foreign language" with a substantial amount of terms and concepts that are new to most undergraduate students. Thus, students should take the key terms and definitions from the textbook and class sessions and simply memorize them. While this belief was not cited as the only aspect of effective learning, the faculty reporting this belief felt that some aspect of rote memorization was necessary to acquire facility with a discipline's definitions and units of measurement.

Individualized instruction. Finally, two respondents expressed the belief that learning best occurs in one-on-one situations where the faculty member can provide individualized instruction to the student. Both respondents mentioned that office hours represented one of the most valuable learning opportunities for undergraduates, and one even argued that it was the most important part of the course. In such a venue, the instructor can help students get past "cognitive humps" and assist them in recognizing precisely where they are encountering challenges with the material. In addition, one respondent argued that in an active learning classroom, where students are directly engaged with one another and the instructor, a sort of individualized instruction can also take place if students feel comfortable asking questions in class.

Belief types by discipline

Given the important role that the discipline plays in academic life, I next analyzed these data according to the disciplinary affiliation of each respondent who cited a particular belief. The results should be interpreted with the different sample sizes for each disciplinary group in mind, with mathematicians making up the largest group (n=17) and geologists the smallest group (n=8). Thus, a more accurate or informative measure may be the proportion of respondents reporting each belief (see Table 7, below).

Table 7

Belief types by disciplinary group (n=56)

	Belief Type	Biology (n=11)	Chemistry (n=9)	Math (n=17)	Geology (n=8)	Physics (n=11)
1	Practice and perseverance	3 (27%)	4 (44%)	13 (76%)	2 (25%)	5 (45%)
2	Variability	4 (36%)	6 (67%)	5 (29%)	1 (13%)	5 (45%)
3	Hands-on/ Application	4 (36%)	3 (33%)	4 (24%)	5 (63%)	2 (18%)
4	Articulating	5 (45%)	2 (22%)	4 (24%)	3 (38%)	2 (18%)
5	Not in the classroom	4 (36%)	0	5 (29%)	4 (50%)	4 (36%)

6	Visualizations	2 (18%)	6 (67%)	1 (6%)	3 (38%)	1 (9%)
7	Active construction	4 (36%)	1 (11%)	4 (24%)	1 (13%)	1 (9%)
8	Connection to experience	3 (27%)	2 (22%)	0	2 (25%)	3 (27%)
9	Scaffolding	1 (9%)	3 (33%)	2 (12%)	1 (13%)	1 (9%)
10	Examples	0	2 (22%)	2 (12%)	0	1 (9%)
11	Explication	0	0	4 (24%)	0	1 (9%)
12	Repetition	1 (9%)	2 (22%)	1 (6%)	0	0
13	Osmosis	1 (9%)	2 (22%)	0	0	0
14	Memorizing	1 (9%)	1 (11%)	0	0	0
15	Individualized instruction	1 (9%)	0	1 (6%)	0	0

These data provide an interesting illustration of possible differences among the groups in the study sample. For example, some beliefs are notable in the relatively high or low numbers of references from particular disciplinary groups. While all groups reported the belief of practice and perseverance, the math faculty in the study did so with the highest proportion of respondents (i.e., 76%). For the belief about visualizations, chemistry faculty reported this belief the most (67%) followed by geology faculty (38%), but the other groups referenced the importance of visualizations with far less frequency. Regarding the belief about explication, more math faculty reported this belief (24%) than any other group, especially biology, chemistry, and geology faculty, none of whom referenced the belief. Conversely, some interesting results pertain to groups that did not make any references to particular beliefs. For example, no chemistry faculty reported the not-in-the-classroom belief, whereas other groups reported the belief with some regularity. While the small sample in this study renders these data and conclusions exploratory at best, the notion that disciplinary communities may vary according to their epistemologies regarding scientific inquiry as well as teaching and learning issues is well established in the field (Clark, 1983; Austin, 1996; Umbach, 2007).

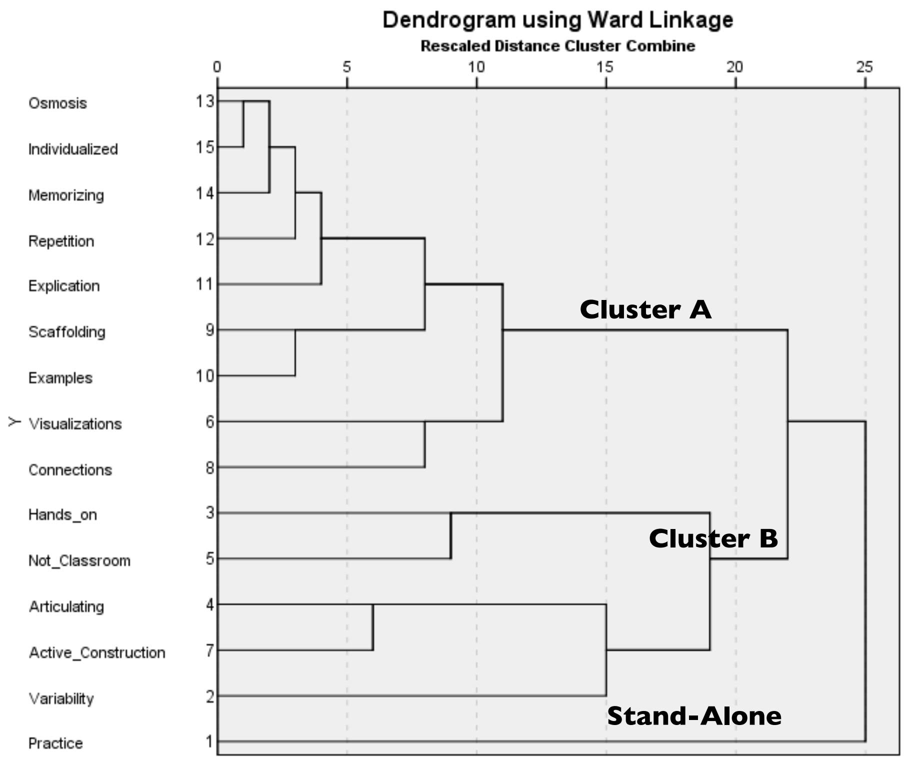
Dimensionality of beliefs

As previously noted, several researchers investigating the psychological antecedents to teaching (e.g., approaches, conceptions, etc.) argue that they exist on a continuum from teacher-centered/content-oriented to a student-centered/learning-oriented (Kember 1997). That is, pedagogical thinking is characterized according to the actor who is viewed as the most prominent or instrumental (i.e., teacher or student) and the purpose of instruction (i.e., information transmission or learning facilitation) that faculty consider to be the most important in the classroom (Samuelowicz and Bain, 2001; Trigwell, Prosser, & Taylor, 1994; Kember & Kwan, 2002). In addition, Trigwell, Prosser and Taylor (1994) found that faculty beliefs about student learning varied according to structural (i.e., learning to satisfy external or internal demands) and referential (i.e., topic of beliefs such as information accumulation and conceptual change) dimensions. Given these findings in the literature, I then analyzed the data to explore whether or not an underlying dimensionality could be discerned.

First, a cluster analysis using Ward's method was conducted (see Figure 1, below). The resulting dendrogram suggests that the 15 beliefs fall into two clusters: The first cluster (hereafter Cluster A) includes the following beliefs about student learning: osmosis (#13), individualized instruction (#15), memorizing (#14), repetition (#12), explication (#11), scaffolding (#9), examples (#10), visualizations (#6), and connection to experience (#8). The second cluster (hereafter Cluster B) includes the following beliefs about student learning: hands on/application (#3), not in the classroom (#5), articulating (#4), active construction (#7), and variability (#2).

Figure 1

Cluster analysis dendrogram of belief types



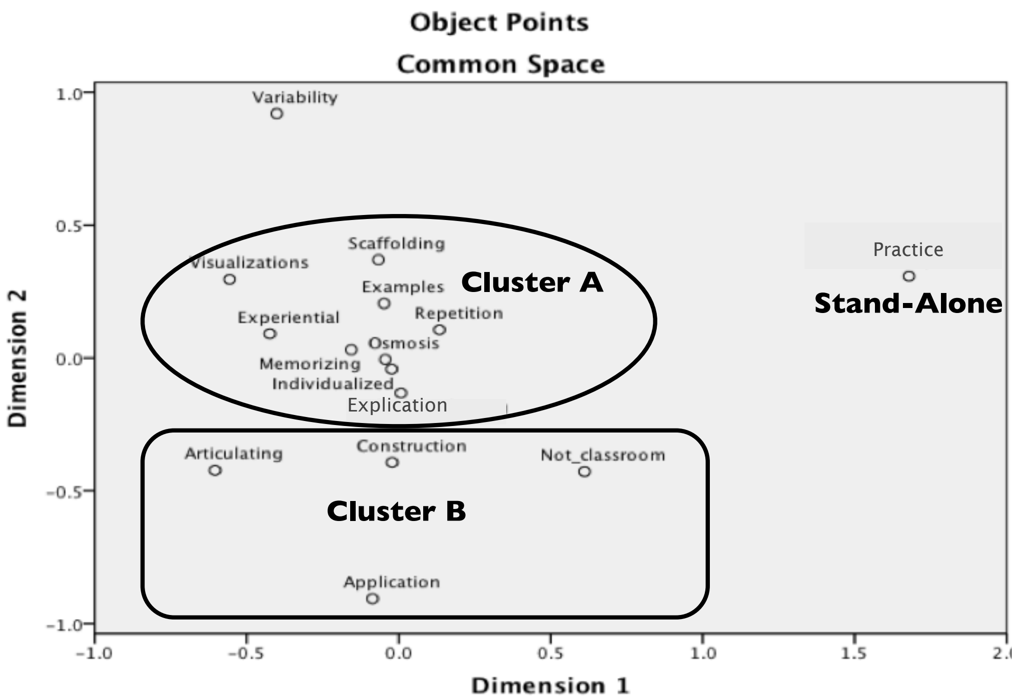
The most highly reported belief of practice and perseverance (#1) did not cluster with the other groups, which suggests that either hierarchical cluster analysis is not a necessarily good fit for these data, or that this belief was sufficiently dissimilar from the others so as not to be included in the two main clusters. That is, respondents who reported the practice and perseverance belief may have done so in conjunction with the other 14 beliefs but in no distinct pattern, such that little to no similarity among the beliefs could be discerned by the cluster analysis. These results does not necessarily mean that the practice and perseverance belief represents its own "cluster" or dimension. Indeed, the 27 faculty reporting this particular belief also reported 13 other beliefs. Subsequent analyses using the furthest neighbor (i.e., complete linkage) method resulted in similar groupings, thereby indicating some stability to the results.

Second, I conducted a multidimensional scaling analysis of the data, which represents the proximities between pairs of objects as distances in low dimensional spaces. The arrangement of the belief types in the MDS graphs was similar to the clusters identified in the cluster analysis. The large group in the center of the graph overlaps with beliefs within Cluster A (e.g., osmosis (#13), individualized instruction (#15), memorizing (#14), repetition (#12), explication (#11), scaffolding (#9), and examples (#10). A more diffuse grouping along the bottom of the graph includes beliefs from Cluster B (e.g., hands on/application (#3), not in the classroom (#5), articulating (#4), and active construction (#7). Both variability (#2) and practice and perseverance (#1) are located in spaces distant from these two groups (see Figure 2), which suggests that these two beliefs are dissimilar from those beliefs in the two groups located at the center of the graph.

Since neither cluster analysis not multidimensional scaling provide any information about the nature of the results, a subsequent interpretive step is necessary. That is, these data reduction techniques are useful heuristics for exploring the nature of the data. To further interpret these results I returned to the interview data. Using an inductive analytic approach I re-examined the interview data in light of the results from both analyses (Corbin & Strauss, 2007). This involved organizing the interview data into two distinct groups (i.e., Clusters A and B), with text associated with particular beliefs grouped with other text within that same cluster. This analytic procedure resulted in the identification of a single theme that best explained the

Figure 2

Multidimensional scaling graph of the belief types



variation among the two clusters: the agent who is seen as playing the principal role in constructing knowledge and meaning – the teacher or the student. That is, the beliefs vary based on who the faculty view as the individual who should be the primary agent who makes sense of the material. The student is always the individual doing the actual learning, and the instructor is always visible in the instructional process, but the clusters suggest differences in how faculty view their role in the learning process.

In Cluster A, it is the teacher that constructs meaning and presents them through a variety of methods: students learn by being in their mere presence (osmosis), one-on-one instruction (individualized), by memorizing facts that the teacher presents (memorizing), by repeating ideas (repetition), clearly explaining the material (explication), appropriately sequencing material (scaffolding), and so on. Thus, learning takes place largely through student absorption or internalization of knowledge that the teacher has constructed and presented. In Cluster B it is the student who constructs meanings. The student applies knowledge to hands-on experiences of his/her own (hands on/application), they are learning on their own outside of the classroom (not in the classroom), vocalizing their own thoughts and ideas (articulating), and so on. Thus, learning occurs primarily through the student's own construction of knowledge and meaning. However, it is important to note that the beliefs in Cluster B also implicitly include the teacher as one who creates environments for learning such as hands-on demonstrations or field-work experiences.

In the case of the two most highly cited beliefs (i.e., practice and perseverance belief and variability), I suggest that these beliefs cannot be interpreted in relation to this dimension of student- or teacher-centered knowledge construction. Instead, these beliefs represent their own unique set of views about teaching and learning that do not necessarily pertain to which agent is constructing meaning. That is, they represent stand-alone beliefs that exist outside of the dimension that is widely reported in the literature as characterizing the bulk, if not the entirety, of faculty thinking about teaching and learning. As such, the data contribute a new insight into the nature of faculty beliefs, as containing 13 beliefs that can be characterized according to this long-standing dimension, but also that two distinct and widely held beliefs that are of a different type and order are held by faculty in regards to student learning.

Further contradicting findings from the literature on faculty thinking (e.g., Trigwell & Prosser, 2004), the data do not suggest that faculty can be characterized entirely as having either a student-centered or a teacher-centered set of beliefs about learning. This is because 66% of the respondents in the study (37) reported beliefs that were not limited solely to Cluster A, Cluster B, or either of the stand-alone beliefs (See Table 8). While 19 individuals did report beliefs that lay solely in one of these categories, a majority reported beliefs that cut across these categories.

Table 8

Distribution of respondents reporting beliefs in single clusters or across clusters (n=56)

	# of Respondents
Mixed (across belief types)	37
Only Cluster A	3
Only Cluster B	9
Only Practice/Perseverance	4
Only Variability	3

These results suggest that the dimensionality underlying these beliefs is not an either-or proposition where individual faculty must be assigned to a single cluster (Postareff & Lindblom-Ylanne, 2008). Instead, individuals may hold a variety of beliefs along a single dimension comprised of two poles representing student- and teacher-centered beliefs, or that there are actually two (or more) dimensions whereupon individuals may hold strong or weak beliefs on different dimensions simultaneously (Eley, 2006).

CHAPTER FIVE: RESULTS – CLASSROOM OBSERVATION DATA

Next, I turn to an examination of classroom teaching practices in which I seek to identify the configurations of teaching methods, cognitive engagements, and instructional technologies that are enacted during a class-period. In this section I report these configurations in the form of network affiliation graphs, which provide a representation of the repertoires of practice for each of the disciplines in this study. While each individual faculty member has his or her own repertoire (i.e. their own configuration of teaching methods, cognitive engagements, and instructional technologies), the graphs presented below suggest that disciplines constitute an important context through which individual-level repertoires are constructed. In other words, the graphs represent the patterned behaviors of teaching for particular communities of practice, into which new members (e.g., new faculty, graduate students, etc.) are socialized. The data presented in this section represent relationships between two or more codes, and thus represent how distinct dimensions of practice interact with one another (i.e., affiliations among system components).

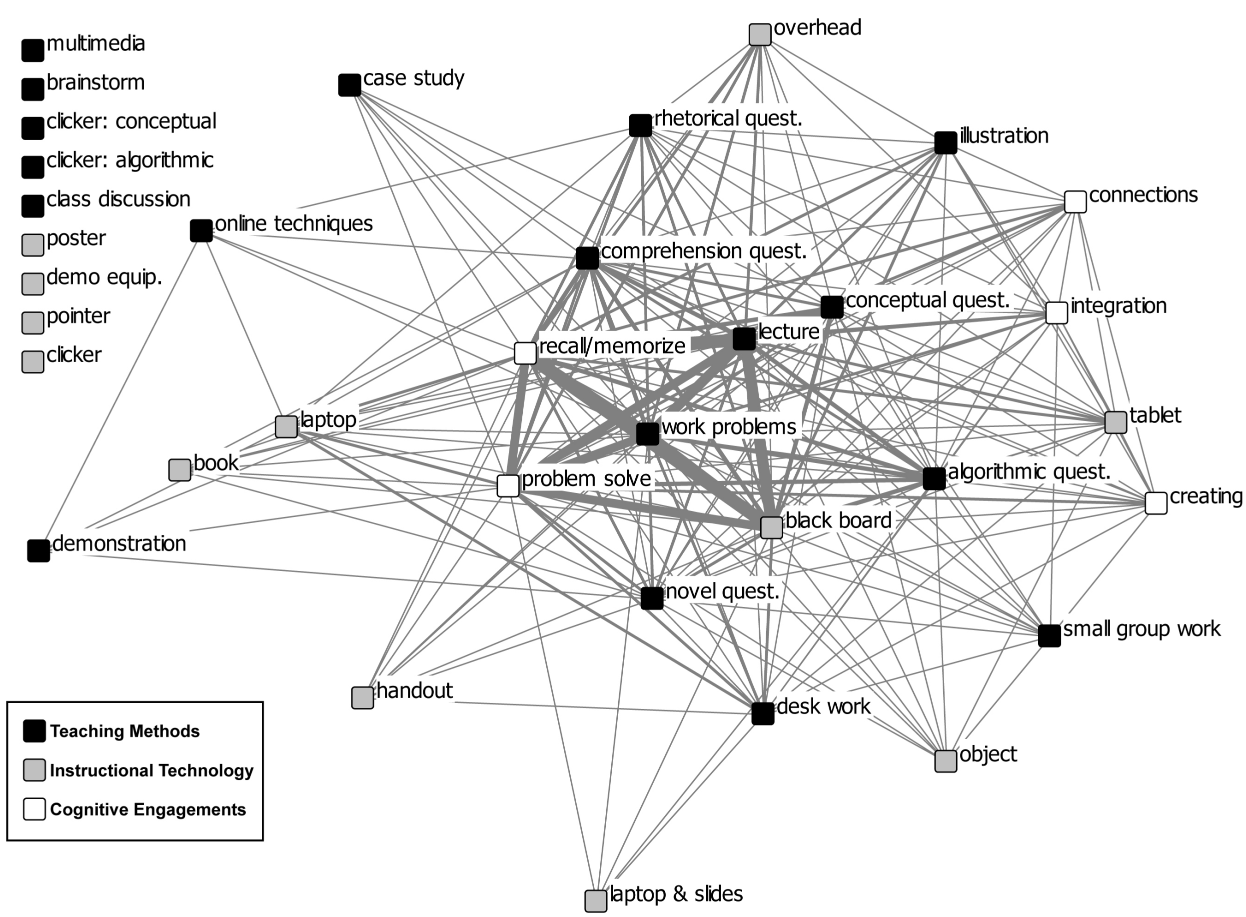
Math instructors. The graph[19] in Figure 3 reveals a repertoire of practice with a dense central core and a relatively limited set of teaching practices overall. The limited breadth of the mathematicians' repertoire is also detected in the relatively low density (Δ) of the dichotomous graph (0.335), which reveals that 33.5 percent of all possible co-occurrences between codes are present in this graph.[20] As a group, the mathematicians demonstrate a repertoire of practice that frequently requires students to problem-solve and receive/memorize information by working out problems and lecturing at the chalkboard. For instance, at times an instructor simply would write

[19] Note that the codes arranged vertically along the upper left side of the graph are those that were not observed in any class, and are thus disconnected from the graph.
[20] In practice it is not likely possible that a complete graph (density of 1.000) would be observed in this context, because some techniques cannot feasibly be used together.

an equation on the chalkboard accompanied by a verbal description of the equation (lecture-memorize-chalkboard). At other times, however, the writing of equations is accompanied by computational questions posed to the students (lecture-problem solving-chalkboard), and example applications in which the instructor clearly guides students through the problem solving process (working through problems-problem solving-chalkboard). These mathematicians use different combinations of teaching methods (working through problems and lecturing) and cognitive engagement (problem solving and memorization), but the artifact medium (i.e. chalkboard) remains constant.

Figure 3

Co-occurrence network of observed codes among math instructors (381 intervals; n=18).



Selected "triads" further illustrate the different combinations of teaching methods, cognitive engagements, and instructional technologies within this activity system. Over half of all observed five-minute intervals included the 'lecture-receive/memorize-chalkboard' triad (60%), and 39% included the 'worked out problems-problem solving-chalkboard' triad. These core practices are supplemented with a range of question styles, including comprehension questions (21% of intervals), display conceptual questions (21%), and display algorithmic questions (24%).

Physics instructors. The graph for physics instructors (Figure 4) shows a very different picture, revealing a more diffuse central core than in the graph for math instructors. In addition, the breadth of physicists' repertoire is greater than that of mathematicians.[21] That is, the density (Δ) of the physicists' graph (0.538) reveals that 53.8 percent of the total possible co-occurrences between codes were observed. This means that physicists, as a group, combined a greater number of teaching methods, cognitive engagements, and instructional technologies than the mathematicians. The physicists' repertoire frequently required students to problem-solve and make connections through the use of demonstrations, and to receive/memorize information while lecturing at the chalkboard and using PowerPoint slides with pointers. The physicists' repertoire is also frequently supplemented with the use of clickers, multimedia, display conceptual questions, and illustrations. Thus, these physicists' repertoire delivered the course material through lecturing and demonstrations—supplemented by instructional technology—that are coupled with a wide range of cognitive engagements.

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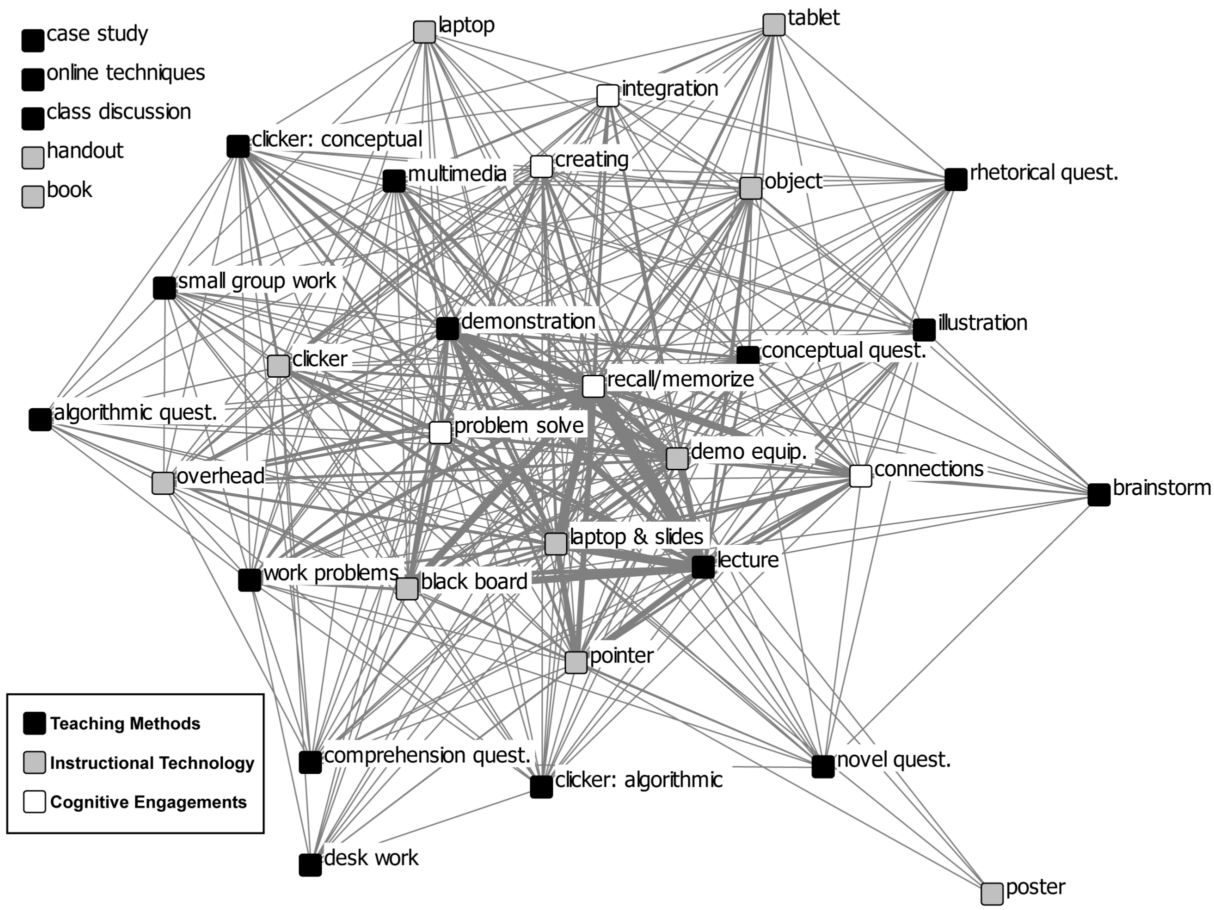
[21] In this context "greater" should not be equated with "better". I am not making any evaluative judgments here, but rather am seeking to make comparative descriptions and raising hypotheses about the nature of the cross-disciplinary variations.

Figure 4

Co-occurrence network of observed codes for physics instructors (219 intervals; n=11)

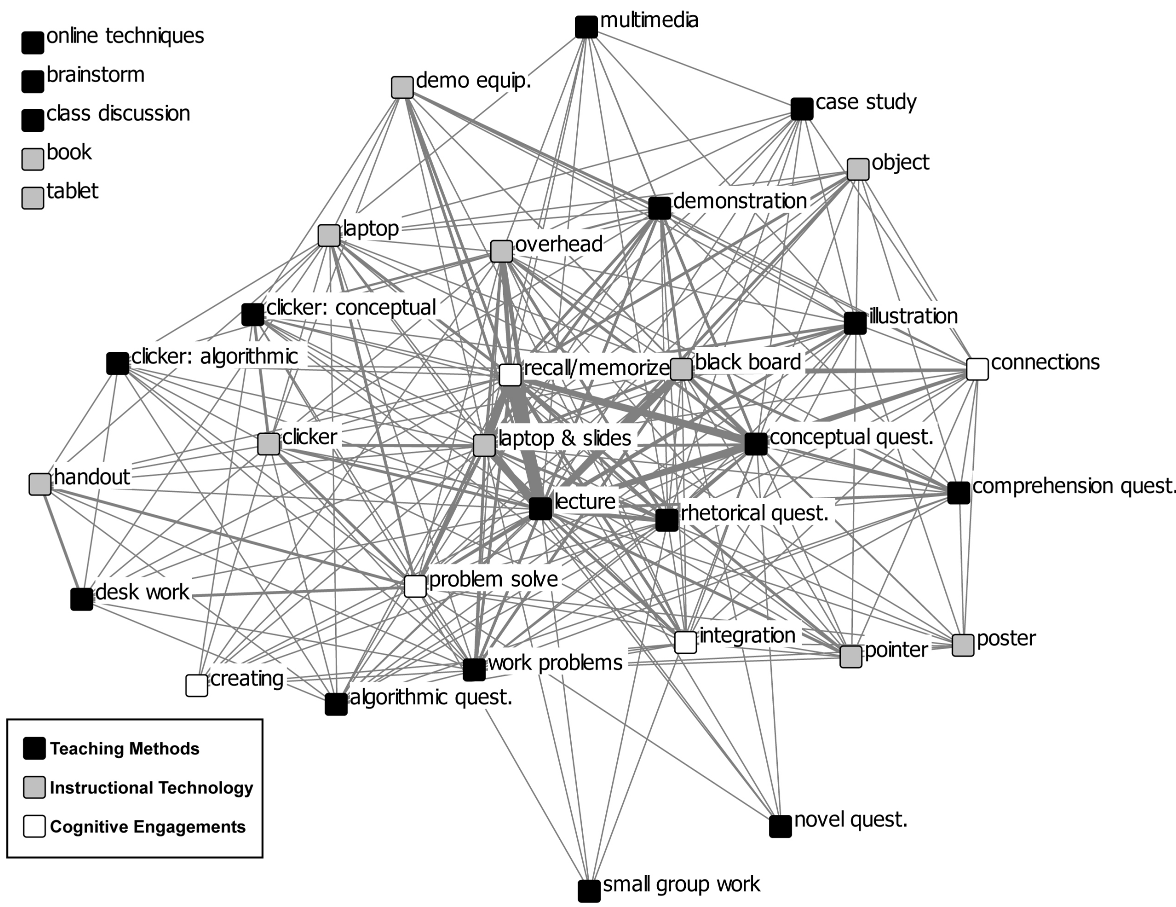


Importantly, there is a difference in problem solving through demonstrations than problem solving through the application of equations at the chalkboard. Although the latter form of problem solving does occur (12% of intervals), problem solving with the use of demonstration equipment provides a physical experience of the subject matter that reduces the level of abstraction found in equations alone. Among the eight relatively common triads observed across all disciplinary groups, the physicists exhibit some frequency of each one. While the 'lecture-receive/memorize-laptop/slides' and 'lecture-receive/memorize-chalkboard' triads were the most common affiliations (51% and 46% respectively), three additional triads were observed in more than ten percent of all observed intervals including ‘worked out problems-receive/memorize-chalkboard (16.%),’ ‘worked out problems-problem solving-chalkboard (12%),’ and ‘demonstrations-receive/memorize-demonstration equipment (28%).’

Chemistry instructors. The chemists’ graph (Figure 5) reveals a core set of practices surrounded by a set of secondary practices, which suggests a multi-layered repertoire. This repertoire contains a core set of practices that is similar to the physics instructors depicted above, although the density (Δ) of the graph is less (0.415).

Figure 5

Co-occurrence network of observed codes for chemistry instructors (180 intervals; n=9)



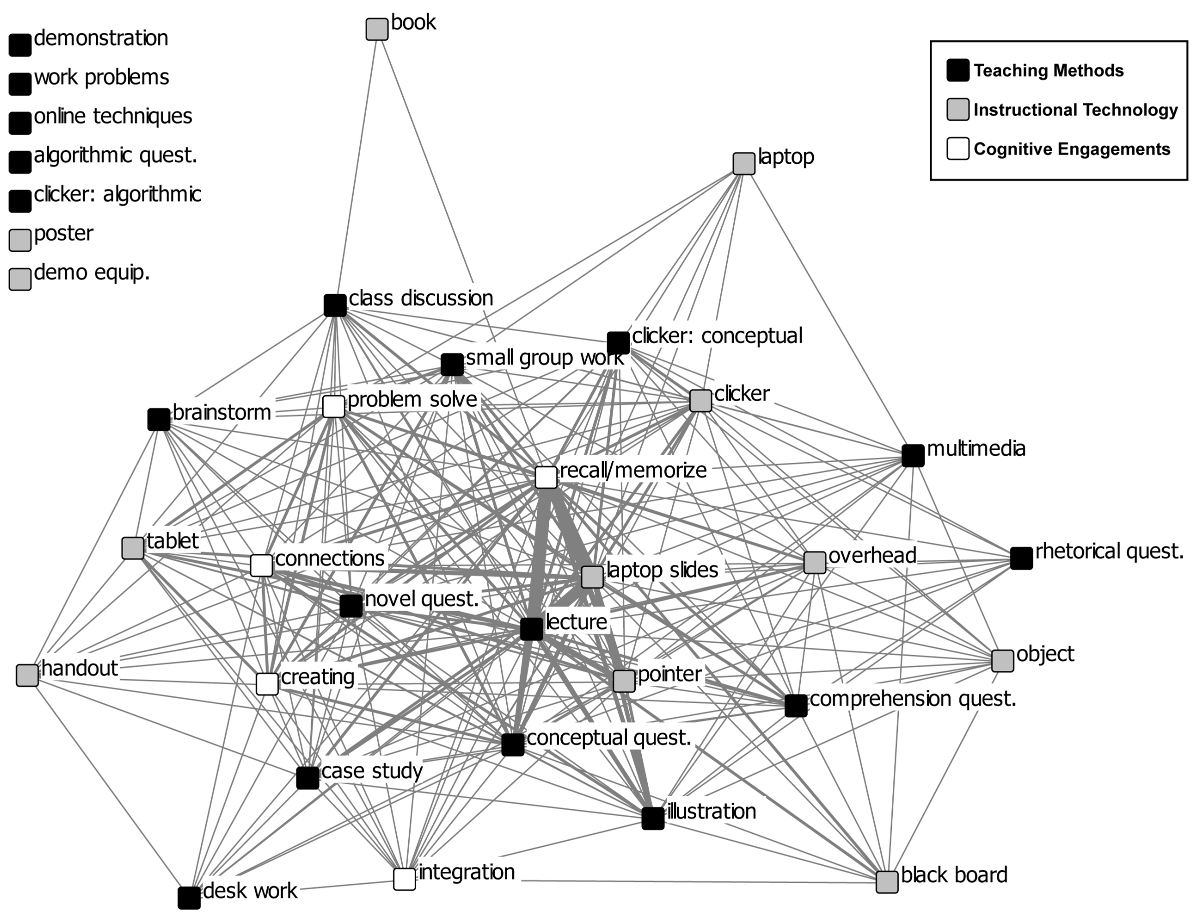
The repertoire among chemists requires students to receive/memorize information as the instructor lectures, poses conceptual questions, and uses a laptop computer or chalkboard. The core of this repertoire is supplemented by working out problems and asking students to engage in problem solving, posing comprehension questions, utilizing illustrations, and using instructional technology such as overheads, clickers, and demonstration equipment. Similar to the physicists, problem solving among these chemistry instructors involves both abstract formulas at the chalkboard, as well as physical demonstrations using equipment (e.g., chemical experiments accompanied by problem-posing questions). At other times, however, equations or chemical bonds were presented at the chalkboard or through slides (PowerPoint or overhead projector), and no problem solving was required of the students (i.e. only memorization was required).

The most notable divergence, however, is the fewer number of observed triadic affiliations among the chemists relative to physicists (though still greater than the mathematicians). In particular, chemists were less frequently observed using triads that involved small group work and demonstrations. The most frequently observed triads were the 'lecture-receive/memorize-chalkboard' (40%), followed closely by 'lecture-receive/memorize-laptop/slides' (36%). The 'worked out problems-receive/memorize-chalkboard' triad was observed in ten percent of all intervals among chemistry instructors.

Biology instructors. The biology instructors in our sample have a repertoire that frequently requires students to receive/memorize facts, concepts, and procedures by lecturing with a laptop and slides (see Figure 6). The density (Δ) for the biologists' graph is 0.415, meaning that the proportion of all possible observed code co-occurrences is greater than mathematicians, identical to chemists, but less than physicists.

Figure 6

Co-occurrence network of observed codes for biology instructors (224 intervals; n=11)



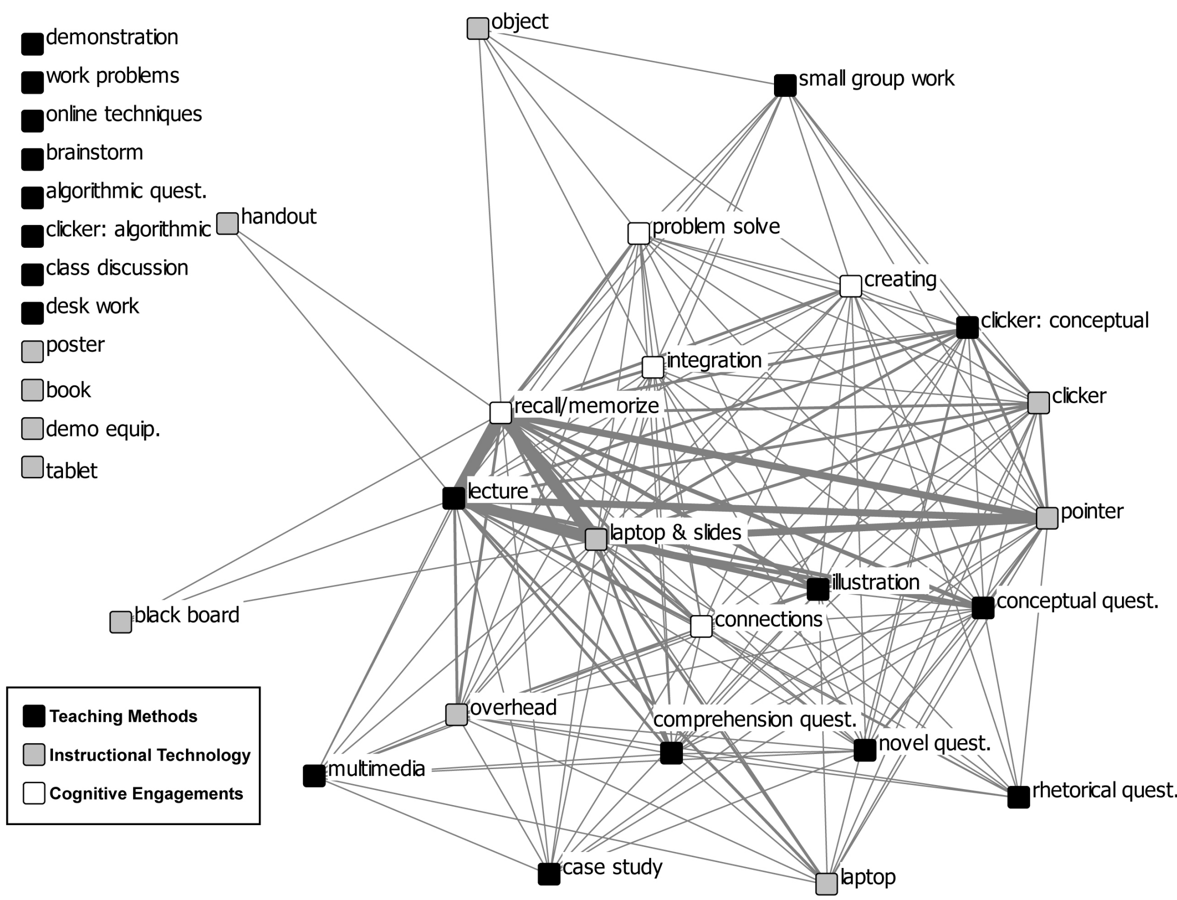
Unlike the observed mathematics, chemistry, and physics instructors, these biology instructors did not work out problems or present equations on the chalkboard. Rather, the observed biology instructors spent a significant amount of instructional time presenting conceptual information and definitions through the use of laptops and slides (i.e., PowerPoint). This is evident in the graph as well as the large percentage of intervals (69) in which the 'lecture-receive/memorize-laptop/slides' triad was observed. When problem solving was asked of the students, it was often observed in the same intervals with small group work and laptop/slides (8% of all intervals).

Biologists also stand out in terms of their use of small group work and whole class discussion. For example, the 'small group work-problem solving-laptop/slides' triad was observed in 7% of all intervals, the greatest frequency among any discipline. On its own, 'small group discussion' appeared in 12% of all five-minute intervals among the biologists. These instructors also frequently supplemented their core repertoire with conceptual questions (23% of intervals) and whole class discussion (11%). In fact, biologists were the only instructors observed to use whole class discussion with any frequency. Biologists also frequently provided opportunities for creating (14%) and making connections to the daily lives of students (20%). The latter cognitive demand was often observed in the same intervals as small group work and laptop/slides (4% of all intervals).

Geology instructors. The geology instructors exhibited the most limited repertoire among the observed instructors in our sample. As can be observed in Figure 7, this repertoire is almost exclusively comprised of the 'lecturing-receive/memorize-laptop/slides' triad (80% of all intervals). This latter triad often consisted of graphical depictions of geologic events or processes portrayed on PowerPoint slides. A graph density (Δ) of 0.269 reveals that 26.9% of the total number of possible code co-occurrences were observed, far lower than mathematicians (0.335), biologists (0.415), chemists (0.415), and physicists (0.538). The relatively limited repertoire among these geologists is also evident in the relatively large number of teaching techniques and instructional technologies that are disconnected from the graph (aligned vertically along the upper-left portion of Figure 7).

Figure 7

Co-occurrence network of observed codes for geology instructors (174 intervals; n=8)



These geology instructors frequently supplemented their core repertoire with conceptual questions (24% of all intervals), often with the use of clickers (12%), and made use of illustrations (18%) at a greater frequency than any other of the observed disciplines. While nearly every interval (97%) included the 'receive/memorize' cognitive demand, geologists more often required that students integrate concepts from the course (9%) relative to the other disciplines.

CHAPTER SIX: RESULTS – CASE STUDIES

Finally, I conclude the presentation of results for this dissertation study by integrating across the data types reported thus far – beliefs, belief dimensionality, and classroom teaching practices – through in-depth case studies of three STEM faculty. In tracing the processes of instructional decision-making and practice, the actual experiences of faculty as they plan and teach specific classes are illuminated, in contrast to the opaque depiction of practice that aggregated data provides. In so doing, other elements impinging upon decision making are considered that have not yet been reported in this study: instructional goals, prior experiences, and perceived affordances in the social and organizational environment (Schoenfeld, 2000; Stark, 2000). In exploring the nature of this relationship I pay particular attention to if and how an individual's beliefs influence how they plan and then teach their courses. This is done through the thematic network method, where particular attention is paid to sequences of events, ideas, or concepts that can be closely associated with one another either through the respondents' own statement or through analyst interpretation (Miles & Huberman, 1994). Only those thematic networks pertaining to beliefs and teaching practice for each individual are highlighted in this analysis. Finally, I pay close attention to the ways in which beliefs shape the problem spaces that faculty construct for their teaching task, which pertains to how they conceive of the situation, goals related to the situation, and available strategies for reaching those goals.

The three faculty highlighted in this chapter were selected on the basis of high degrees of "interactive" teaching from their classroom observations. Given the national interest in interactive teaching methods, and the relationship between beliefs and these practices (e.g., Gibbs & Coffey, 2004; Samuelowicz & Bain, 2001), I identified three individuals whose teaching exhibited features (i.e., question-asking, diverse cognitive engagements, and pacing) commonly associated with instruction that is interactive and engaging (see Methods section for more details). Thus, the data reported in this chapter sheds light on the degree to which pedagogical beliefs influenced the use of interactive teaching practices in the classroom. Put another way, the data address this critical question: Is the relationship between beliefs and practice direct and causal as posited by much of the postsecondary literature on faculty thinking (e.g., Trigwell & Prosser, 2004), or is it a more complex and dynamic relationship as suggested by research on K-12 teacher cognition, cognitive psychology, and curricular design in higher education?

Case analysis 1: Dr Bentley (Physics)

The first case describes the teaching practices of Dr. Bentley (a pseudonym), who is a full-time lecturer in the Department of Physics at a large, public research university. At the time of data collection Dr. Bentley was teaching the third quarter in the calculus-based introductory physics series. This course is intended for science (e.g., geology, chemistry, biology) and engineering majors with solid backgrounds in mathematics. The class being considered during the interview was focused on the harmonic oscillator and the pendulum equations. In response to the question regarding views about student learning, Dr. Bentley responded as follows:

> My view is that it (student learning) is incredibly varied. In other words, as many people there are, there are probably that many different ways that humans attain knowledge. But on the other hand, there may be a best way overall and I would say that that is personal perseverance. They (the students) as individuals must decide that they have to really work through it. Also I think for many students the breakthrough is to realize they need to take physics and actually apply it to things.

> If they understand how a car works or a fluorescent light works, that is when they have started to get there, to really learn it.

In this response Dr. Bentley expressed three different beliefs about student learning: variability (#2), practice and perseverance (#1), and hands-on/applications (#3). In addition, Dr. Bentley later added that his classes were “definitely not a key to them understanding,” which is the belief that learning takes place outside of the classroom (#5) and that learning is easier when “you can see it,” which refers to visualizations (#6). In summarizing his pedagogical beliefs, he stated that “a huge fraction (of students) will not retain what you say” and emphasized the importance of personal investment and hard work. The beliefs about hands-on/applications and visualizations are the only beliefs reported by Dr. Bentley that could be directly observable during a class session, though he did not explicitly link these beliefs to his plans for the observed class. In expressing such a range of views, Dr. Bentley is one of the 37 faculty in this study whose beliefs did not fall solely within one of the two identified clusters or in the stand-alone beliefs of practice and perseverance and the variability of learning. Instead, his beliefs fall under both Clusters A and B, as well as these two stand-alone beliefs. Thus, Dr. Bentley cannot be characterized as having a solely student-centered or a teacher-centered set of beliefs about learning, but instead he exhibits a diversity of pedagogical beliefs that span the continuum of teacher-student centeredness in relation to the agent responsible for constructing meaning, as well as the two additional beliefs about the nature of learning and the importance of hard work.

Next, Dr. Bentley was asked to what degree these beliefs were evident in his teaching, and he noted that the size of the class acts as a substantial situational constraint to this teaching. This observation was interesting in that there was no hesitation in his response, thereby indicating that class size plays a particularly salient role in Dr. Bentley’s thinking. However, in this response it was not immediately clear which belief was constrained by class size, though later in the interview Dr. Bentley alluded to the fact that it was challenging to do hands-on activities in large lecture halls. Thus, it appears that class size is perceived to be an impediment to the hands-on/applications belief about student learning (#3). Indeed, in his response to this follow-up question he also stated that given the class size he attempts to “get them to interact with me” through teaching techniques such as regularly asking questions.

In addition, Dr. Bentley reported that several other factors influence how he was approaching the class being observed. First, he expressed a goal for the class that he directly linked to his classroom behaviors – that of having the students be directly involved and engaged during the class. He noted that one way of realizing this goal was through regularly posing questions to the students throughout the class period. This goal is similar to the beliefs regarding students learning through hands-on activities (#3) and outside of the classroom (#5) which implies students’ being directly engaged with the material. Second, Dr. Bentley noted that his previous experiences as a student and as an instructor influenced how he approached his teaching. His prior experiences as a student centered on recalling which topics he found confusing, which led to his spending more time on these topics and considering how to teach them in as accessible a manner as possible. Dr. Bentley also drew on his experiences with what has worked (and not worked) in previous classes to determine how future classes will be planned and taught. In addition, he had prior experiences with educational researchers in his department who had exposed him to ideas including scaffolding and different ways to motivate and engage students. Third, Dr. Bentley perceived that several factors within his organizational environment represented constraints and affordances to his teaching. The curriculum and syllabus demarcate the type and sequencing of content in the course, such that Dr. Bentley felt that he had little say regarding what material will be included in the course. Thus, what material the community of physics faculty within his department value, and considered critical for undergraduate students, is imposed upon Dr. Bentley. Finally, he felt that the type of students within his course exerted a strong influence on how he teaches. For example, since the students in this course had previous coursework in mathematics and were mostly engineers, he made a special effort to include a significant number of computational exercises in his classes and homework assignments. Thus, instructional goals, prior experience, and perceived affordances all appear to play a role in influencing how this instructor plans his classes and approaches his classroom teaching.

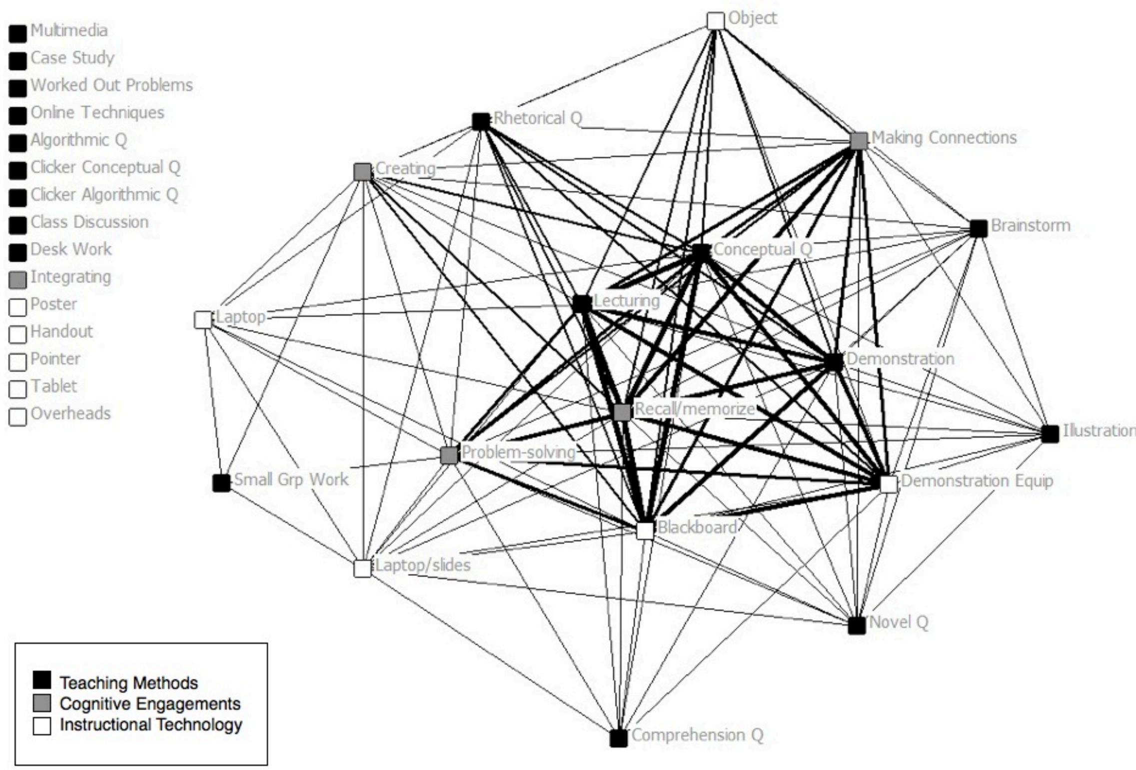
In regards to his specific plans for the class being observed, Dr. Bentley stated that he planned to apply the harmonic oscillator equation and then use these techniques to find the pendulum equation for the pendulum at low angles. The specific teaching methods that he planned to use to discuss these topics included asking several questions and using clickers in order to keep the students "involved" in the class, demonstrations, and the chalkboard for writing out equations. Importantly, Dr. Bentley observed that his use of demonstrations was strongly influenced by other faculty in the department who encouraged their use. In addition, the department had a designated staff person who managed a large selection of demonstration equipment and assisted each instructor in setting them up before class and taking them down after class.

In the observed class, Dr. Bentley began by outlining three main goals for the day's class: to discuss harmonic oscillators, energy, and the simple pendulum equation. He then discussed Hooke's Law while lecturing at the chalkboard, and then demonstrated the principle using a large pendulum hanging from the ceiling. The remainder of the class followed a pattern of the following commonly used teaching behaviors: lecturing at the chalkboard (observed in 90% of all 5-minute intervals), demonstration (70%), and posing display questions seeking new information (80%). In addition, in Dr. Bentley's class students were observed to be in the following modes of cognitive engagement: recalling and memorizing (90%), making connections to the real world (80%) and problem-solving (40%). Finally, Dr. Bentley primarily used the blackboard (80%) and demonstration equipment (70%) in terms of instructional technology. Thus, the class can be characterized as one with a considerable amount of lecturing at the chalkboard while students were in a mode of passive listening, but also with an equal amount of demonstrations with students in a mode of making connections to the real world. In other words, Dr. Bentley's class was a hybrid of the traditional lecture and a more visually engaging series of demonstrations and questions posed to the students.

However, as suggested in the previous chapter, these code proportions taken in isolation are misleading because they obscure how these elements interact with one another throughout the class period. The affiliation graph for Dr. Bentley's class (Figure 8) provides a more dynamic depiction of his classroom practices.

Figure 8

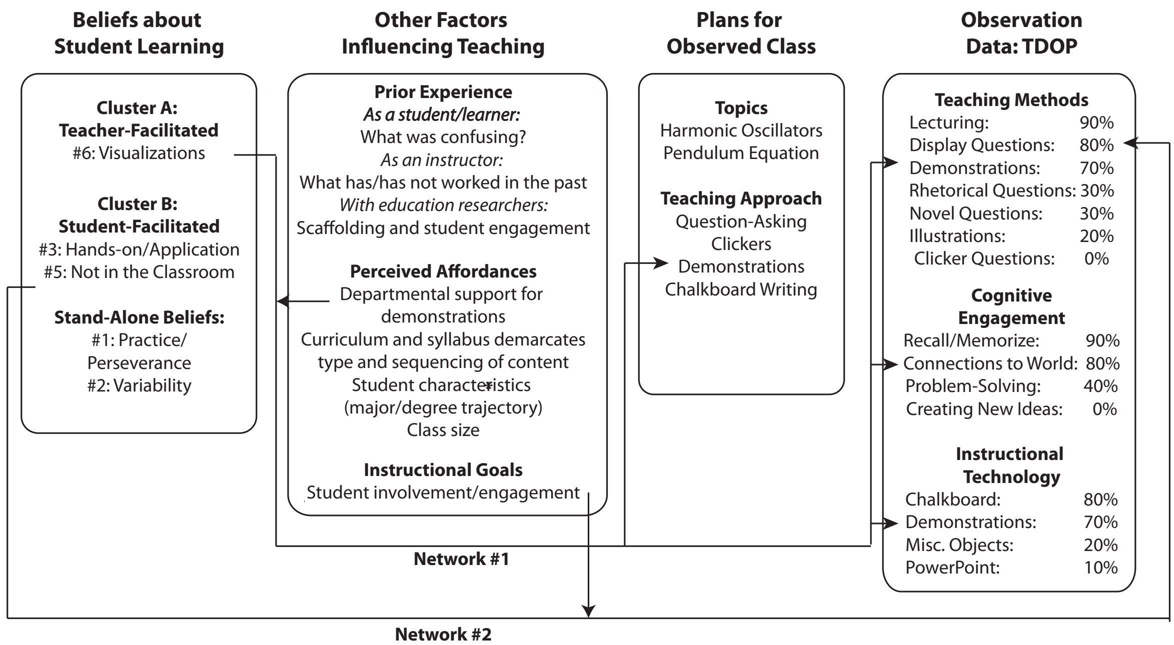
Co-occurrence network of observed codes for Dr. Bentley (10 intervals; n=1)



A graphic depiction of the data described in this case study, from Dr. Bentley's pre-existing beliefs to his actual classroom teaching, and the two thematic networks identified in the data that link the various elements influencing his decision-making process are depicted in Figure 9 (For details on the thematic network technique see the Methods chapter).

Figure 9

Thematic network analysis of Dr. Bentley's planning and teaching



Thematic network #1 represents the relationship among the visualizations belief (#6), the perceived affordance related to departmental support for demonstrations, and the use of demonstrations as a teaching method and instructional technology with associated implications for the cognitive engagement of students' making connections to the world. This network suggests that the belief interacted with a perceived affordance to contribute to the use of demonstrations during class. Thematic network #2 represents the relationship among the hands-on/application (#3) belief, the instructional goal of directly involving students in the class, and the observed teaching practices of posing questions to students during the class period. This network suggests that the belief interacted with an instructional goal in a way that contributed to the regular posing of questions during the class. Finally, while Dr. Bentley did not directly link his belief in the variability of learning styles to the diversity of teaching methods used in his classroom (e.g., lecture, question-asking, demonstration), it is possible that this selection of varied methods of instruction was in part informed by this belief.

However, while Dr. Bentley reported particular beliefs (e.g., visualizations) that could be interpreted as being related to specific behaviors (e.g., demonstrations), no evidence exists that supports a causal relationship between beliefs and teaching in this case. Instead, I suggest that the data is more appropriately interpreted in light of prior research that indicates beliefs play an important role in defining tasks and organizing information (Nespor, 1987; Nisbett & Ross, 1980). In this way, beliefs may act to construct aspects of the problem space that faculty perceive in relation to a particular teaching task. A key aspect of this process is that the beliefs will act to define the parameters of the new task or problem, such that the teaching act itself can be seen in a variety of ways (e.g., information dissemination to actively facilitating learning).

The beliefs that Dr. Bentley articulated can be interpreted as the activated gestalt of beliefs, goals, and perceived affordances related to teaching undergraduate physics, which in turn defined the problem space in which he approached his planning and classroom instruction. In particular, his beliefs that students must have a "breakthrough" and actually "apply (physics) to things" (i.e., the hands-on/application belief) suggests that Dr. Bentley views the problem of learning as one contingent upon having students be placed in positions where they can have personal interactions with the material on their own terms. Such a perception of the situation is related to his goal of engaging students in the classroom, which is another key component of the problem space. Finally, such framing of the problem of teaching could then be associated with particular instructional strategies such as periodic questioning, which were in fact observed during the classroom observation.

Thus, while no claims can be made regarding causal relationships between Dr. Bentley's beliefs and practice, his beliefs may in fact play a role in defining the problem space (i.e., the situation, salient goals, and available strategies) of instruction in which he plans and teaches his course. In any case, the data to indicate that factors such as goals and perceived affordances exert a considerable influence on Dr. Bentley's decision-making, which is consistent with prior research (e.g., Schoenfeld, 2000; Speer, 2008). Thus, beliefs appear to play an important, yet by no means an exclusive, role in shaping the teaching behaviors of this instructor.

Case study 2: Dr. Newton (Math)

The next case features Dr. Newton, who was a full-time lecturer in the statistics department at Institution A at the time of data collection. Dr. Newton was teaching the 3rd course in a three-part introductory statistics series, which was a requirement for engineering, computer science, and economics students, whereas the other courses were intended for social science and medical degrees. This course was calculus-based and heavy on the mathematics, whereas the other courses were less rigorous mathematically. Dr. Newton had been teaching the course for four years, and had taught at the institution for over a decade.

In response to the question about how students best learn in his field, Dr. Newton stated that students learn the best through practice and perseverance (#1) and not by attending lectures or classes (#5).

> The main way (students learn) is privately banging one's head on a problem – that's the best way I think of learning something. Not attending lectures, not taking tests and quizzes, not doing group studies or studying with friends. But the best way is to just sit there with a problem before you and just keep banging your head on it until it hurts. (Mathematics faculty: Lines 23-29).

Thus, Dr. Newton's beliefs include practice and persistence (#1) and not in the classroom (#5). These beliefs fall under Cluster B and the stand-alone belief of practice and persistence, which suggests that Dr. Newton cannot be characterized as solely holding a student- or a teacher-centered set of beliefs. He then elaborated on these beliefs by describing the process whereby working diligently on problems facilitates learning:

> When it hurts. If you start asking questions, the answers will then stick, but before it hurts the answers will just go straight through you.

This statement reflects a view that struggle is an important antecedent to comprehension. When asked whether or not these views were evident in how he taught the course, Dr. Newton replied "I hope not" but noted that he regularly shares this view with the students in his class. This reply suggests that he felt that the practice and perseverance belief would not translate well to a classroom setting, though he then observed that he often works through examples and problems during class, though the 50-minute class period is not sufficient to work through a problem in a substantive fashion. For this in-depth immersion into problem-solving Dr. Newton relies on homework assignments. Interestingly, the practice and perseverance belief had previously led him to assign up to 10 problems a day to his students, but over time he recognized that this approach was leading to his students being over-worked and dissatisfied with his course.

Other factors that influenced how Dr. Newton teaches include the goals he has for students in the course and his prior experience teaching the course. One of his primary goals was to "keep them awake" and this was largely accomplished through the use of two particular teaching techniques: the use of a digital tablet, and by regularly posing questions. The tablet is used because it is "very dynamic" and interactive, as opposed to PowerPoint slides that he feels lulls students to sleep. The advantage of the tablet over the chalkboard is that lecture notes can be posted online as pdf files, which students appear to like as study aids. Dr. Newton also noted that his experience as an instructor had shown him that keeping students alert and engaged was an important antecedent to effective learning. Based on this experience he stated that he regularly poses questions to his students during class, such that his classes could be characterized as "question-driven" Further, he noted that by forcing students to answer questions, other related questions will be raised in their minds which then piques their curiosity and increases their engagement with the material. While Dr. Newton did not explicitly label these sentiments as "views of learning" or beliefs, and in fact he clearly stated that these observations do not "supersede" his points about problem-solving, they are clearly informed by some views about how students best learn. [22]

For the course being observed, Dr. Newton planned on introducing and discussing how to standardize Z-scores by first starting with theory and then ending the class with examples. As previously noted, the planned teaching approach included the use of the digital tablet, regularly posing questions, and working through problems with the students. For the class being observed Dr. Newton planned to continue working through how to find the area under the normal distribution from the previous class, then onto theory and examples related to standardizing Z-scores. The specific teaching techniques that he reported included the digital tablet, lecturing about the theory of Z-scores and then working through examples, and regularly posing questions.

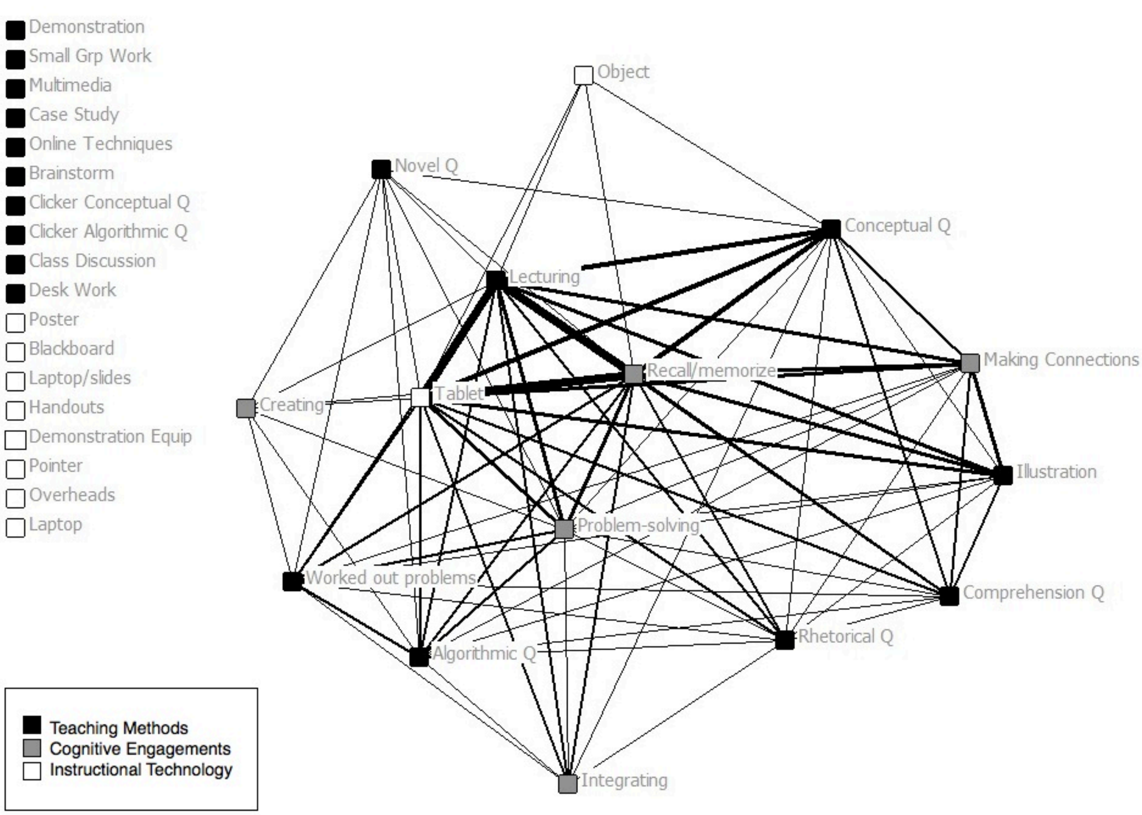
In the observed class, Dr. Newton began by displaying the lecture notes on his digital tablet from the previous class, and reviewed the algebra involved in finding areas between the normal curve. He then worked through how to compute the area between two values, and posed several questions while doing so such as "How do we standardize the result?" At one point, he

[22] This example underscores the limitations of relying on interviews to elicit beliefs, as clearly some beliefs are so tacit or unconscious that they may not be clearly labeled as such by individuals.

directed the students to work on finding the area on a table that was depicted on the screen. In regards to the TDOP data, Dr. Newton was observed regularly using the following teaching methods: lecturing (in 90% of all 5-minute intervals), posing questions (40%), using illustrations (40%) and working through problems (40%) teaching methods. Students in his classroom were observed in the recall and memorize information cognitive engagement mode (90%), making connections to the real-world (40%), and problem solving (45%). Instructional technology observed being used in Dr. Newton's classroom included the digital tablet (90%), where his notes were being projected onto a screen (see Figure 9).

Figure 9

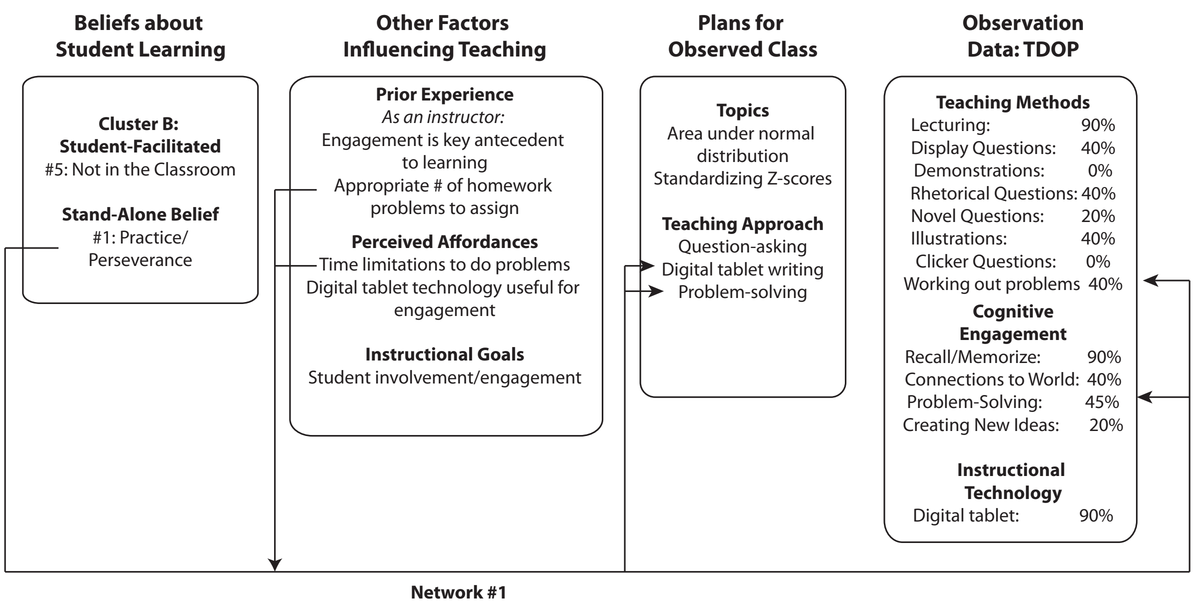
Co-occurrence network of observed codes for Dr. Newton (10 intervals; n=1)



A graphic depiction of the data described in this case study, and one thematic network that establish either direct or indirect relationships between beliefs and teaching practice is depicted in Figure 10

Figure 10

Thematic network analysis of Dr. Newton's planning and teaching



Thematic network #1 represents the relationship among the practice and perseverance belief (#1), Dr. Newton's prior experience with assigning homework problems, the perceived affordance related to time constraints related to problem-solving, the stated plan to work through several problems in the observed class using a digital tablet, and finally the use of problem-solving as a teaching method with associated implications for the cognitive engagement of students.   This network indicates that one of Dr. Newton's beliefs interacted with his prior experience and perceived affordances to contribute to his plan for the class, which then was largely enacted in the classroom. The activated combination of beliefs, prior experience, and perceived affordances also can be seen establishing one aspect of the problem space of instruction for Dr. Newton, such that the task of teaching students about normal distributions and standardizing z-scores is viewed through the lens of these pedagogical thoughts. As with the analysis of Dr. Bentley, no claims can be made regarding causal relationships between beliefs and practice, but the data do suggest that beliefs framed the task at hand and that other factors played an influential role in his decision-making. That being said, the belief about the importance of practice and perseverance did influence Dr. Newton's emphasis on homework problem sets as a principal feature of his student's activities during the course. He also attempted to integrate problem-solving into the classroom portion of the course as well, thus suggesting that this deeply felt belief does play an important role in how he plans and teaches his classes.

Case Analysis 3: Dr. Weston (Biology)

The third and final case features Dr. Weston, who was a full-time lecturer in the biology department at the time of data collection. He had been at Institution B for over 10 years, and was teaching a junior-senior level capstone course in molecular cell and developmental biology. The course has 120 students enrolled, and is taken by students who have completed all four required core courses for the biology degree, so that all students have a relatively solid background in molecular biology, genetics, cell biology, and other core topics in contemporary biology. In response to the question about student learning, Dr. Weston initially expressed the variability view (#2), and observed that a student's learning style will dictate how they best learn, regardless of how a teacher teaches:

> I think that different people learn key concepts differently, and that some students prefer to listen. So I guess there's two answers to that question: one is that I think that students have clear preferences for learning styles, and even when you try to be active in your teaching approach some students will still only learn in the way that they find most comfortable for themselves, and they'll refuse to participate in things they are not comfortable with.

Interestingly, Dr. Weston then characterized this view as a "student perspective" in that it placed the student and their preferences for teaching and learning at the forefront of considerations about instruction. In contrast, the "teacher's perspective" emphasized the instructors' considerations for the material in favor of thoughts about students' abilities or learning styles. Dr. Weston also characterized the teacher's perspective as the "information dissemination view" where teaching is seen as a matter of conveying information in the textbook, such that students could easily be getting the same material from reading a book or learning at home on their own. These accounts indicate that for faculty such as Dr. Weston, beliefs about student learning contain within them beliefs regarding instruction.

Dr. Weston stated that he personally leaned towards the student perspective, and he specifically reported a belief that students learn best by being actively engaged in the material (hands-on/application #3) as well as actively constructing their own understanding of the material (#7). A key feature of this the learning process for Dr. Weston was students' actively articulating (#4) their own thoughts and ideas to the instructor through question-and-answer sessions, and with their peers through small group work exercises. In expressing this view, he stated that while "reflection and independent study" are important, having a dynamic classroom environment was an indispensable component to learning. Thus, the classroom is seen by Dr.

Weston as playing a central role in student learning, where information is not simply disseminated to students but the instructor can lead students to actively "think about how it all fits together." He further elaborated on this belief by stating that taking notes and listening doesn't lead to effective comprehension of the material, but that students must be engaged in an "active pursuit of the topic in the classroom" where the student is actively struggling with the material, with the professor and peers to converse with. Thus, in Dr. Weston's view an element of struggle and challenge is an important element to learning, as well as engagement in the social environment of a classroom where the instructor and fellow students are seen as resources and instruments of learning. Dr. Weston also reported beliefs regarding learning occurring outside of the classroom (#5). As a result, Dr. Weston's reported beliefs mostly lie within Cluster B, with the exception of the belief about the variability of learning styles.

For the observed class, Dr. Weston planned on discussing synapse formation in general and eye anatomy in particular. In terms of teaching methods, he planned on lecturing, which he apologetically justified by saying that "I still do transmit information" and that "I have tried to do away with it entirely and it never just quite works." This observation is telling, because it indicates that the oral delivery or transmission of information, which is viewed in the literature as an unsophisticated teaching approach that should be avoided (Samuelowicz & Bain, 2001), was seen by Dr. Weston as an indispensible part of teaching. As he noted, "there's always a time in the class where it seems like I just have to say a few things or nobody will have a clue where to get started." So he planned to lecture as an introduction to the material, to "frame" the class period and the activities for the next 50 minutes, and to introduce new terms. Dr. Weston also planned on using clicker questions as a precursor to small group discussions, PowerPoint slides, and to pose several questions to students throughout the class period. The planned use of questioning was informed by his "belief in the Socratic method," and to ensure that students are paying attention and participating in class. Thus, Dr. Weston felt that an important precursor to learning was student alertness and attention, which was a sentiment also expressed by Dr. Newton.

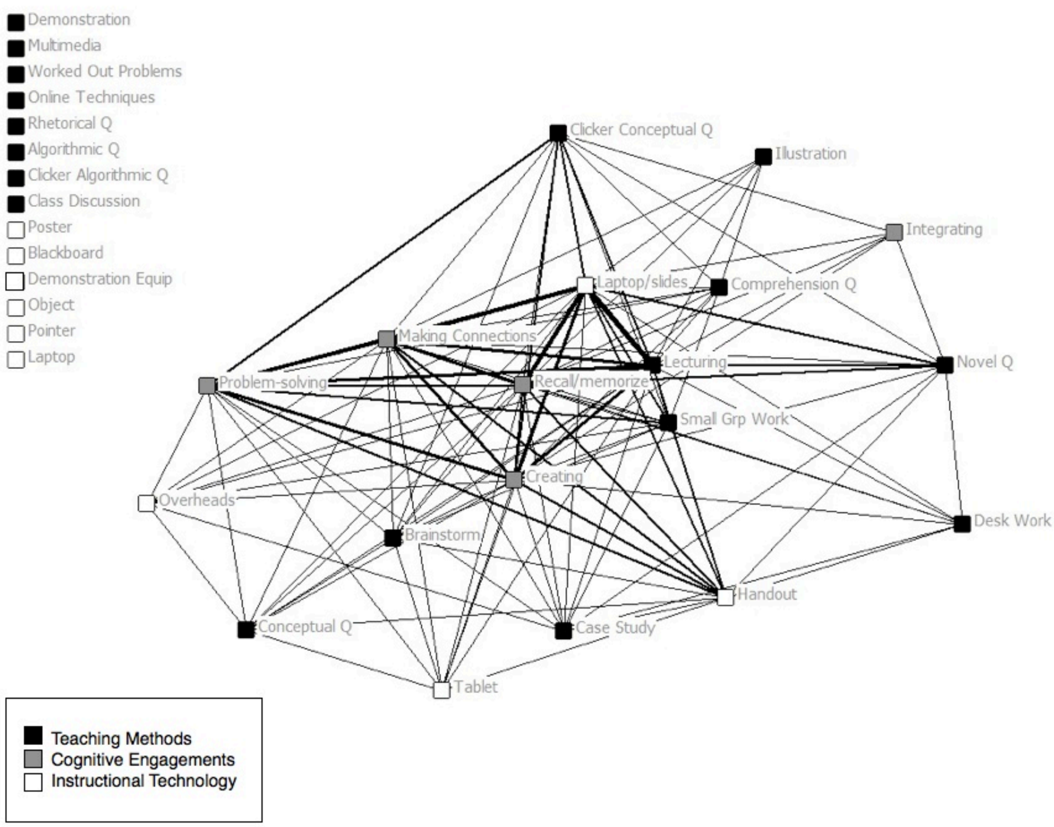
Dr. Weston then made more general observations that illuminate his decision-making process. First, in discussing how he typically addressed new topics, Dr. Weston noted that a defining factor is time – and whether he'd had a chance to figure out "the right sequence of things that I think will trigger them to really learn." For some topics she hasn't had the time to engage in such in-depth planning, and thus resorts to simply presenting information followed by practice or clicker questions. Second, she noted that after seven years of teaching by "pure" lecturing she realized that she "hated teaching that way," and felt that the students were not learning very well. This sentiment and observation coincided with the growth of a community of faculty actively engaged in science education on campus, which provided a rich resource of teaching tips and materials. Perhaps most importantly, this group provided a supportive network of other like-minded educators, which was considered by Dr. Weston to be extremely important given the research-oriented mission of her department and institution.

In the observed class Dr. Weston exhibited a variety of teaching methods including lecturing (in 87% of all five minute intervals), posing novel questions (20%), using clickers (27%), small group work (20%), case studies (13%), and illustrations (13%). Student in his classroom were viewed as being cognitive engaged in the classroom in the following ways: recalling and memorizing information (67%), making connections to the world (67%), problem-solving (53%), creating new ideas (60%) and integrating information (13%). Finally, Dr.

Weston mostly used two instructional technologies including PowerPoint slides (93%) and an overhead projector (13%) (See Figure 10).

Figure 10

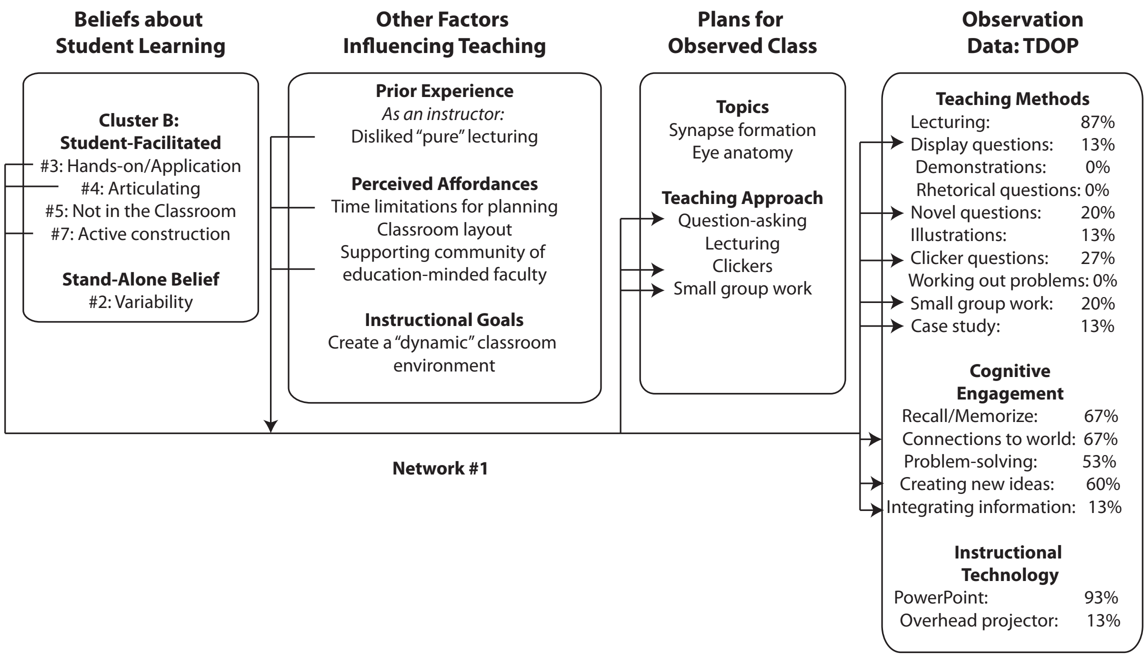
Co-occurrence network of observed codes for Dr. Weston (15 intervals; n=1)



A graphic depiction of the data described in this case study, and one thematic network is depicted in Figure 11.

Figure 11

Thematic network analysis of Dr. Weston's planning and teaching



Thematic network #1 represents the relationship among three beliefs centered on student's being actively engaged with the material including hands-on/application (#3), articulating (#4), and active construction (#7), Dr. Weston's prior experience as a "pure" lecturer, and perceived affordances related to time constraints and supportive colleagues in shaping his planning and classroom teaching practices. Most of Dr. Weston's beliefs fell within Cluster B that emphasized the student as the primary agent of meaning construction, and several of his planned and observed practices were consistent with such a view (e.g., question-asking, clicker use, and small group work). His stated belief about the variability of learning styles could also be considered an underlying factor in his selection of a variety of teaching methods, much like Dr. Bentley's physics class. However, the evidence does not indicate that these beliefs had a unilaterally causal relationship to these practices, as is suggested in the literature. Instead, Dr. Weston's prior experiences and perceived affordances also played an important role that supports the notion that a variety of cognitive resources are brought to bear on new tasks (Nespor, 1987).

Finally, the substantial use of lecturing during the observed class (87% of all 5-minute intervals) is notable given the dominance of student-centered beliefs expressed by Dr. Weston. However, he provides a clear answer regarding his use of this pedagogical technique that is sometimes regarded as ineffective (e.g., PCAST, 2012), in that at some point an instructor just has "to say a few things or nobody will have a clue where to get started." The co-existence of a high degree of lecturing and high proportions of interactive teaching techniques and a diverse range of student cognitive engagement types suggests that it may not be the case that faculty who value students' construction of meaning do not lecture, and that lecturing does not automatically translate into unsatisfactory instruction.

CHAPTER SEVEN: DISCUSSION

In this dissertation study I drew upon a situative perspective of cognition and practice to examine the beliefs that 56 STEM faculty had about how students learn in their disciplines, the underlying dimensionality of these beliefs, the classroom teaching practices of these 56 faculty, and how the beliefs of three instructors actually influenced how they planned and taught their classes. While the literature on K-12 teachers' pedagogical beliefs indicates that they should be viewed as important influences on curricular design, instruction, and assessment, several conceptual and methodological challenges raise questions about the reliability and practical utility of research findings at the postsecondary level. In particular, the disjuncture of the postsecondary literature on faculty thinking (e.g., Hativa & Goodyear, 2001; Samuelowicz & Bain, 2001) from both research on K-12 teacher cognition and the theories of human cognition upon which the latter body of literature is largely based, represents a missed opportunity to utilize theoretical frameworks that can illuminate one of the most pressing problems facing the field – what is the relationship between faculty beliefs and their teaching practice (Kane, Sandretto, & Heath, 2002)?

Building on promising lines of inquiry that utilize a situative perspective to analyze instructional decision-making (e.g., McAlpine, Weston, Berthiaume, & Fairbank-Roch, 2006; Schoenfeld, 2000), I argue that a more multi-dimensional view of practice that encompasses both planning and classroom teaching in general, and an in-depth analysis of how a specific element of this complex puzzle (i.e., pedagogical beliefs) actually influences these practices and the construction of problem spaces for teaching, would provide an important contribution to the field. In this section I elaborate on the results reported in this dissertation and explore possible implications of these findings for instructional improvement at the undergraduate level in general, and in math and science disciplines in particular.

The benefits of a situative account of faculty teaching

Situative theory provides a robust analytical lens through which to investigate nuances of course planning and classroom instruction. In this section I briefly review the key results from the study as they pertain to findings on course planning and classroom instruction as seen through the situative perspective.

Course planning. As previously noted, the situative perspective views individual actors and their corresponding cognitive activity as functioning in relation to the task environment (Greeno, 1998). In particular, the situative approach is uniquely suited to ill-structured domains where the problem space (i.e., the situation, goals, and problem-solving strategies) are either unknown or emergent, which are frequently encountered in educational settings. The data reported in this dissertation suggest that the process of constructing the problem space for the faculty in this study engages pre-existing beliefs, prior experiences, and perceived affordances in the organizational context that each pertain to the instructional task at hand. In the case studies reported in this dissertation, I demonstrate how Drs. Bentley, Newton, and Weston drew upon these diverse cognitive resources as part of their planning process that ultimately led to the development of a lesson plan. Thus, a core finding pertaining to course planning reported in this study is that beliefs do not unilaterally determine planning but instead interact with other cognitive resources to shape how the task is perceived and ultimately addressed.

This finding raises questions about assumptions regarding the direct and causal relationship between antecedents to teaching (e.g., beliefs and approaches) and actual classroom instruction. As previously noted, postsecondary researchers tend to view the relationship between thought and action in mostly direct and causal terms. Such arguments include Kember (1997) who stated that "a lecturer who holds an information transmission conception is likely to rely almost exclusively on a unidirectional lecture approach" (p.270), and Pratt (1992) who wrote that teacher self-reports of their beliefs and approaches to teaching should be viewed as "surrogate evidence for their actions" (p.206). Going even further, Trigwell, Prosser, and Waterhouse (1999) argue that a "chain of relations from teacher thinking to the outcomes of student learning," an argument based on evidence gathered using the ATI and other survey instruments. Notably, in each of these cases the authors do not draw on a cognitively informed theoretical framework with which to conceptualize faculty thinking or to interpret their findings.

I suggest that the data reported in this paper – that beliefs interact with prior experiences, goals, and perceived affordances to influence planning decisions - raises questions about such conclusions. Instead, the evidence indicates that there is not a simple one-to-one correspondence between faculty beliefs and their classroom practice. Overall, the findings support recent evidence that suggests that the relationship between faculty cognition and classroom practice is far more complex than previously thought (e.g., McAlpine, Weston, Timmermans, Berthiaume & Fairbank-Roch, 2006). This perspective is consistent with the role that beliefs play in framing new situations or tasks, such that beliefs may be one of the more salient constructs at play in determining these problem spaces. Thus, beliefs are but one consideration or factor that enters into the course planning process. A particularly influential type of cognitive schema appears to be perceptions of how the environment either constrains or affords particular tasks (Greeno, 1998). In a study of physics faculty planning procedures, Henderson and Dancy (2007) found that faculty teaching introductory courses reported that certain "situational constraints" including student attitudes toward school, lack of time, and departmental norms kept them from adopting new approaches to course design and classroom instruction. Further, the argument that the relationship between pedagogical thinking and practice is a complicated one is bolstered by decades of research in the K-12 sector (Shavelson & Stern, 1981; Borko, Roberts, & Shavelson, 2008).

There are several implications regarding the finding that beliefs are but one type of schemata that may influence faculty planning and classroom practice, and that the precise mechanisms governing this complex relationship is not well understood. First, attempts to predict planning and teaching practice based on faculty beliefs or approaches alone are of limited utility. This is due to the complexity inherent in the decision-making process such that a single factor cannot be demonstrably and causally linked to behavior. In particular, attempts to link specific "types" of beliefs or teaching approaches to practice are doubly flawed, given this complexity as well as the arguable practice of assigning individual faculty to single belief or teaching approach types. The second implication follows from the first. Claims regarding the correspondence between "types" of beliefs and the quality of instruction, which are based in part on questionable underlying assumptions regarding causality as well as the quality or degree of sophistication of both belief "types" as well as teaching practice itself, are untenable. Instead, little evidence exists suggesting that one type of belief is inherently superior to another, and considerable questions exist regarding assumptions about the quality of one pedagogical technique to another.

For example, the technique commonly called "lecture" is particularly subject to this reductionist approach, as what is generally meant by the term – a discourse given before an audience – actually masks a myriad of specific pedagogical behaviors such as distinct rhetorical strategies and the use of different instructional technologies (e.g., Hativa, 1995). Further, the lecture method is often assumed by researchers to be less pedagogically effective than other techniques, yet as Saroyan and Snell (1997) argue, “A lecture can be as effective as any other instructional strategy so long as it is appropriately suited to the intended learning outcomes and is pedagogically planned and delivered” (p. 102). This suggests that the assumption that a teacher with student-oriented beliefs will not use a “unidirectional lecture approach” (Kember, 1997) is not supported by the literature or the data presented in this paper. In the case of Dr. Weston, whose beliefs mostly were in the student-centered Cluster B, he still lectured in 87% of the 5-minute intervals. Indeed, Dr. Weston himself observed that lecturing was a necessary part of teaching regardless of his beliefs regarding student learning, and that dispensing entirely with it would be inimical to the students experience in the course. This raises questions about the single-minded focus against “lecturing” that some policymakers and researchers have adopted in striving to improve the quality of undergraduate education.

Classroom instruction. The situative perspective also provides a way to investigate classroom teaching itself that avoids the reductionist, uni-dimensional view of instruction as the use of overt teaching methods. Instead, instructional practice is seen in terms of participation in local activity systems that encompasses teachers, students, features of the organizational context (e.g., instructional technology) and the course material. Thus, focusing on a single component in isolation obscures the complexity of instruction and omits critical features of the teaching and learning dynamic (Cohen & Ball, 1999; Halverson, 2003). Classroom observation data were reported in this study by disciplinary group, given the influence of academic disciplines and knowledge communities on faculty work in general, and classroom teaching in particular (Becher & Trowler, 2002; Hativa, 1995; Neumann, Parry, & Becher, 2002). A situative perspective also emphasizes the importance of participation in the regular practices of distinct communities as a key aspect of learning and socialization, such that the accounts of classroom instruction reported here represent the cultural practices for these groups at the time of data collection.

The data illustrate a substantial amount of disciplinary specificity to the way that teaching methods, cognitive engagements, and instructional technologies are linked through pedagogic action. Thus, instructors utilize different configurations of these dimensions of teaching in the classroom. This was seen, for example, in the varying prevalence of practice triads across disciplines.. Insights into the disciplinary variation of teaching sheds light on the cultural practices and tools that are in use by each group, which may represent entrenched behaviors that are both challenging to alter as well as opportunities for future growth and development (Gutierrez & Rogoff, 2003; Lattuca, 2005).

Each disciplinary group exhibited certain practices in common as well. These include the primacy of classroom practices such as lecturing, the receive/memorize cognitive engagement, and, with the exception of the mathematicians, frequent use of PowerPoint. However, even in cases where the entire sample exhibited similarities, each group utilized them in slightly different ways, and in different configurations with other methods, types of cognitive engagement and instructional technologies. For example, it is apparent that lecturing is a central feature of classroom instruction in the study sample, as the oral presentation of facts, concepts, and principles constitute a part of the central teaching "core" of each discipline in the study sample, ranging from being present in 75% of the five-minute intervals for mathematics faculty to 93% for physics faculty. However, lecturing is often affiliated with other teaching methods, such as demonstrations, working out problems, rhetorical questions and using illustrations or examples – such that to characterize a class period (or even portions of it) as just "lecturing" is inaccurate. A mathematician in our study, for instance, quickly switched between lecturing, working out problems, and posing questions while discussing direction fields. Other instructors observed in this study regularly interjected questions and illustrations during class periods where they were primarily lecturing, such that the lecture portion itself was used in conjunction with these other techniques.

While lecturing most often co-occurred with the ‘receive and memorize’ cognitive engagement (e.g., 90% for physics faculty), it also co-occurred with other cognitive engagements. Among physics faculty, for example, lecturing frequently co-occurred with problem solving (26% of intervals), connections to the real world (21% of intervals) and integration with prior knowledge (7% of intervals). This suggests that the lecture method can be used in different ways to engage students in varied cognitive states, and that a lecture does not need to be synonymous with only asking learners to passively receive and memorize information. That being said, the high rate of co-occurrence between lecture and the ‘receive and memorize’ cognitive engagement does indicate that this pairing is both common and widespread across the disciplinary groups in this study.

Lecturing was also consistently affiliated with instructional technologies such as chalkboards (e.g., 62% for mathematicians), PowerPoint slides (e.g., 73% for biologists) and demonstration equipment (e.g., 31% for physicists). Each of these artifacts acts to mediate the relationship between instructor and learner in different ways, and provide different opportunities for learners to engage with the topic at hand. For example, the widespread use of PowerPoint slides shifts students’ attention from a sole focus on the instructor to the visual representation on the slide, which can vary in degrees of visual and pedagogical quality. In one case a geology faculty noted that he spends hours selecting meaningful and arresting images for his slides, in part due to the nature of geological knowledge as being highly visual and therefore amenable to the use of graphics as a learning tool. Thus, it is important to consider lecturing in relation to the role of instructional technology as well.

Finally, in all but four instances the lecture method was not used exclusively for an entire class period, but instead was used for shorter periods (e.g., 5-10 minutes) and/or was interspersed with other teaching methods. In this way, collapsing a 60- or 90-minute class into a single method, which most survey or questionnaire instruments require faculty to do when self-reporting regularly used teaching methods, obscures the temporal component of actual classroom instruction. Collectively, these findings suggest that faculty teaching is best viewed as a practice comprised of multiple dimensions that interact with one another in varying ways throughout time

Focus on types of beliefs

One of the main contributions of this study to the postsecondary literature is that faculty in the study sample had 15 distinct types of beliefs for student learning. As such, this study provides the first empirical evidence for this belief since Prosser, Trigwell, and Taylor (1996), and the first focused exclusively on math and science faculty. In the earlier study the five conceptions of learning included: (a) learning as accumulating more information to satisfy external demands, (b) learning as acquiring concepts to satisfy external demands, (c) learning as acquiring concepts to satisfy internal demands, (d) learning as conceptual development to satisfy internal demands, and (e) learning as conceptual change to satisfy internal demands (Prosser, Trigwell, & Taylor, 1996). In the present study, a more diverse set of beliefs that included a variety of topics (e.g., how students best learn, how to arrange the classroom, how to best teach) were reported. Two of the beliefs reported in this study merit further consideration, given that many faculty in the study sample reported them (i.e., practice and persistence, and variability), and their possible implications for teaching practice and faculty development.

Practice and perseverance. The most commonly reported belief was that student learning is best achieved when the student engages in a diligent course of study with the material on their own time (27 respondents). This belief emphasized the importance of students working diligently working on homework problems and making a strong commitment of time and energy to studying. This perspective that hard work is a key feature of student learning and success at the undergraduate level in general, and in math and science disciplines in particular, is not without precedent. Some have pointed to practice and persistence as a critical predictor of student persistence in math and science disciplines (Drew, 2011). This is due in part because of the perception that these fields are by nature difficult to master, such that without hours of study and diligent practice it is difficult for students to learn, succeed, and continue on to the next level of training.

Interestingly, evidence suggests that undergraduate student study habits are changing in ways that may conflict with this foundational belief. Babcock and Marks (201) found that the average full-time student at four-year colleges studied 14 hours per week in 2003, as compared to 24 hours per week in 1961. This decline holds true across most disciplines, even among engineering students who reported the most hours studied per week. Thus, the expectations that faculty have regarding a basic and fundamental aspect of student learning and success – that of practice and persistence – may not be met by the study habits of contemporary students. The implications for this conflict on faculty approaches for planning and classroom instruction, as well as their participation in professional development, is an important question that should be pursued in future research. This is particularly important given that policymakers and researchers tend to focus on faculty teaching as one of the primary reasons contributing to student attrition and poor learning outcomes, rather than focusing on student study habits (e.g., PCAST, 2012; Seymour & Hewitt, 1997). The widespread nature of the belief regarding persistence and practice suggests that for many faculty in this study, poor student outcomes are due in part to students' amount of effort, and not just their own actions in the classroom. While I do not suggest the veracity of either perspective, there exists a tension between these different causes of poor outcomes (i.e., the student or the teacher) that should at least be acknowledged by policymakers and practitioners engaged in instructional improvement at the postsecondary level.

The practice and persistence belief also suggests that some faculty do recognize the merits of a deep and substantive engagement with the material as an important precursor to learning. This view is consistent with research from cognitive psychology and the learning sciences that demonstrates that long-term retention and comprehension is facilitated by encountering and persisting through challenging problems and tasks (e.g., Craik & Tulving, 1975; Diemand-Yauman, Oppenheimer, & Vaughan, 2011). This perspective was expressed one math faculty who stated that "when it hurts" the material will "stick." While I do not suggest that the practice and persistence belief is informed by a nuanced appreciation of the learning sciences, it is possible that some faculty may have a folk theory of student learning that is supported in part by empirical evidence.

Finally, because of the small sample included in this exploratory study, no definitive conclusions can be drawn about the precise relationship between this belief and subsequent teaching practice. However, the data do suggest that the practice belief may act to frame how faculty approach their planning and teaching. For example, Dr. Bentley discussed how this belief is at the core of his teaching and learning philosophy, and that he viewed class time as an opportunity to facilitate students' practice in working through problems. Thus, the problem space pertaining to the class on how to standardize z-scores was seen through the prism of this fundamental belief. However, given that he recognized that spending 50 minutes solely on problem-solving was untenable, the belief was more directly expressed through the assignment of homework problem sets.

Variability and learning styles. Another widely held belief is that how students learn varies from person to person (20 respondents). The belief that students learn according to different styles, and that differentiated instruction should be provided to students whose learning abilities and preferences vary within a given classroom, is widespread in the educational literature. This view is particularly common in the STEM education literature. For example, in their widely cited paper on the implications of learning styles for engineering teaching, Felder and Silverman (1988) argue that teachers should meet the needs of all learning styles (e.g., auditory, sensory, etc.), and that when mismatches occur between these styles and faculty teaching, results include student boredom and poor performance. However, the idea that learners have different learning preferences independent of ability and content, and that these have implications for subsequent learning outcomes, is without basis in the empirical literature (Riener & Willingham, 2010). While research does support the notion that students do have preferences for learning, adapting teaching styles to learning preferences makes no statistical difference under controlled conditions. As a result, Riener and Willingham (2010) argue that instructors should present information in an appropriate manner for the content and the level of prior knowledge and expertise of students, but not in terms of the different learning preferences of their students. It is important to note that the lack of experimental evidence does not prove that adapting teaching styles to student preferences has no impact on student learning in actual classrooms. In any event, the salience of this cautionary note in relation to the data reported in this study is that faculty attempts to teach in accordance with various student learning styles are leading some instructors to diversify their pedagogical repertoire. For example, one instructor stated that given the range of student learning styles, he deliberately planned his classes to include lectures, hands-on exercises, readings, and web-based modules. Another respondent noted that based on this belief she approaches teaching in terms of "more than one pathway" to teaching and learning, and packages course material in a variety of ways including lecture, video, demonstrations, and homework assignments. This instructor felt that this approach had the benefit of engaging students while also allowing them to "make it their own" depending on their unique learning styles. Others noted that such an approach to teaching was desirable because the current generation of students expected to be entertained during class and generally had limited attention spans. Of course, the use of a diversified instructional approach may also be due to the growing use of instructional technologies and digital media by faculty, and not solely based on a belief about learning styles. One question raised by this finding is whether a differentiated approach to instruction, at least in terms of the use of particular teaching techniques, does in fact facilitate students in "making it their own" or if it results in an overly multi-modal and incoherent approach to instruction. Future research on the specific relationship between faculty beliefs about student learning and their selection of particular teaching tools would shed light on this matter.

Underlying dimensionality of agent constructing knowledge/meaning

The findings confirm prior research indicating that faculty thinking in general, and beliefs about student learning in particular, can be characterized according to a student-centered or a teacher-centered perspective (Kember, 1997; Prosser, Trigwell, & Taylor, 1994; Samuelowicz &

Bain, 2001). The two clusters of beliefs identified in this study vary according to the agent who is seen as playing the principal role in constructing knowledge and meaning – the teacher or the student. That is, the clusters suggest differences in how faculty view their role in the learning process. In the literature these results are generally interpreted to indicate that faculty can be characterized as holding a particular "type" of belief, with subsequent implications for classroom instruction and student learning based on the inherent superiority of student-centered thinking (e.g., Trigwell, Prosser, & Waterhouse, 1999). However, two critiques of the literature raise questions about the "either/or" hypothesis regarding the degree to which an individual can be described exclusively as holding a particular belief type (Postareff & Lindblom-Ylanne, 2008), and whether or not the precise mechanisms linking beliefs to practice are in fact known (Kane, Sandretto, & Heath, 2002).

The evidence suggests that while faculty approaches to teaching could be characterized as being either student- or teacher-focused, they cannot always be considered mutually exclusive categories to which individuals can be assigned. This is because 66% of the respondents in the study (37) reported beliefs that were not limited solely to Cluster A, Cluster B, or the practice and perseverance belief. This result suggests instead that faculty will hold more complex belief "systems" or combinations of beliefs (Nespor, 1987). While the data do indicate that some faculty reported beliefs exclusively in Cluster A (3), Cluster B (9), and the two stand-alone beliefs, the fact that most faculty (37) reported beliefs that cut across these clusters and/or beliefs further supports the position that an "either/or" perspective unnecessarily simplifies the complexity of how faculty actually think about their practice (Postareff & Lindblom-Ylanne, 2008). Further, the case study analyses suggest that these beliefs are also linked to other cognitive constructs such as prior experience, goals, and perceived affordances, such that describing an individual's pedagogical thoughts in terms of a single type of belief may be an overly reductionist stance that obscures the complexity and systemic nature of cognition.

In addition, based on the data no conclusions regarding the hierarchical structure of belief types whereby one belief subsumes all others (e.g., Trigwell, Prosser, & Taylor, 1996), or the inherent sophistication of particular beliefs can be made (Entwistle & Walker, 2000; Linblom-Ylanne, Trigwell, Nevgi, & Ashwin, 2006). This latter point is particularly important because such conclusions may have important implications for practitioners and policymakers interested in improving postsecondary education. Instead of suggesting the superiority of student-centered beliefs (i.e., Cluster B) I interpret these findings as mere descriptions of the beliefs faculty have about student learning. That is, until and unless certain types of beliefs could be empirically linked to the enhancement of student learning outcomes, such evaluative judgments are premature. Furthermore, given that individual faculty frequently report multiple types of beliefs, characterizing a person with such complex beliefs as being sophisticated or not is particularly spurious.

Finally, I suggest that the consistent finding regarding the dimensionality of pedagogical thinking in general and beliefs in particular can be interpreted in a way that sheds light on the mechanisms linking faculty beliefs and practice. Research on attribution theory, which focuses on how individuals explain the causes of events or outcomes (Kelley, 1973; Weiner, 1985), has been widely applied to educational settings. According to Weiner (1985), individuals have causal ascriptions for events, and that there are underlying structures to these ascriptions (e.g., locus of causality, stability and controllability). For instance, the locus of causality refers to whether or not an individual ascribes the cause of an event to internal or external factors. When an event occurs (e.g., a student fails a test) individuals will engage in an attributional "search" that generates explanations and attributions that ultimately affect cognitive and behavioral reactions (Perry, 1997). The result of this search will also influence future motivation towards engagement in related tasks. In addition, over time causal attributions can play an influential role in decision-making, as encoded cause-effect relationships or schema allow an individual to make fast and cognitively economical decisions about attribution (Kelley, 1973).

Research on attribution theory in education has tended to focus on the K12 sector, and researchers have explored questions such as teachers' causal attributions of problematic situations (van Opdort et al, 2005), teachers' attributions of gender differences regarding achievement in mathematics (Fennema et al, 1990), and the reliability of situational cues in shaping teachers' attributions for student achievement (Borko and Shavelson, 1978). An interesting body of work in this area has explored how teachers' views of student abilities or expended effort regarding learning outcomes influences rewards and punishments (Lanzetta & Hannah, 1969; Weiner & Kukla, 1970), finding that teachers generally rewarded students who overcame low abilities to succeed (i.e., no ability and a little effort) and chastised those who failed to use their abilities and did not succeed (i.e., high ability and low effort). In higher education, attribution theory has been applied more to student learning than to teaching behaviors, particularly on the perceived control that a student has for his or her own learning and performance (Perry, 1997). Perry (2003) has elaborated on attribution theory to focus on the construct of *perceived personal control*, or the subjective judgment a person makes about their capacity to influence events.

While the beliefs discussed in this paper are not attribution beliefs in terms of locating the cause of a particular outcome (i.e., student learning), the results indicate that a key characteristic underlying these beliefs pertains to the identity of the agent who is most active in constructing knowledge and meaning as part of the learning process. In the case of teacher-centered beliefs, it is the teacher who plays the central role in constructing knowledge that is then communicated to the students through a variety of teaching methods. Learning in this case can be viewed as the internalization of the teacher-constructed knowledge. In the case of student-centered beliefs, the teacher also plays a role in communicating knowledge but it is the students who then play the central role of constructing meaning and knowledge. Thus, learning becomes an activity that entails not only internalizing teacher-packaged knowledge but also the active re-organization of that knowledge into the student's own terms. Importantly, in both cases the student is perceived as having the capacity to influence their own success or failure, as evidenced by the foundational belief of persistence and practice as well as the need for students to be active and engaged respondents in interactive teaching situations. Where causal attributions may vary is the degree to which a teacher holding student-centered, teacher-centered, or combinations of both, perceives themselves as having the capacity to influence student learning. In each of the cases presented in this paper, the instructors felt that as teachers they had a high degree of control over shaping an instructional milieu in which optimal learning could take place. However, each of the faculty also stated that at a certain point it is up to the student to dedicate sufficient time and energy to studying. This suggests that causal attribution beliefs held by some faculty may in fact identify both the teacher and the student as the locus of causality for student learning. In any case, future research is required to explore the precise relationship between attribution beliefs and pedagogical behaviors such as the use of specific teaching methods and planning procedures, and the willingness to participate in professional development.

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CHAPTER EIGHT: IMPLICATIONS AND NEXT STEPS

Implications for instructional improvement at the postsecondary level

This study has several implications for how policymakers, faculty developers, and education researchers approach instructional improvement at the postsecondary level. While evidence suggests that faculty teaching practices are beginning to incorporate more interactive teaching methods (DeAngelo, Hurtado, Pryor, Kelly, & Santos, 2009), many policymakers and educators argue that change is too slow and that much work remains to be done (PCAST, 2012; Tagg, 2012). [23] Strategies for affecting changes in faculty teaching include a variety of approaches such as curricular reform, organizational re-structuring, and professional development initiatives. In particular, professional development is viewed as a critical leverage point due to the fact that many faculty have not received formal training in pedagogy and learning theory (Halpern & Hakel, 2003). While many efforts adopt a comprehensive approach that focuses on supporting changes in faculty beliefs and pedagogical knowledge, instructional skills, and organizational systems (Saroyan & Amundsen, 2001), a growing number of researchers and faculty developers are paying particular attention to faculty thinking as a principal lever of change. As McAlpine and Weston (2000) state, "Fundamental changes to the quality of university teaching…are unlikely to happen without changes to professors' conceptions of teaching (p. 377)." Based in part on this sentiment, some faculty developers are designing programs that place considerable emphasis on encouraging faculty to develop student-centered beliefs and teaching approaches (Ho, Watkins, & Kelly, 2001; Lindblom-Ylanne, Trigwell, Nevgi, & Ashwin, 2006). These

[23] Further contributing to the perception that efforts over the past three decades have not been successful in a wholesale change in undergraduate instruction is evidence that some interactive teaching practices such as Peer Instruction (Mazur, 1997) are being adopted with varying degrees of pedagogical quality and efficacy (Turpen & Finkelstein, 2007). This process of local adaptation can sometimes result in a kind of "lethal mutation" that essentially subverts the intentions of the instructional designer to result in classroom practices that are less than effective (Brown & Campione, 1994).

programs are based on three key assumptions from the literature: (a) that faculty beliefs have a direct and causal relationship to practice, (b) that individual faculty can be characterized as having a particular "type" of belief, and (c) the "student-centered" type of belief is inherently superior to the "teacher-centered" type and directly leads to high-quality teaching and enhanced student outcomes.

Yet higher education researchers are increasingly calling into question each of these premises, largely due to methodological limitations in the empirical research upon which they are based (Devlin, 2006; Kane, Sandretto, & Heath, 2002; Meyer & Eley, 2006). The data reported in this paper lend support to questions regarding these assumptions. In addition, I suggest that the paucity of frameworks based on theory and evidence from cognitive psychology and the learning sciences and has contributed to overly simplified and reductionist accounts of faculty thinking. As a result, I argue that faculty development initiatives focused on supporting faculty to adopt student-centered beliefs are unsupported by empirical research. This is not to say that professional development should not place teachers and their growth and professional development at the center of instructional reform efforts, nor that teacher thinking is inconsequential in regards to classroom practice. As Fullan stated, "educational change depends on what teachers do and think – it's as simple and as complex as that" (2001, p.115). However, I suggest that given the lack of evidence regarding the causal links among faculty beliefs, teaching, and student outcomes, faculty developers would be better served in taking a broader outlook on faculty practice that encompasses the organizational context, pedagogical skills and techniques, and aspects of cognition. Such a systems-oriented approach is common in the K-12 sector (e.g., Clarke & Hollingsworth, 2002; Putnam & Borko, 2000) in large part because of the recognition that teaching practice is situated within specific instructional settings. Promising examples of such an approach exist at the postsecondary level and programs that aim to deepen the pedagogical skill set and knowledge base of faculty while also addressing the constraints and affordances posed by the local context should be encouraged in the future (Saroyan & Amundsen, 2001).

Another argument against the singular promotion of student-centered beliefs is the potential of such approaches to have the unanticipated effect of alienating faculty and fostering resistance to pedagogical improvement. Some observers of instructional reform efforts in higher education state that the dominant approach to organizational change promoted by funding agencies such as the NSF are based on a top-down theory of behavior change (Fairweather, 2008). That is, projects demonstrated to be successful at one location can be exported to other locations with the expectation of wholesale adoption. By coming into local colleges and universities with a priori assumptions about matters such as effective curriculum, the sources of poor educational outcomes (e.g., the faculty) and the role of faculty beliefs, educational designers may be fostering resentment among faculty who feel as if their experiences and perspectives are being ignored (Henderson & Dancy, 2008). In particular, I argue that faculty development projects based on the assumption that student-centered beliefs are superior to teacher-centered beliefs run a particular risk in generating a strong backlash from faculty in general, but especially faculty in the math and science disciplines.

This is due in part to evidence that what some perceive as resistance is not just a belligerent reaction against change but may be a principled response to innovations or policies that are viewed as detrimental to organizational functioning (Piderit, 2000). Similarly, research on reform implementation in the K-12 sector demonstrates that policies and innovations will be interpreted, adopted or rejected, and adapted largely based on the cognitive frameworks of teachers as they function within specific contexts (Coburn, 2001; Spillane, Reimer, & Reiser, 2002). Thus, designing professional development initiatives that are based on evidence from the learning sciences while also paying close attention to local practices, traditions, and conditions may increase the chances that a new policy or innovation will be accepted (Cobb, Zhao, & Dean, 2009). One of the ways that detailed insights into local practice can be translated into practice is to identify locally salient ways of thinking and acting that could be built upon when designing an intervention. Tailoring new policies or products to local practice is a core idea in diffusion of innovations theory (Rogers, 1995) as well as fields focused on affecting behavior-change such as public health (Helman, 1997). One aspect of current practice to consider is the pre-existing patterns of teaching as depicted in the network graphs presented in this dissertation. These graphs provide a snapshot of classroom teaching that are likely "taken for granted" by entire communities of practice, which in this case are faculty within a particular discipline.

As an example of how insights into local practice can be used by practitioners engaged in instructional improvement, I discuss how two belief types reported in this study can be used to inform the design and implementation of pedagogical reform efforts.[24] First, given the foundational belief that student learning is dependent on student practice and persistence, it is not unlikely that professional development efforts that place the onus of student achievement squarely on faculty while minimizing or ignoring the role of students may not be well received. Indeed, researchers of K-12 school reform note the unfairness of singling out teachers as both the source of the problem as well as the primary agent of change and improvement (Cohen & Ball, 1990). Given evidence that some faculty resent being characterized as *the* primary barrier to pedagogical improvement, this suggests that a more effective approach by policymakers and

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[24] In making these recommendations I follow the suggestion of Clark (1988) who argued that researchers of teacher cognition can serve an important role as "consultants" to instructional designers by shedding light on local actors' belief systems and how they function in specific settings.

researchers engaged in educational improvement initiatives may be to build upon the expertise and opinions of faculty rather than viewing their skills and experiences through a deficit model framework. As Henderson and Dancy (2008) point out:

> Instead of making them feel they are bad teachers and that they are being told to adopt research innovations (for instruction) because the researchers know best, these instructors would like the (educational) research community to recognize that they have valuable experiences and expertise and work with them to improve teaching and learning (p. 86).

Thus, I recommend that the policy statements (e.g., PCAST, 2012) and professional development initiatives that focus exclusively on faculty behaviors as the primary cause of student outcomes at the very least acknowledge the role of student study habits and persistence in determining their success or failure.

Second, faculty are often characterized as being ignorant of learning theory and generally lacking knowledge about the learning process and that this lack of knowledge is a key factor leading to poor student outcomes (Halpern & Hakel, 2003). However, the data suggests that some faculty may in fact have a folk theory of student learning that is not inconsistent with empirical evidence from cognitive psychology. This folk theory is that effective student learning is essentially a “struggle” and a considerable challenge. As with the belief regarding practice and persistence, professional developers may be well served to at the very least acknowledge that faculty do have a theory of learning, that it may actually be a good one, and that these theories can be elaborated upon with a more formal course of study in the learning sciences. That is, instead of assuming that faculty have no knowledge about learning, it may be more productive and less threatening to acknowledge existing beliefs about learning and to explore how they are consistent or inconsistent with evidence from the learning sciences (e.g., Bransford, Brown, & Cocking, 1999).

Next steps

This study is part of a larger research program focused on ascertaining the cognitive, socio-cultural, and organizational features that both shape and constitute faculty planning and teaching practices. Based on the findings and analysis presented in this paper, several fruitful avenues for future research that also address this broad problem are apparent.

First, I suggest that instead of seeking to prove the causal links among belief types, faculty teaching, and student outcomes, efforts be made to produce more detailed and rigorous descriptions of practice in the field. This may include ethnographic analyses of faculty decision-making and practice in specific cultural environments, in-depth case studies of individual instructors on a micro-level (e.g., Speer, 2008; Schoenfeld, 2000), or task-based analyses that examine subtle features of how faculty perform tasks in their daily work (e.g., Halverson & Clifford, 2006). While it may be the case that the literature contains enough descriptions of practice so that the broad outlines of faculty practice are well known, there are too few robust ethnographic studies of how faculty and departments make curricular decisions and engage in teaching both undergraduate and graduate students. In recommending ethnography as a particularly useful approach to pursue, it is important to note that simply conducting interviews or observations for one day or one week at a given site is insufficient to conduct an ethnography (Wolcott, 1975). Instead, in-depth immersion and participation in a community's daily work and practices is required in order to properly situate observed practices within their socio-cultural and organizational contexts (Agar, 1996; Wolcott, 2008). Conducting such ethnographic analyses in multiple institutional types (e.g., research universities, community colleges, etc.) and in different parts of the country would also provide greater insights into the generalizability of case study-based findings.

Second, future research in this area should consider focusing on domain-specific beliefs and their relationship to specific instructional practices. That is, instead of eliciting generalized beliefs about teaching and learning and linking them to correspondingly generalized teaching behaviors, researchers should aim at more finely grained beliefs and practices. Evidence from psychology (e.g., Bandura, 1997; Ajzen, 1991) and education (Pajares, 1992) indicates that beliefs about specific topics (e.g., teaching undergraduates in Chemistry 101 about combustion) are better predictors of behavior than coarsely grained beliefs (e.g., about teaching in general). Examples of research focusing on domain-specific beliefs and specific behaviors exist in the K-12 literature (e.g., Nathan & Koedinger, 2000) but little work has been done using this approach at the postsecondary level.

Third, given prior research that indicates beliefs can act to filter new information, frame problems and tasks, and guide activity (Fives & Buehl, 2012; Nespor, 1987; Pajares, 1992), future research should explore precisely how beliefs may act to influence faculty teaching in these ways. The data reported in this paper provide preliminary evidence that beliefs may act to frame the “problem” of teaching through the activation of a gestalt of beliefs, goals, prior experience, and perceived affordances, all of which collectively act to establish the parameters in which a task is interpreted and courses of action selected (Norton, Richardson, Hartley, Newstead, & Mayes, 2005). Research on this topic can be conducted using experimental methods that involve respondents with different beliefs viewing similar stimuli (e.g., videotapes of classrooms, instructional scenarios) and then discussing them (e.g., Yadav & Koehler, 2007).

Fourth, further research exploring the relationship between faculty thinking and practice remains necessary. This exploratory study simply maps out some of the terrain regarding this complex phenomenon, and the area remains what Kane, Sandretto and Heath (2002) called a "vast sea of uncharted research" (p.184). Researchers addressing this topic should continue to integrate both self-report data with observations of classroom practice in order to capture faculty espoused theories as well as their theories-in-use (Argyris & Schon, 1976). Additionally, mediating factors such as goals, prior experience and perceptions of the constraints and affordances within the instructional environment should also be accounted for in research on this topic. In particular, research investigating the effects of changes in one of these areas (e.g., perceived affordances related to departmental support for demonstrations) on faculty thinking and practice should be conducted. Such investigations would begin to untangle the degree to which linear or recursive relationships exist among the disparate factors that comprise local systems of practice (Halverson, 2003). Research focusing on how beliefs may influence practice through unconscious or automatic mechanisms should be conducted, largely due to increasing evidence that much of our behavior is determined by processes outside of conscious awareness (Bargh, 2005; Feldon, 2007). Research in this area could utilize techniques from the priming literature to prime certain beliefs of faculty prior to performing certain instructional tasks (e.g., Bargh & Fergus, 2000).

Finally, further investigation regarding the role of students in the faculty thinking-practice dynamic is necessary. Too often students remain invisible in research exploring faculty cognition, and this study is an example of this phenomenon. Given that faculty considerations of students' career trajectories and abilities play an important role in behaviors such as course planning (Stark, 2000), future research should integrate students more directly into research designs. For example, research on student views of their own learning (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Weiman, 2006; Biggs, 1988) could be integrated with investigations of faculty beliefs and instructional practices that would provide a multi-dimensional account of teaching and learning. In particular, researchers could examine the implications of faculty and student beliefs about learning that are well-aligned or poorly aligned, and any subsequent impacts on student performance. In any case, research on faculty thinking and practice should begin to view the educational experience in a more comprehensive fashion that foregrounds the presence and influence of students, and not relegate them to unimportant observers or recipients of faculty work (Ball & Cohen, 1996).

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Appendix A

Interview Protocol for CCHER Interview

Intro script

Thank you very much for taking the time to talk with me today and for letting me observe two of your classes. As the email mentioned, we are exploring the personal, cultural, and organizational influences on teaching introductory courses in large research universities. Your insights into this issue will help us to better understand the real-world constraints facing instructions in higher education. For the questions I'm about to ask you, please answer in as much detail as possible, and share any associations or connections that may occur to you while you are speaking.

[Note to interviewer: tangents will need to be limited, so don't hesitate to cut people off nicely; probe if topic not discussed or volunteered in response to primary question]

Grand Tour: Overview questions re: target course (5 min)

1. Please tell me basic information about the class I observed/will be observing? **(brief)**
    - Probe: level, content, role in department

2. How much leeway do you have in determining the content of this course?
    - Does departmental policy or tradition enter into the decision?

3. What are your goals for students in this course?
    - Probe: What are the origins of these goals? (dept policy, personal philosophy, mentor, etc)

4. What is your view about how people best learn key concepts in your field at the undergraduate level? (e.g., apprenticeship, memorization, hands on experience, doing problems, etc.)
    - Probe: Is this view evident in how you teach this course?
    - Probe: Is this a discipline-specific view?

Specific aspects of behaviors re: target course (10 min)

5. What specific teaching techniques do you plan to use in the class?
    - Probe: What factors did you take into account as you selected these techniques?
    - Probe: Do you have specific goals for each of these methods? (e.g., cover textbook, engage students)

6. How are you sequencing topics and/or activities in this class?
    - Probe: What factors did you take into account when you made this decision?
    - Probe: Do you have a particular pedagogical strategy motivating this decision?

7. What are the specific steps you take in presenting a new topic? (e.g., intro topic, provide illustration, work out problem, test comprehension)

- (If not answered in Q4 or Q5)

8. Do you plan on using any specific props, objects, or technology in your class?
    - Probe: If so, where did you get the idea to use them?
    - Probe: Does your department support or encourage their use?

9. Do you pose many questions to the students in this course – and if so, how specifically do you do so?
    - Probe: What is your rationale for posing questions?

Role of culture in teaching re: target course [5 min]

10. If you didn't use particular teaching techniques such as [fill in based on prior response], would your colleagues care? Or be disappointed?
    - [If yes] How, if at all, do these expectations influence how you teach course X?
    - Probe: If they exist, are these expectations formal or informal?

11. Do you think that instructors teach differently based on their status within the department or field?
    - Probe: Does this pertain to you?

12. Do you ever seek advice or input about your teaching from others? If so, who do you talk to or where do you get info about teaching?

13. Does your department encourage you to put energy into your teaching activities? **(if time)**

Schema for teaching (in addition to Q2 & Q7)**[2-3 min]**

14. How effective do you think you are as a teacher?
    - Probe: How do you know?

STEM Education Reform [5 min)

15. Have you been involved in any teaching-related projects at [Institution Name]?
    - Probe: If so, what activities were you involved in?
    - Probe: If so, why?
    - Probe: If not, why not? [If not, skip to #17]

16. How, if at all, has this project influenced your teaching?

17. As you may know, there are significant efforts at the national level to reform undergraduate instruction. What do you think about this? What recommendations do you have for people if they want to change teaching in undergraduate STEM courses?

Do you have any additional points you'd like to make about any of the questions I've asked?

In 2 years we will be collecting our 2nd wave of data for this study. If you are teaching an undergraduate course in the spring of 2012 would you be willing to participate in this study again?

Thank you very much for your time, and please fill out the survey.

Appendix B

*Use **pencil** to code the lesson in the categories.*

Minutes	0-4	5-9	10-14	15-19	20-24	25-29
Teaching Methods	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW	LEC IL DEM SGW MM CS PS OT B RQ DCQ DAQ CQ NQ CL CD DW
Notes: Include brief description of what the instructor is actually doing here (e.g., content being discussed, sequence of argumentation, etc.)						
Cognitive Engagement	RM PS CR IN CN	RM PS CR IN CN	RM PS CR IN CN	RM PS CR IN CN	RM PS CR IN CN	RM PS CR IN CN
Notes:						
Instruct. Artifacts:	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T
Notes:						