Teaching Approaches of Community College Mathematics Faculty:

Do They Relate to Classroom Practices?

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Abstract

We report findings from a qualitative investigation of how 14 faculty members in the mathematics department at a community college described their approaches to teaching and contrasted those with analyses of their mathematics lessons. We characterized instructors' teaching approaches into Traditional, Meaning Making, or Student Support and mathematical questions asked in lessons in terms of their complexity as either novel or routine. There is close alignment between how instructors describe their approaches to teaching and how they enact them in their classroom talk, but we found it difficult to differentiate instructors' approaches when considering the complexity of the mathematical questions asked. Beyond attending to teaching approaches, increasing the complexity of questions that instructors ask might improve students' opportunities to learn.

Keywords: teaching approaches, mathematics education, questioning practices, post-secondary education, community colleges

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Research on teaching and learning in higher education has increased substantially since the early 1990s, when several studies were initiated in different countries (Kember, 1997; Kember & Gow, 1994; Menges & Austin, 2001). In spite of this work, *instruction*, defined as the interactions that happen in the classroom between students, teachers, and content which are mediated by specific environments (D. K. Cohen, Raudenbush, & Ball, 2003), remains largely under theorized in higher education research. We make this claim based on the diverse labels that scholars in higher education have used to describe various aspects of teaching—'teaching conceptions,' 'teaching styles,' 'teaching orientations,' and 'teaching approaches' (Kember & Kwan, 2000; Lowyck, Elen, & Clarebout, 2004; Prosser & Trigwell, 1999). Some of these labels have not been defined, and most do not refer to the interactions occurring between students and teachers on the mathematical content that students have to learn. Indeed, most of higher education studies on teaching look at what can be seen as elusive aspects of the interaction (e.g., approachability, clarity, style, organization, and flexibility). Adding to this mix, there is substantive work in the past two decades that has advanced the idea that 'student-centered approaches' can be more effective than 'teacher-oriented' or 'content-oriented' ones (Åkerlind, 2003; Barr & Tagg, 1995; Grubb & Associates, 1999; Grubb & Cox, 2003; Kember & Gow, 1994; Prosser & Trigwell, 1999) particularly in terms of student learning (Kember & Gow, 1994). Usually 'teacher-centered' and 'content-centered' approaches are used interchangeably to refer to situations in which the teacher delivers content to students who are assumed to be passively learning the material by sitting in the classroom taking notes without much interaction besides questions and answers to clarify content. These two approaches are usually defined in opposition to 'student-centered' approaches, which are used to describe situations in which the students work in groups during class, answer questions for which they have to reflect and share answers with a partner, or solve problems for which no solution is known (as in problem- or inquiry-based learning).

Most of these studies on 'teaching approaches' are conducted through the analysis of inventories of students' perceptions about their learning processes or interviews about instructors' perceptions of teaching (Ashwin, 2009; Meyer & Eley, 2006). Studies that take into account the interaction between instructors and students are rare (Ashwin, 2009). As a result, there are two gaps in the literature, one regarding the connection between what instructors say about teaching and their actual classroom practice (Kane, Sandretto, & Heath, 2002), and another about the nature of the interactions that happen in the classroom on particular content and that have a strong bearing on what students ultimately learn. These analyses are more common in the K-12 literature, particularly in the mathematics education literature (e.g., A. M. Cohen, 1985; Schoenfeld, 1988; Stipek, Givvin, Salmon, & MacGyvers, 2001), where it is typical to study the quality of the interaction (e.g., questions, teachers' moves) between students and teachers in specific lessons on specific content (e.g., fractions, proofs). The very different environments of K-12 schools and higher-education institutions (e.g., mandatory versus voluntary student attendance, teacher preparation in content and pedagogy versus preparation in a discipline, requirement to follow local or national standards versus academic freedom) suggest that similar analyses might yield different results in the higher education context. The goal of this paper is twofold. First to investigate the ways in which teaching approaches obtained from instructors' interviews manifest in mathematics instruction at a community college and second to determine whether faculty who mostly use student-centered approaches create opportunities for students to also engage with more complex mathematical questions.

We chose to study instruction at *a community college* for four reasons. First, because community colleges are recognized as 'teaching' institutions, they provide, at least theoretically, an ideal space to investigate instruction. Second, being open access institutions, community colleges bring a diverse students and teacher body that can make instruction more complex than in a more selective setting. Third, the rising costs of higher education, has made the community college an attractive option for many students seeking to obtain a college degree. Obtaining such a degree is becoming more prominent in the national discourse (Office of the Press Secretary, 2010) and has been associated with high paying jobs and increased levels of health, wealth, and civic participation (Baum & Ma, 2007; Baum & Payea, 2005; Dowd, et al., 2006). Fourth, although there is substantial documentation on how community college student characteristics such as age, prior achievement, ethnicity, and patterns of course taking, including whether they require remediation or not, are related to retention and success (Adelman, 2005; Bahr, 2010; Feldman, 1993; Goldrick-Rab, 2007; Pascarella, Wolniak, Pierson, & Terenzini, 2003; Stigler, Givvin, & Thompson, 2010a; Waycaster, 2001), there is little research on the factors associated with mathematical instruction that can be closely related to retention and success in community colleges (Mesa, 2007). Indeed, a review of the literature related to mathematics instruction in community colleges yielded no studies that attended to how classroom processes are conducted, revealing instead associations of the term *instruction* with *instructors* (i.e., part- versus full-time), *curriculum* (i.e., the courses that students take), *assessment* (i.e., the grades students obtained in their math courses), or *pedagogical innovations* (e.g., whether graphing calculators, group projects, or writing is used, Mesa, 2007). Some studies have started to investigate a possible connection between instruction and students' opportunity to learn mathematics by analyzing how students and teachers discuss mathematical content (Mesa, 2010b, accepted; Mesa & Herbst, 2011) and how textbooks use examples to illustrate mathematically demanding work (Mesa, 2010a; Mesa & John, 2009; Suh, Mesa, Blake, & Whittemore, 2010a, 2010b).

We chose to study *mathematics* instruction, for three reasons. First, substantial work has been done in the K-12 literature on instruction in mathematics, thus providing a good starting point for our analyses. Second, in the most recent report from the College Board of Mathematical Sciences, (Lutzer, Rodi, Kirkman, & Maxwell, 2007) nearly 1.7 million students were taking a mathematics course in a community college in the year 2005. This figure is a 26% increase from the figure in 2000 and roughly 51% of the undergraduate population taking a mathematics course in the U.S. And last, but not least, the controversies surrounding the value and cost of remediation in general (Attewell, Lavin, Domina, & Levey, 2006; Bailey, 2009; Bailey, Jenkins, & Leinbach, 2005; Bailey & Morest, 2006; Melguizo, Hagedorn, & Scott, 2008), and in particular in mathematics (Bahr, 2008, 2010) affect community colleges more directly given that they deal with nearly 83% of all the remediation that is needed (Lutzer, Maxwell, & Rodi, 2002; Lutzer, et al., 2007).

This paper is organized into five sections. We start with a summary of the literature that is relevant to the goals of this paper. In the methods section we describe how we sampled, collected, and analyzed the data, and the limitations of the study. We follow this by the main findings of the analyses. In the discussion section we put forward several conjectures that can explain our findings. We conclude with suggestions for further research and implications for practice.

Literature Review

Teaching is a complex endeavor. Bringing different lenses to the analysis of instruction at community colleges has brought to the fore the differences in conceptualization of teaching used by scholars in two different fields, higher education and mathematics education. The literature in higher education have developed constructs such as ‘teaching conceptions’ and ‘teaching approaches’ to categorize the variety of teaching across disciplines and colleges and universities. In contrast the literature in math education have attended more closely to the interaction between students and instructors with specific mathematical content, developing notions such as ‘socio mathematical norms’ (Cobb, Wood, Yackel, & McNeal, 1992; Yackel & Cobb, 1996) to describe behaviors in classrooms that determine how students, instructors, and mathematical content play out in the day-to-day work.

Independent studies of teaching in higher education conducted in different countries have arrived at comparable constructs using different terminology (Kember, 1997; Stes, Van Petegem, & De Maeyer, 2010; Trigwell & Prosser, 2006). When studying different aspects of instruction in higher education, the most general concept used by researchers is “teaching conceptions,” defined as the set of instructors’ beliefs and values toward teaching (Kember, 1997; Kember & Gow, 1994; Prosser & Trigwell, 1999). When describing specific strategies, methodologies, and instructional activities, some scholars use the concept “teaching approaches” (Gregory & Jones, 2009; Grubb & Associates, 1999; Kember, 1997; Prosser & Trigwell, 1999). Meyer and Eley (2006) have critiqued some of these studies pointing out methodological weaknesses in their use of inventories and questionnaires and sample-biases in interviews. In addition they raise questions about the inconsistent use of categories such as beliefs, conceptions, approaches, and orientations, which makes it difficult to use them to describe teaching. In our review we also found substantial variation in terms of samples and instruments used, and more importantly, little agreement in the definition of constructs that the instruments were meant to measure.

Most of these characterizations of approaches to instruction suggest a hierarchy that implies that student-centered approaches are more effective than teacher- or content-centered approaches (Åkerlind, 2003; Kember & Gow, 1994; Prosser & Trigwell, 1999). These studies, following Marton and Säljö's (1976) study on students' learning, claim that the student-centered approach is more effective because it promotes a 'deep' rather than 'surface' students' approach to learning. Using a national database in the United States, Laird and colleagues (Laird, Shoup, Kuh, & Schwarz, 2008) found evidence that instructors in hard-applied fields (e.g., engineering) use strategies that promote students' deep approaches to learning less frequently than instructors in soft disciplines (e.g., social sciences). Jarvis-Selinger, Collins, and Pratt (2007) found that academic disciplines influence teaching approaches, with mathematics being the most content-centered discipline among the 16 disciplines studied. Kember, Kwan, and Ledesma (2001), studying classrooms with adolescent and adult students, found that, in contrast to content-centered instructors, student-centered instructors identify different groups of needs and experiences among their students and adapt their teaching according to those needs and experiences.

While these studies establish a clear dichotomy and separation between student- and teacher- or content-centered approaches, Kember and Kwan (2000) proposed six categories to classify instructors as following either a teacher-, content-, or student-centered approach and found that no instructor could be positioned as exhibiting any single position. Akerlind (2003), taking a developmental perspective, proposed a nested hierarchy of approaches. That is, instructors using student-centered approaches develop a more complex view of teaching and are able to acknowledge and understand other teacher- or content-centered approaches. Other studies argue that there is not a single teaching approach that fits all learners' needs and suggest that the best teaching approach is one that fits the instructor's goals (Angelo & Cross, 1993; Pratt, 1992) or the students' learning approaches (Felder & Silverman, 1988).

Although the higher education literature acknowledges the relevance of disciplinary knowledge, higher education scholars have tried to identify changes and practices that can improve the effectiveness of faculty teaching across disciplines (Hativa & Marincovich, 1995). Thus, most studies show a preference for student-centered approaches arguing that they better help students, regardless disciplinary differences. The effort to generalize teaching deemphasizes the role of content in instruction. This generalization makes it problematic to identify practical and effective ways to improve teaching, and therefore, students' learning, in particular content areas.

An important assumption of investigations on instruction in K-12 mathematics education is that social interactions are crucial for learning (Cobb, et al., 1992; Wood, 1995). Learning is both an individual and a social process, with social processes—the ways in which the classroom community works with and talks about mathematics—revealing what is valued and accepted as mathematical practices in that community (Yackel & Cobb, 1996). Studies of classroom interactions provide detailed analyses of students' and instructors' exchanges with the ultimate goal of describing the quality of learning that happens with a specific mathematical tasks in a particular context (Cobb, Stephan, McClain, & Gravemeijer, 2001; Yackel & Rasmussen, 2004). These analyses have highlighted the crucial role that language has in shaping what and how students learn mathematics (Pimm, 1987; Voigt, 1995), and demonstrated that in general the view of mathematics as a collection of disconnected facts and arbitrary laws with little or no application to real problems and produced in isolation through an individual process, is the result of specific classrooms practices where students are socialized into this view of mathematics (Bauersfeld, 1988, 1995; Schoenfeld, 1988, 1992).

Studies of this nature have been conducted in undergraduate settings. Stephan and Rasmussen (2002) analyzed the collective generation of knowledge in a differential equations classroom that had been using a curriculum centered on challenging tasks. The research design was a classroom teaching experiment[1] that collected several data sources (class video recordings, students' interviews, copies of written work, researchers' journals and recordings of their meetings) and analyzed them to describe the way in which six mathematical practices emerged in the first half of the course. These practices (predicting individual solutions, refining and comparing individual predictions, creating and structuring a slope field as it relates to predicting, reasoning about the unknown in the equation as both a variable and a function, creating and organizing collections of solution functions, and reasoning with spaces of solution functions) were part of the mathematical norms for participating in the classroom and were necessary to establish ways in which knowledge was being created in and shared by the community. By looking at language the authors describe how the community constructs the meaning of differential equations from utterances, texts, and other tools that are available to them.

Studies on K-12 mathematics instruction are also framed by an interest in changing the way in which students and teachers deal with mathematics; moving towards viewing

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[1] In a teaching experiment a researcher generates hypotheses about students learning trajectories about a mathematical notion; a task is designed to test the plausible trajectory and as the student works with the tasks the researcher can confirm or disconfirm the learning processes that happened (Steffe, 1994). Classroom teaching experiments include the instructor and are more complex, since they attempt to look not only at individual, but also at collective learning. See Cobb (2000).

mathematics as a connected set of ideas—with procedures that make sense and have important applications, and problems that admit more than one way of working and more than one solution—and more importantly as a body of knowledge that is collectively generated—with agreed upon reasoning practices that 'make sense,' and in general advocating for what could be seen as a more student-centered approach. Such view of mathematics has traditionally been reserved to the mathematically inclined, and has in general been alien to school age students. Reforms proposed by the National Council of Teachers of Mathematics (National Council of Teachers of Mathematics [NCTM], 1989, 2000) have promoted changes towards this more accurate view of how mathematics is produced. Similar reforms proposals in which more cognitively demanding mathematical work is done have been made in the undergraduate setting (Blair, 2006), but it is unclear that these proposals have reached a critical mass of classrooms to make a significant impact. In addition, the attention to the mathematical content by the research community has left unexamined other activities and ways of behaving that are important for teachers as they work with students who bring a wide range of interests and capabilities into the classroom. This is particularly evident at community colleges in which little research of this nature has been conducted (Mesa, 2008, 2010b).

Following Cohen, Raudenbush, and Ball (2003), we define instruction not only as 'what the teachers do, say, or think' but what they 'do, say, and think with learners, concerning content, in particular organizations and other environments, in time" (p. 124, see Figure 1). Thus, studying instruction requires to see not only what teachers 'do, say, or think', but also, what happens in the classroom when teachers interact with students *and* with the mathematical content, and how that might be influenced by specific classroom and institutional environments. This definition allows us to, first, differentiate whether an approach to teaching is 'centered' on the student, the teacher, or the content, and second, to zoom into the classroom to study the interactions that occur in order to describe the nature of teaching.

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Regarding the first point, we propose that because the instructor is the ultimate orchestrator of the activity of instruction in any given lesson (the instructor selects the content, the activities, the order, decides when to ask questions, monitors students working in groups, designs assessments, etc.) all instruction is, in fact, teacher-centered, and that a more adequate distinction of approaches should be one in which what is ‘privileged’ is either the content or the student. In this paper we then refer to teaching approaches as actions and strategies enacted and described by instructors when teaching mathematics or referring to teaching mathematics. We call student-centered approaches those in which the students play a significant role in determining those actions and strategies and content-centered approaches those in which it is the content that takes more prominence in defining actions and strategies.

Regarding the second point, we investigate the nature of the interactions in the classroom, both those that frame the mathematical activity and those geared towards creating opportunities for engaging students with more cognitively demanding mathematical work. The research questions that we addressed in our study were:

- How do teaching approaches manifest in mathematics instruction at a community college?
- Do faculty who use mostly student-centered approaches create opportunities for students to also engage with more complex mathematical questions?

Methods

Site

The setting for this study is a large suburban community college in the Midwestern United States with two small satellite campuses, an approximate enrollment of 12,000 students, and an average retention rate of 50%. The mathematics department has 17 full-time and about 75 part-time instructors and offers an average of 22 different courses per term, including remedial math (e.g., fundamental math, beginning and intermediate algebra); science, technology, engineering, and mathematics [STEM] preparatory courses (college algebra, college trigonometry, and pre-calculus); and college level mathematics courses for professional degrees (e.g., business, health, and education) and STEM degrees (e.g., calculus, linear algebra, and differential equations). Like other community colleges across the U.S., students may also obtain their general education diploma (GED). This particular college was chosen because the students' rating of teaching in the mathematics department was high (above 4.2 on a scale from 1 to 5), which suggests high student satisfaction with teaching. In addition, the department had recently appointed a very dynamic department chair, committed to investing time to improve teaching. Moreover, like other colleges in the state, the faculty feel pressure to increase passing rates in their courses and received substantial support from the administration to engage in activities that would result in better passing rates. These activities include support for a faculty development group, time off for periodic evaluation of curriculum and syllabi, incentives for managing the coordination of the large number of part-time instructors, a college wide program to address students' orientations towards learning, and in general *carte-blanche* for initiatives that would clearly focus on increasing passing rates. These reasons made this college special, yet similar to other large colleges that are concerned with passing rates.

Data Collection

The primary sources of data come from in-depth interviews of instructors and observations of their teaching. See Appendix A for the questions asked. Over a two and a half-year period (Fall 2007-Fall 2009), we interviewed fourteen instructors and observed lessons taught by each instructor. In the first phase of data collection (Fall 2007-Winter 2008), instructors were selected from a list provided by the chair that included 'good' teachers: their sections filled up first and their end of course evaluation scores (provided by the students) and their passing rates were above the average in the department. We sought a balance between the type of course taught (e.g., remedial or non-remedial) and the faculty's employment status (e.g., part- or full-time), gender, and years of experience. Ten instructors were invited to participate and seven agreed to partake in the study. In the second phase (Fall 2008-Fall 2009), all 12 instructors teaching a STEM preparatory course (college algebra, trigonometry, or pre-calculus) were invited to participate in the study. Eight of them accepted the invitation, including one instructor, Emmet, who participated in the first year, yielding a sample of 14 instructors. Table 1 presents the characteristics of the instructors who took part of the study and the courses observed.

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Each instructor was observed at least three times in order to obtain a characterization of students' participation patterns and of the nature of questions asked. The three observations during the first phase were spaced out during the semester to get a sampling of teaching across time; the three observations during the second phase were consecutive lessons to get a sampling of how a topic evolved. If, in addition, an instructor participating in the second year was teaching more than one section of a STEM preparatory course, each section was observed three times as well (e.g. Emmet taught three trigonometry sections in the second year and Elizabeth taught two sections of pre-calculus and one section of trigonometry). This resulted in the observation of nine different courses and 24 different sections (for a total of 72 classroom observations). The classes were audio-taped and extensive field notes were taken about where the students were sitting, where the teacher was in the room, what the students and the instructors were doing, who was saying what, and what was written on the board. Memos were written after each lesson to fill in details and capture the observers' impressions about the classroom interactions. All audio recordings (observations and interviews) were transcribed verbatim, noting the gender of the speaker for students, and pauses that lasted 3 seconds or more. Recording time was also included in the transcript to get a sense of how long instructors spent on different activities (for more details see Mesa, 2010b).

Analytical Frameworks

We performed three separate analyses, using two different frameworks. One framework was derived from the higher education literature and was used to analyze the interviews and all talk in the classroom that was not on mathematics content; we called this talk *framing talk*. The second framework was derived from the K-12 literature and was used to analyze mathematical questions. There is a pragmatic reason for this distinction derived from the state of the literature on analyzing mathematics instruction in higher education. While in the higher education literature there is an abundance of descriptions of teaching approaches derived from teachers' interviews and their behaviors in the classroom, there are none that attend to the nature of the mathematical interactions. And while in the mathematics education literature there is an abundance of frameworks to describe the nature of the mathematical interaction, there are very few that attend to general aspects of teaching when such teaching is not 'reformed,' that is, when teaching does not resemble the ideal models proposed by the NCTM *Standards*. In developing the analytical frameworks for our study we followed mostly a top-down approach, relying on existing categorizations and distinctions, but we augmented these categories with our own thematic and line-by-line analysis. The two frameworks were developed independently of each other. We discuss these frameworks next.

Teaching Approaches Framework. The development of the analytical framework that was used for coding the instructor interviews and the framing talk in the classroom followed a top-down approach that combined two perspectives on teaching approaches from the higher education literature. The first perspective, from the work by Grubb and associates (1999), proposes three approaches: *traditional*, *meaning making*, and *student support*. Teachers in the traditional approach prioritize content transmission and use mostly lecturing. These instructors place themselves as the authority in the classroom and emphasize covering the content and the importance of examinations. In contrast, teachers in the meaning making approach prioritize students' learning and use activities that encourage students' participation. This approach is also known as learning to learn and can be seen in project-based learning, or inquiry based learning. According to Grubb, the student support approach is particularly prominent in community colleges. This approach prioritizes students' needs (e.g., increasing their self-confidence) over learning the content. These instructors are highly empathetic to students' life circumstances; for them, learning the content is secondary to students' needs. We consider the *traditional* approach content-centered and the *meaning making* and *student support* approaches student-centered.

The second perspective comes from the work by Gregory and Jones (2009). Their description of teaching approaches, which was generated through a grounded theory process based on interviews and classroom observations at Australian universities, allowed us to capture more nuances and differences among the instructors we interviewed and observed. Gregory and Jones propose a model with four approaches: *distancing*, *adapting*, *clarifying* and *relating*. These approaches are generated by the intersection of two continua: (i) *focus on ideas (distancing and adapting) or focus on people (clarifying and relating),* which resembles the dichotomy content- and student-centered, and (ii) *structured (distancing and clarifying) or flexible style (adapting and relating)*, which introduces a new dimension that describes instructors' willingness to adapt the structure of their lessons to students' needs. This perspective positions the traditional approach closer to 'focus on ideas' than 'focus on people' but allows us to differentiate between approaches that are either *distancing* or *adapting*, thus, avoiding the tendency found in the higher education literature of classifying the bulk of traditional instructors into a large and homogeneous category, particularly when dealing with mathematics instructors (e.g., Grubb & Associates, 1999; Jarvis-Sellinger, 2007).

Combining these two perspectives, we created a framework with six categories: Traditional Distancing, Traditional Adapting, Meaning Making Clarifying, Meaning Making Relating, Student Support Clarifying, and Student Support Relating. Instructors who espouse a Traditional Distancing approach privilege covering the content that has been structured to fit in a certain period of time and do not indicate taking into account students' needs or their different learning styles for organizing their lessons, whereas instructors who espouse a Traditional Adapting approach, also privilege covering content but they take into account students' needs related to the content and change strategies and class structure as needed. Instructors espousing a Meaning Making Clarifying approach make expectations and demands from students explicit, but they do not modify the class structure to accommodate students' needs. They may see themselves as learning facilitators. Instructors following a Meaning Making Relating approach also see themselves as learning facilitators, but take into account students' needs, developing relationships among students and between students and the instructor. Instructors assuming a Student Support Clarifying approach make expectations and demands from students explicit, but place substantial emphasis in boosting students' self-confidence and in helping them with strategies that would make college easier. Although the content might be secondary, these instructors do not adapt the pre-established structures of their classes to fit students' needs, instead guiding students to use resources available for them in the institution. Instructors following a Student Support Relating approach are similar to those following the Student Support Clarifying approach in that they seek opportunities to boost students' self-confidence and de-emphasize the importance of the content, but they do take into account students' needs, developing relationships with students and between students, during class time.

We used this framework to analyze instructors interview and the framing talk in the classroom. Framing talk—talk that might not be necessarily content related—plays an important role in teaching. Such talk allows instructors to engage students with the content, create a good classroom climate, or maintain students' attention during lectures through the use of personal stories or humor or by using students' names.[2] The strategies used by instructors in faming talk can vary in goals, duration, and complexity. We identified strategies that ranged from stressing the importance of homework to calling students to solve problems on the board. Using a combination of bottom-up and top-down approaches—looking at our data and following the descriptions of teaching approaches in our six-category framework—we identified 32 different

[2] We acknowledge that other non-verbal cues (e.g., movement in the room, voice inflection) that were captured in our fieldnotes and audio recordings can also be important strategies that instructors use to engage students. However, we decided not to attend to these features, because these are can be highly inferential and compromise the reliability and validity of the coding process.

strategies that we organized into each three main categories, Traditional, Meaning Making, and Student Support. Table 2 shows the definition of each category and a list of instructors' strategies used during framing talk that we believe manifest these categories in the classroom.

----- Insert Table 2 here ----

Mathematics Questions Framework. We see questions as opportunities that instructors create to engage students in mathematical activity. With this framework, we sought to characterize the opportunities that are created in terms of their complexity, by describing how *novel* the questions are. The development of this analytical framework followed a combination of top-down and bottom-up approaches drawing from a number of frameworks that analyze questions in classrooms (Nassaji & Wells, 2000; Nystrand, Wu, Gamoran, Zeiser, & Long, 2003; Wells & Arauz 2006) and specifically in mathematics classrooms (Nathan & Kim, 2009; Truxaw & DeFranco, 2008) and using the data we collected. We describe these briefly.

Using data from middle school mathematics classrooms, Nathan and Kim (2009) looked at how one teacher regulates participation though the cognitive complexity of teacher elicitations based on the type of response requested: choice (yes/no), product (recall of factual information), process (explanation or student opinion), and metaprocess (justification based on their own reasoning). Truxaw and DeFranco (2008), also with middle school mathematics classroom data, mapped the flow of discourse from univocal (monologic) to dialogic and what teaching practices (deductive, inductive, and mixed) were associated with each. Using data from science, language arts, and history in elementary and middle schools, Wells and colleagues (Wells & Arauz, 2006; Nassaji & Wells, 2000) developed the Developing Inquiring Communities in Education Project (DICEP) coding scheme to look at changes in the characteristics of teacher-whole-class discourse and the wide variety of functions that the basic Initiation-Response-Follow-up/Evaluation (IRF/IRE) sequence can take. The DICEP coding scheme includes the separation of a transcript into episodes, sequences, exchanges, and moves, each of which is then coded on many aspects including content, participation structure (i.e. whole class, group, dyad), goal, function, and cognitive demand. We attended mainly to their coding of cognitive demand. Using data from English and social studies in middle and high schools, Nystrand and colleagues (2003) investigated how particular discourse moves affect the ensuing discourse patterns, with particular interest in what increases the likelihood of dialogic discourse. In that study, questions from both the teacher and students were coded for authenticity (authentic meaning that questions had no pre-specified answer) and cognitive level. The questions were also coded for uptake (the use of another student's previous statement) and the teacher's evaluation of a student's response. In our case these aspects were crucial for making decisions about the quality of the questions.

To generate our analytical framework for questions, we synthesized features of these various frameworks and created a categorization of questions that we applied to several of our transcripts, initially attending to content, intention, complexity, and execution. Each transcript was analyzed in several stages. First the transcripts were parsed in order to identify all questions that both instructors and students asked. We then took each teacher question and determined whether the question was mathematically oriented or not, whether the instructor expected to obtain an answer from the students (intention), the level of complexity of the question (routine: the answer or procedure was known by the students; novel: the answer or procedure was not known by the students), and whether the students answered the question or not (execution). We made the classification taking into account the talk that preceded and followed the question. In Table 3 we present the descriptions used to characterize the complexity of the questions in the transcripts that are pertinent to this study[3]. We used slightly different definitions for questions that were posed by the students. In this article we focus solely on teacher questions.

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Analyses

Interviews. The instructors were interviewed prior to the classroom observations to obtain their views about teaching and learning, their context, and institutional support for instruction (See appendix A). We started by identifying segments in the interviews in which the instructors described a particular teaching strategy, an anecdote related to teaching, perceptions about the environment or resources within the classroom, or personal beliefs or values related to teaching. We coded these segments using a word or a short phrase that best described the theme discussed (Merriam, 2009). Next, we organized each code and its excerpts into one of our six-category framework. See Table 4 for examples. The definitions of the categories were refined in two phases, each involving the two authors separately coding the same interview and comparing and discussing alignment and discrepancies. The inter-rater agreement in the first phase was 69% and 93% in the second. After reaching this level of agreement, the second author coded all the remaining interviews, and both authors discussed passages that were difficult to categorize in order to reach an agreement before summarizing the results. Using the total number of codes assigned to each interview as a reference (these ranged from 7 to 64 with a mean of 31), we found the percentage of codes that fell into each of the six categories. Each instructor was then labeled with one or more of the six teaching approaches. To be considered as exhibiting any given approach, more than 10% of the codes in the interview must belong to that category. Thus,

[3] The framework has categories for other types of questions asked that are not pertinent to the analysis reported herein (see Mesa & Lande, 2010 for details).

in order to be labeled as following only a Traditional Distancing approach, instructors needed to have less than 10% of codes in each of the other categories. This threshold is meant to acknowledge that instructors in general tend to follow more than one approach as they teach and to avoid simplistic labeling of their approaches.

---- Insert Table 4 here ----

Framing Talk. Reading and discussing the classroom transcripts, we looked for evidence that the instructors' framing talk referred to any of the 32 categories listed in Table 2. The second author coded the transcripts; the classifications were then discussed with the first author to assess consistency. We then determined how frequently each instructor used these strategies. Rather than seeking to establish how long instructors used a particular strategy we assessed how many times they used a given strategy. We excluded Edwina's classroom transcripts from this analysis because her transcripts were too short (she solved 8 to 10 prepared examples on the board for about 20-30 minutes and then let students work individually on their practice homework for about 50 minutes) and generated very few codes that did not give us confidence that we were appropriately characterizing this aspect of her teaching.

In Table 5 we provide examples of how these strategies were coded in the transcripts.

--- Insert Table 5 here ---

Mathematical Questions. Questions in the classroom transcripts were coded in several stages; one transcript was coded by seven coders independently (except for the first author, all were graduate students who were trained in the protocol and were cognizant of the goals of the project). This process was used to refine definitions and agree upon decision making strategies. Pairs of coders were assigned a new transcript and they independently coded and met to compare coding and to discuss discrepancies. These discrepancies were discussed in several weekly meetings in order to clarify and refine the definitions of the codes. Once we reached inter-rater agreements above .70[4] for each pair, independent coders coded the rest of the transcripts from the second phase (39 lessons). The third author verified the consistency of the coding. The second author coded one classroom transcript for each instructor who participated only in the first phase (6 transcripts). We did not code all the first-phase instructors' lessons because our analysis of the transcripts of the second phase lessons showed remarkable consistency across all lessons of the same teacher. The number of instructor and student questions coded ranged from 23 to 203 per lesson; we calculated the percentage of each type of question (novel and routine) for each teacher.

Limitations

Community colleges in the U.S. are not homogeneous institutions. Community colleges vary according to a wide range of factors, such as their surrounding community, size, infrastructure, students' demographics, and state policies. Our site represents a large community college, with several universities and other community colleges within a commuting distance of 50 miles. Thus, our results might not be generalized to community colleges with other characteristics. The depth of the analyses that we conducted, however, provides information that might be applicable to colleges with similar characteristics.

Most of the instructors in our sample volunteered to participate in this study and were recognized as "good" by their institution and the students (their sections filled up faster, their

[4] We used Cohen's κ to determine the level of agreement in coding, because this coefficient is better in helping identify the major discrepancies in the coding. Initial values varied from .35 to .69, but subsequent rounds of coding using new transcripts and the more robust definitions, improved the agreement among raters. We considered the coding robust when values were close to or above .70 (range .69 - .93). All discrepancies were discussed in meetings and resolved through consensus.

passing rates and their teaching evaluations were above average in the department). This implies that our results might not be applicable to all mathematics instructors at community colleges, especially in those cases in which the teaching is unsuccessful or below the standard expected by the institution. On the other hand, because our results are from a sample of what this institution and their students consider good mathematics instructors, they gives us a glimpse of a paradigmatic vision of good mathematics teaching at community colleges.

Another limitation relates to the scope of our method and analysis. It is possible to identify inconsistencies that are produced by a lack of shared understanding between us—the researchers—and the instructors (Speer, 2005). For instance, when instructors said that they are interested in promoting “learning to learn” in their classroom, they may have in mind a different type of classroom interaction than the one we envision using the literature on exemplary practices. We sought to minimize this problem of interpretation by asking and coding for concrete strategies (seat work, use of calculator, types of evaluation, etc.) and using evidence from the transcripts that were then vetted by the coders in order to make the classifications. This attention to concrete strategies and evidence leaves less room for interpretations of teachers’ statements.

Findings

We organize our results by the three analyses we conducted and include illustrative quotes and passages from interviews and classroom observations to illustrate our findings. These analyses provide us with three different lenses that together help to characterize how these instructors teach mathematics in this community college.

Approaches to Teaching from Instructor Interviews

In our first analysis, we coded instructor interviews using the six-category teaching approaches framework described in the methods section. Figure 2 illustrates for each instructor the extent to which they belong into any given category according to their description of their teaching approaches. In the figure the shaded area in each block represents the percentage of codes that fell into any given category for each instructor. To attribute a certain teaching approach to an instructor, the category must contain 10% or more of the total number of passages coded for that instructor. For this reason, blocks that represent ten or less percent appear gray in Figure 2.

Consistent with the findings by Grubb and associates (1999), most of our instructors' descriptions of teaching described traditional approaches to teaching. In our sample, 11 out of 14 instructors were classified into a traditional approach, 10 were classified into a Meaning Making approach, and 7 were classified into a Student Support approach.

Our six-category framework allows us to identify some nuances between the traditional approaches making it possible to differentiate instructors using a Traditional Distancing or a Traditional Adapting approach. Although these categories are similar in that they privilege the content and the instructor's authority, they differ regarding the extent to which they take into account students' difficulties with the mathematical content.

---Insert Figure 2 here---

If we conceive of these six approaches as points over a continuum, the Traditional Distancing category can be seen as epitomizing one extreme—the content-centered approach. A distancing approach refers to structured lectures that give prominence to ideas rather than to people. The instructors in the Traditional Distancing category will not consider the students' needs or their different learning approaches, but they would expect that their students learn the material on their own, and prefer to cover pre-defined content in a certain period of time. In our data, three instructors, Ernest, Edwina, and Elizabeth were positioned mainly in the Traditional Distancing category but as Figure 2 suggests, there were other instructors who described teaching strategies that fall within this category. What matters most to these instructors is that the students receive all the content that is expected to be covered, even if their students cannot keep up with the pace of the lecture. According to the instructors of the college level mathematics courses, the syllabus includes such a large number of topics that instructors have to go fast through all of them. Elizabeth, referring to her pre-calculus class, explains:

> Because this is [a] content heavy class […] I need to be able to move quickly in this class and so I need to make sure that they have everything. So this way I know that they've gotten it all, you know what I mean, because it's fast. I mean this is one of those classes you go fast, you do the whole book and it has a very broad spectrum. I mean everything from beginning algebra through trig, problem solving, conics, I mean it covers a lot. (p. 3)

Another characteristic of the Traditional Distancing approach is the perception that the instructor is the sole authority for presenting knowledge "from a level above and articulate [it] to a level below [i.e., to the students]" (Elizabeth, p. 4). According to Elizabeth, for example, the students remain at a different level, a level in which math is inaccessible. Thus, instructors of mathematics represent a certain elite with access to knowledge that the majority does not have: "I have two degrees in math and there's not a whole lot [at the] human level when you're learning this. I mean you're speaking in another language, it's like Latin," (Elizabeth, p. 5). This perception ensures the importance of the instructor in a traditional model because the instructor with a Traditional Distancing approach *must* bring mathematics down to the students' level. According to this approach, students do not have direct access to new content independently, such as through their textbooks. Thus, in order for students to study independently and access mathematical knowledge, they need the instructor's assistance, who acts as the "translator" of mathematics.

Instructors perceive students as a source of pressure for maintaining a traditional approach to teaching mathematics. Instructors claim that attempting to engage students in projects or group work when they are not well prepared or have not mastered basic concepts can produce high levels of "anxiety" in students. Therefore, instructors say, students are more comfortable with a traditional approach in which they are not threatened by the expectation of exposing their [lack of] mathematical knowledge or expected to obtain the information by themselves. As Emmet points out, "They read only the problems you give them. Not more than that. They rely on the teacher to give them the information that they're supposed to have without having to spend too much time reading, yeah" (p. 20-21).

Even though the majority of our instructors hold Traditional approaches to teaching, they do not conceive teaching mathematics as a depersonalized activity disconnected from the diversity and mathematical backgrounds of their students; our instructors do not hold exclusively a Traditional Distancing approach to teach. In fact, in our interviews, we found evidence of the Traditional Adapting approach in 11 instructors (Figure 2). Traditional Adapting refers to an approach in which the instructor, without losing the focus on ideas and knowledge transmission, adapts the structure of his or her teaching according to students' needs. Elliot, who also teaches mathematics at a nearby university, makes accommodations to his lectures to account for students' life circumstances, which may constrain the flow of the class and the content:

> So I have to kind of be a little lenient with life's issues that get in the way sometimes with this type of school. At [the university] it's very different, [the

> students] all live there. Most of them don’t work, so they don’t really have the same excuses. (p. 7)

Some instructors espousing the Traditional Adapting approach are also willing to modify their lectures according to cues from their students about understanding. For instance, Elizabeth “reads” the body language of her students in order to notice if they are confused. “I try to gauge body language, facial expression of course. It’s pretty easy to tell when they’re lost. It’s not as easy to tell when they’re not,” Elizabeth explains (p. 1-2). This suggests that when she realizes that their students are confused, she might change her pace of content transmission.

Even though descriptions of traditional approaches were prominent, we found evidence of Meaning Making approaches in the interviews of ten instructors. Instructors exhibiting a Meaning Making Clarifying approach seek to promote deeper learning and to connect mathematics to real world contexts, making clear the expectation of what must be achieved. However, these instructors do not adapt their class standards or structures according to students’ needs. Six instructors had a relevant percentage of codes in the Meaning Making Clarifying category. Elrod, who teaches statistics, represents well this category. He asserts that understanding the purpose and meaning of statistics is what matters and that students’ understanding is more important than grades on tests, because the latter focuses on computational skills:

> I’m a lot less concerned about how they do the computations even though ironically and given the institutional constraints, that’s how they’re graded based on, ‘can they compute this?’ But I know that they’ll forget that as soon as they leave the class, so what I really want them to understand is why are they doing this, and why do people who do stats run those computations, what can you do with that. (p. 4)

It is important to note that in spite of acknowledging that tests do not assess what is important, Elrod does not suggest alternative evaluations or activities, instead accepting that testing for skill in computation is an institutional constraint.

Instructors using the Meaning Making Relating Approach differ from instructors using the Meaning Making Clarifying approach in that it they are willing to adapt their class standards or structures according to their students' needs. The Meaning Making Relating approach was most evident in the interviews of Emily, Erin, and Elliot. A distinctive marker of Meaning Making Relating instructors was that they acted as guides or coaches, mediating between the students and the content. For instance Elliot uses the metaphor of a football coach to illustrate his effort to generate a classroom open to questions and mistakes. This effort pays off by the students' commitment to "push themselves" to learn math:

> As far as their performance, I basically, it's almost like a football coach. You know you just you tell them you believe in them and you know what they can do and it's just a matter of you need to study this way and make sure that your thinking caps are on and I know you're going to do well. And for some reason I get the feeling that they don't want to let me down so they tend to push themselves. (p. 3)

Meaning Making Relating instructors tend to engage students despite their perceived lack of interest in math. These instructors are willing to use different approaches and strategies in order to keep the students interested in the content. Erin sees her two-hour class as a challenge, in which she uses different activities to engage their students: "I try to, every ten to fifteen minutes, have something different happening because after about ten or fifteen minutes they're done" (p. 3). Erin believes that the students have a history of disengagement with mathematics and experienced approaches that did not work for them. She suggests that this interaction might break this students' relationship with the content: "they need to be involved, they need to talk about it, they need to struggle with it, they need to share their work" (p. 3).

Elena, one of the instructors that we identified predominantly as a Meaning Making instructor, exhibits both clarifying and relating approaches. Elena reports that generally 25% of the time in her classes is allocated to hand-on activities where students work in groups or pairs with playing cards, fraction pieces, dice, or other materials. Although Elena uses Meaning Making (or constructivist) approaches in teaching, she has to "fight" students' resistance to engage in participatory activities because students "want to be told" (p. 2). This resistance is augmented when a large proportion of students in her college level class come from a remedial class. Elena asserts that in remedial classes students are "being spoon fed" through a "lock step" system and that her task is to convince them that they can do the work (p. 4).

Unlike Traditional and Meaning Making approaches, Students Support approaches do not place students' mastering or understanding the content as the main goal of instruction. Rather, Student Support Relating approaches focus on improving students' self-confidence and in developing relationships among students, and between the students and the instructor. In the Student Support Relating category, the importance of "covering the content" is reduced. It is more important to respond to the students' needs, which usually extend beyond understanding the content. Instructors who were teaching a remedial mathematics course (Erik, Erin, Elena, and Elizabeth) each exhibit some features of this category. Erik, the instructor who best demonstrates this approach, asserts,

> All they need, they don't really have motivation problems, they have confidence problems. And that's when you kind of turn into a counselor more than an instructor… My goal for my students, my primary goal, is to dispel the fear that they have of math (Erik, pp. 3-5).

As noticed by Grubb and associates (1999), instructors using this approach tend to use their personal experience to build a better relationship with their students. Erik indicates: “if my experience coincides with my students’ experience then I’ll use it in class… my students come in with the same kind of fears I came with” (Erik, p. 1). Instructors exhibiting this approach also show high levels of commitment to teaching: “I get calls from my students at 2:00 in the morning. You know, I work with them all the time and I’m just patient with them. I let them learn” (Erik, p. 5).

It is interesting to note that instructors might adapt or modify their approaches about mathematics instruction depending on the class level. For example, when Elizabeth—who displays a strong tendency towards Traditional Distancing approach—talks about her remedial courses, she shifts abruptly her descriptions towards a vision related to the Student Support Relating approach:

> [Here] the math isn’t the problem. In this class you can tell them, ‘oh go see a tutor or meet me in my office,’ and mostly we can clear up most of the problems in class, I mean any questions or problems they have I’m happy to talk about with them in class. I tell them I don’t want to move to the next thing until you’re ready, but you have to tell me when you’re ready. (p. 9)

Similar to the Student Support Relating instructors, Student Support Clarifying instructors attend to students’ self-confidence more than to learning mathematical knowledge, but they see structure and clear rules rather than personal relationships as the best way to improve self-confidence and address students’ needs. According to our framework, Edward is the only instructor who falls into this approach (Figure 2). Edward is cognizant of the students’ fear (Cox, 2009) and is willing to change that attitude. His strategy is to clarify standards and set expectations early. Edward stresses the importance of “being direct and up front with students about expectations” (p. 7). He sees patience and hard work as the key for students’ success.

In summary, the analysis of instructors’ interviews confirms Grubb and associates’ (1999) findings. First, we identified the three general approaches to teaching: Traditional, Meaning Making, and Student Support, with Traditional being the most commonly described by our participants (see Figure 3). Four instructors were identified as holding mostly Traditional approaches (less than 10% of any of the other categories identified in each interviews), three holding a combination of Traditional and Meaning Making approaches, three holding Meaning Making and Student Support approaches, and four holding all of the approaches. Finally, no instructor was classified as exhibiting only Meaning Making or only Student Support approaches to teaching, which might be a consequence of the content in which the study has been focused. Second, with our six-category framework we were able to illustrate that within each of these general approaches, instructors exhibit distancing, adapting, clarifying, or relating approaches that seem to be strongly defined by external constraints given by this particular setting. Third, and perhaps the most important finding, is that most instructors were classified as using more than one approach with four classified as mostly traditional, and only three not using much of the traditional approaches. Thus, we found that most of the instructors declare that teaching mathematics at a community college requires flexibility in teaching and being aware of students’ needs that are beyond learning mathematics. In addition, it appears that instructors describe different approaches when teaching remedial courses, in general exhibiting more student-centered approaches, mainly Student Support, when teaching these courses. According to Grubb and Cox (2005) this positive attitude might be useful in addressing the needs of remedial students.

---Insert Figure 3 about here---

Approaches to Teaching Exhibited in Framing Talk in the Classroom

The framing talk strategies used most frequently were: following the book (used by 12 instructors), connection with real context (9 instructors), knowing names (7 instructors), setting expectations (7 instructors), and assigning students individual work (7 instructors). Although following the book was the only one of the most frequently followed strategy categorized as a Traditional strategy, Traditional strategies were by far the most frequently used by our sample of instructors (see Figure 4). We coded a total of 389 strategies, 174 (45%) of which were Traditional, 112 (29%) Meaning Making, and 103 (26%) Student Support.

---Insert Figure 4 about here---

Figure 5 presents the frequency of framing talk strategies by the three main categories of teaching approach for each instructor; the figure reports the relative contribution of each approach in increments of 20 percent. For instance, 60 percent of Emmet's framing talk was classified as Traditional, 26 percent was classified as Meaning Making, and 14 percent was classified as Student Support. Traditional strategies accounted for 45 percent of the total strategies, all used by nine instructors in the coded lessons. Meaning Making and Student Support strategies accounted for more than 40% of strategies for only two instructors.

--- Insert Figure 5 about here ---

In addition, the frequency and use of different strategies varied substantially among instructors. For instance, Elliot used six different strategies fourteen times in total, all of them Traditional, whereas Elena used 16 different strategies 64 times in total (both classes were X min long).

Mathematics Questions in the Classroom

Our third analysis examined classroom interactions, specifically student and teacher questions that were directly related to mathematical content. We analyzed the complexity of the questions asked during class. Recall that we defined instructors' novel questions as those questions that open opportunities for students to explore the content and seek to make connections to other contexts or previous knowledge that is not the focus of the lesson. Table 6 presents the frequency of questions asked and the proportion of novel questions asked per class. The proportions were weighted to reflect the different lengths of the classes observed, which ranged from 85 to 115 minutes. We used a common length of 85 minutes per class to facilitate the comparison. The large number of mathematical questions that instructors asked in these classes is noteworthy: on average instructors asked 97 questions per 85-minute period, with only three instructors asking less than half of those per class. Thus, an average instructor asks more than one mathematical question per minute. At the same time we found that on average students asked 17 mathematical questions per class. These facts suggest three trends. First, questioning is a popular strategy that instructors use to engage students in class; second, these exchanges must be quick, given that on average a mathematical question is asked every minute; and third, it is teachers, not students who initiate all these exchanges. Thus, the quantity of mathematical questions asked, the pace, and the origin of the questions are mostly consistent with a Traditional approach, in which the instructor holds the knowledge and is the main authority in managing the interaction.

--- Insert Table 6 here ---

There was a wide variation in the frequency of mathematical questions among instructors (standard deviation = 45.31), which suggests, unsurprisingly, that interaction through mathematical questioning is managed differently by each instructor. There were only two cases (Edwina and Earl) where instructors used between more than one-third and two-thirds of class time in activities that did not involve lecturing; but in the segments in which whole class interactions were conducted, the frequency was similar to other instructors. The most noticeable finding is the small percentage of novel questions asked per class. Across all instructors, only 20% of the mathematical questions were classified as novel. For seven instructors less than 20% of mathematical questions were novel. Only Elrod, who teaches statistics, asked more than 40% novel questions in his lesson. It is interesting to note that Erik, who asked the second highest number of mathematical questions per class (163), asked the smallest proportion of novel questions.

Although the percentage of students' novel questions (see Table 6) seems high, these questions account for very few mathematical questions asked per class. In only five classes (Ernest, Elliot, Elrod, Edward, and Earl) did students ask more than 5 novel questions, with students in Elrod's class asking the most, 12.

Table 7 presents two shorts excerpts extracted from Elrod's and Erin's classroom transcripts. These excerpts show the contexts in which questions are asked and the codes that we assigned to each of these questions. Elrod's excerpts is dealing with shapes of distributions and includes several novel questions that generate interaction with the students and prompts some students' questions. His first question, "Which way is it skewed?" leads students to apply the concept of population distribution to a particular case (population income), which has not been discussed in the class before. This question is not answered, in spite of Elrod's four seconds pause, which leads him to answer "to the right" to note the bias of the distribution. Later on, Elrod asks, "how do you explain this one?" referring to another extreme in the distribution; this is an open question that seeks students' explanation of the problem. A female student mentions the notion that outliers can be dismissed through a routine question (asking for confirmation), to which Elrod counters: they are typical for the income distribution. The student then reacts by bringing in knowledge from a previous lesson about standardization, seeking clarification regarding the nature of outliers. Elrod notices the opportunity produced by the student's question: "I am glad that you brought this question" and instead of giving up on the original question, (how do you explain the behavior of the distribution?) and in spite of the student's press for a definite answer (like you said earlier, right?), he asks: "What is unique to this distribution that it allows extremes, extreme outliers?" Thus bringing in another novel question and sustaining the complexity of the interaction.

Using more basic mathematics content, Erin's excerpt from an arithmetic class also contains some novel questions. In this excerpt, Erin discusses a problem that requires operations with mixed numbers. After a student responds with an answer that might be perceived as imprecise, Erin asks, "What do you mean you added everything?" This novel question is taken as indicating Erin's interest in making the student elaborate on the answer. Erin is not directly asking about a specific procedure; she is asking about the meaning of the student's statement. After the student responds, Erin asks a novel question to the entire class, "What do you think about his process?," looking for students' opinions. Erin, without waiting, asks a new novel question, seeking the meaning of a mathematical statement, but again she does not give students' an opportunity to answer, and instead she asks a routine question. These segments provide an illustration of the way in which we saw instructors using novel questions in different mathematics subjects with remedial and non-remedial courses and illustrate the different ways in which students react to novel questions.

--- Insert Table 7 here ---

Discussion

In this section, we contrast the results of these three analyses and propose that instructors' described approaches to teaching are well linked to the framing talk that we observed in the classrooms, but that there is a less clear pattern when we include the complexity of questions that are directly related to the mathematical content.

Our study uses a triad of analysis to describe instructors' approaches to teaching mathematics in community colleges. Our first research question asks about how teaching approaches manifest in mathematics instruction. Instructors' espoused approaches were drawn from interviews and classroom interactions were studied looking at both the framing talk and the complexity of questions. Overall, across our three analyses we obtain a consistent portrait of instruction characterized by an emphasis on traditional approaches, which is seen when instructors talked about and reflected on their teaching, enacted various strategies and activities in the classroom, and interacted with students and the mathematical content through questions. However, a more detailed analysis reveals a variety of approaches. Instructors seem to understand the constraints associated to teaching mathematics in a community college and adapt their instruction to fit their context. This adaptation has been found in other studies about teachers' belief and belief enactment in mathematics education (Skott, 2009). Some instructors are willing to bring student-centered instruction into their classrooms while others are decidedly committed to support students beyond the learning of mathematics.

Comparing our different analyses, we found that instructors' described teaching approaches follow a similar pattern as the strategies they used during framing talk in the classroom, but that these approaches do not parallel the observed use of novel questions. In other words, instructors' approaches are related to some aspects of classroom pedagogy, but these are seemingly unrelated to the use and enactment of mathematical content during instruction.

Our second research question asks whether mostly student-centered approaches (Meaning Making and Student Support) create opportunities for students to also learn more cognitively demanding mathematics. We found no pattern confirming that student-centered approaches offer more novel questions than a more content-centered approach (Traditional). Table 8 shows a summary of our three different analyses. The "From interviews" and "From Classroom Observation"/ "Framing Talk" columns of the table illustrate a similar pattern: instructors towards the top exhibit a Traditional approach to teaching while instructors towards the bottom exhibit strategies associated with a Meaning Making or Student Support approach. In contrast, the last two columns, which refer to the complexity of mathematical questions, do not follow the same pattern. We expected to find higher percentage of novel question for student-centered instructors than for content-centered. Thus, the percentage of novel questions does not necessarily align in the same way with the instructors' description of their approaches to teaching or to their enactment of those strategies in the classroom. There are some notable exceptions. For instance, Ernest holds a Traditional approach, but about 50% of his framing talk is other than Traditional. It appears that Student Support instructors ask a smaller proportion (and number) of novel questions than instructors in the other groups.

--- Insert Table 8 here ---

We believe that the way in which instruction is conceptualized in this setting, in terms of the how mathematical content, instructors, students, and the institutional environment are perceived, plays a significant role in accounting for these findings, including the close alignment between what instructors say in interviews and their framing talk, and the less clear alignment between questioning practices and their approaches to teaching.

Mathematical Content

In interviews, instructors pointed out that some units are rigid (i.e., there is only one way to solve or model certain problems) or too basic (i.e., most meaningful mathematics is seen in higher courses such as calculus), and these units are perceived as reducing the opportunities to ask questions that invite students to explore the knowledge or connect it to other mathematical notions or to real world situations. Although it is true that the amount of content that needs to be covered in these courses is substantial and this may limit the time that instructors have for dealing with novel questions in the classroom, whether the content is basic or advanced, does not limit the instructor's opportunities to ask novel questions (as we have seen in Erin's case, who was teaching a foundations course in arithmetic). It might be the case, however that some mathematical subjects are more suitable for pursuing meaning making approaches. In the case of Elrod, the high frequency of novel questions that he asked could be a consequence of teaching a statistics class; it is possible that statistics offers more ways to ask novel questions than the more basic or calculus oriented classes because of its direct or intuitive connection to real situations. Our sample does not allow us to study the role that different levels of mathematics have on the possibilities for asking novel questions. However, we doubt that level of content might be what determines the small percentage of novel questions that were asked here based on two pieces of evidence. First, the literature in K-12 mathematics suggests also that novel questions can be asked with any type of mathematical content, at any age or level of expertise (Cobb & Merkel, 1989; Doyle, 1988; Schoenfeld, 1989; Silver, Mesa, Morris, Star, & Benken, 2009; Stein, Grover, & Henningsen, 1996). Second, our initial analysis of calculus classes in this college suggests that it might not be a matter of mathematical content but of teachers' experience asking these questions. We turn to the instructors' issue now.

Instructors

Although it seems possible that the large amount of material that needs to be covered and the different types of courses (remedial or non-remedial) might present challenges and limit opportunities for instructors to ask novel questions, it might also be possible that instructors' mathematical knowledge influences their capacity to ask more novel questions (Ball, Lubienski, & Mewborn, 2001; Ball, Thames, & Phelps, 2008; Ball & Wilson, 1990). We found some evidence (although this line of analysis was not pursued in this particular study) of two instructors explaining the same content but attaining different results. One instructor was able to give many different examples illustrating a situation of subtracting improper fractions with unlike denominators in reaction to the confusion students exhibited with the procedure; she connected it to a real-world context (money conversions) and asked several novel questions to students in the process. The other instructor, facing exactly the same issue, kept repeating the same routine questions, did not bring in alternative representations, and did not connect the content to a more concrete situation (such as money). Both instructors hold more student-centered approaches (Meaning Making and Student Support approaches), but they exhibit different level of comfort with the knowledge needed for helping students understand mathematical ideas. Because our study did not explore instructors' mathematical knowledge, we see this as a possible avenue for further investigation. Our current work on instructors' explanations of composition of functions and its relation to inverse functions, suggests that instructors' knowledge of mathematics for teaching might be an important mediator in this process.

Students

These adaptations towards student-centered approaches in the classroom might result in a reduction of the complexity as instructors see students as unprepared to engage, and to interact, with the content. In our interviews, instructors mentioned that students come from a "spoon-feed" tradition, that they have no time to work on their homework after work because they are tired, that they are not willing to participate more actively, and that they feel unsecure when asked to work with interactive strategies. These instructors' perceptions of students as "needing" assistance will push instructors towards helping students make meaning out of the work and support them as they engage in course work, but at the expense of reducing the complexity of the interactions. In the interest of demonstrating that students can answer mathematics questions, and therefore that they can engage in learning, instructors may ask questions that they think their students will be able to answer, therefore, using questions that are usually based on ideas that students have already seen or that they are more familiar with. In this scenario, the complexity of the mathematical activity is never presented as something that can be at the reach of the students.

Institutional Environment

Although instructors mentioned that the institution offers resources that are beneficial for their teaching, they also pointed out some institutional constraints that affect it. For instance, most of our participants mentioned that the content to be covered is so vast that they have to deliver it quickly to have the peace of mind that they have, at least, given students an opportunity to see it. It seems that lecturing is indeed the most suitable strategy to accomplish this; it fulfills the teaching and learning contract—the material is presented, the students are exposed to it, and students are assessed through tests that was presented during class (Brousseau, 1997). This pace might reduce the opportunities to ask novel questions, which can be perceived as requiring long discussions that will take up time needed to cover the content. Another factor outside of instructors' control is student placement. Elliot and Elrod mentioned that the uneven placement of students into courses influences how they teach; when ill-prepared students are placed in advanced classes instructors feel that they have to either adapt their courses to address students' under preparation (which is usually not an option because of the pace constraints) or avoid dealing with students' misunderstanding in order to keep the pace. It appears to us, that the institutional environment rewards the latter option. Further studies are needed to understand how institutional policies influence the ways in which instructors perceive suggestions as feasible for reforming the way they interact with students with mathematical questions.

Why do these constraints seem to have more effect on the enacting of approaches in classroom interactions relating to the content than those interactions that do not? According to our analysis, framing talk strategies are consistent with instructors' espoused approaches. We suggest that when intending to enhance student-centered approaches, the mathematical knowledge represents a special challenge. Promoting a student-centered approach in mathematics requires incorporating specific strategies with specific disciplinary knowledge and the particular institutional characteristics. Our work suggests that the analyses of approaches to teaching must consider the quality of the content at stake because surface behaviors not related to content might provide a false impression that a student-centered approach is per se beneficial for students' learning and success.

In other words, what instructors say and what they do is consistent at a level that does not attend to the mathematical content. This does not mean that non-mathematical interactions have no effect on students learning mathematics. Certainly, this interaction has an effect, and further research is necessary to understand its impact, but we point out that leaving out the nature of the content might be detrimental as well.

Conclusion

We have illustrated that instruction, defined as the interaction between teachers, students, and the content, within specific environments, is a powerful conceptualization that allows us to investigate this phenomenon in a very particular setting and a very specific discipline. Our study makes a contribution by combining previous frameworks and providing more detailed lenses to analyze interactions in mathematics classrooms and the connection between these interactions and instructors' declared approaches in the particular context of the community college. We believe that this particular setting presents important challenges that are unique, therefore creating a rich space for theory testing.

An important conclusion of this work is the need to look at instruction in the content areas and within specific environments so that we can understand the complexity of teaching and can devise context- and content-sensitive strategies that can assist faculty in creating classrooms that involve students and that allow instructors be aware of students' learning. Our findings also suggest that categorizations of teaching approaches need to be augmented with classroom data that attends to the classroom interactions so that they can become a useful instrument for informing and influencing teaching practice in higher education.

An important area of investigation deals with establishing connections between espoused teaching approaches, and classroom data and students' learning. In this paper we have only hinted at the opportunities to learn that the questioning practices may create, and found that using student-centered approaches does not necessarily imply more use of novel questions. A very important question is the nature of students' actual learning and understanding when experiencing particular teaching approaches. We speculate that such a study will require going beyond using grades in courses or surveys on generic content, and instead engage in analyses of students' classroom contributions and interviews with students while solving mathematical tasks. A recent study by James Stigler and colleagues (Stigler, Givvin, & Thompson, 2010b) strongly suggests that performance on tests or behaviors in classroom suggesting proficiency might be underestimating students' actual learning.

Another area that merits further research is the knowledge that instructors need to teach that is not merely disciplinary. Faculty teaching in higher education institutions have, for the most part, a solid preparation in the disciplines. Yet it is unclear if this knowledge is sufficient for teaching. Knowledge of curriculum and of pedagogy are also key, but as Ball and colleagues have illustrated (Ball, et al., 2001; Ball, et al., 2008), this knowledge might be insufficient. An important venue for further investigation is what knowledge, beyond content, pedagogy, and curriculum, is needed when teaching particular subjects. For example, there are models and representations that are useful for instructors to know and use as they teach (e.g., drawings of chemical reactions, the flow of current in circuits, the relationship between fractions, percents, and decimals, the definition of inverse functions, etc.). Yet these are not models and representations that come from generic descriptions of content or curriculum and pedagogy. Their appropriate use requires a specialized form of knowledge that has not been sufficiently described in post-secondary education and that will continue to delay the creation of environments in which student learning is central to the activity of teaching.

One intriguing finding that merits further research is the different approaches that instructors appeared to use when they were teaching students in remedial courses as compared to the approaches they described and enacted in teaching students in non-remedial courses. It appears to us that instructors teaching remedial courses in this college tended to describe and enact approaches consistent with student support. This suggests a welcoming attitude towards under-prepared students, something that has been highlighted as a necessary element that contributes to classroom success in remedial education (Grubb & Cox, 2005). At the same time, the trend of using routine questions in these classrooms is worrisome, as such practice will likely hinder students' opportunities to experience challenging mathematics.

Consequently, our findings have implications for faculty development. For example, besides suggesting that more interaction needs to occur, or that novel questions are important to promote learning, instructors need to understand the process of creating novel questions in their disciplines and to understand the impact of using them in their classroom with their students. Some important examples come from the use of technologies such as clickers (Caldwell, 2007; Crossgrove & Curran, 2008; Martyn, 2007) that are prominent in physics or from using inquiry-based learning in teaching mathematics (Laursen & Hassi, 2009, 2010; Laursen, Hassi, Crane, & Hunter, 2010). As with other suggestions, what matters is the attention to the discipline and to how the interaction in the classroom occurs when using these strategies.

Notes

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Tables and Figures

Table 1

Characteristics of Instructors in the Study.

Name	Teaching Experience (years)	Degree	Year Observed	Course Observed
Earl	13	MA, Math Ed, Psychology	2	College Algebra (2)
Edward	3	BS, Math	2	Trigonometry
Edwina		BS, Math Ed	2	Trigonometry
Elena	20	MA, Math Ed	1	College Math, Found Math
Elijah	7	BS, Engineering	1	Intermediate Algebra, Math analysis
Elizabeth	7	MA, Math	2	Pre-calc(2), Trig.
Elliot	6	BS, Economics	2	Trigonometry
Elrod	2	PhD, Ed. Psych	1	Statistics
Emily	2	BS, Math	1	Arithmetic
Emmet	16	PhD, Physics	1, 2	Algebra, Trigonometry (3).
Erik	2	BA, Math Ed	1	Arithmetic, Beginning Algebra
Erin	19	MA, Math Ed	1	Arithmetic, Intermediate Algebra
Ernest	21	BS, Math Ed	2	Trigonometry
Evan	8	BS, Physics, Math	2	Trigonometry

Note: Shaded entries correspond to part-time instructors. Names are pseudonyms.

Table 2: *Teaching Approaches Framework*

	Framework Categories	Definition of Categories	Framing Talk in the Classroom
Content centered approaches	Traditional (Distancing and Adapting)	Instructors using this approach privilege knowledge transmission and covering the content that has been structured to fit in a certain period of time. • When using *Distancing* approaches they do not take into account students' needs or their different learning approaches for organizing their lessons. • When using *Adapting* approaches instructors take into account students' needs related to the content, adapting strategies and class structure as needed	Access to online resources, assigning homework, controlling time, covering the material, doing it on a particular way, inflexibility with content coverage, giving extra credit, making explicit credential-skill-knowledge, following the book, reference to higher courses, talking about examinations, using calculator, setting expectations, and using humor[a].
Student centered approaches	Meaning Making (Clarifying and Relating)	Instructors using this approach act as learning facilitators and encourage students' participation. • When using *Clarifying* they place emphasis on facilitating students' learning making expectations and demands from students explicit, but they do not modify the class structure to accommodate students' needs. • When using *Relating* approaches, they take into account students' needs, developing relationships among students and between students and the instructor.	Making connections to real world contexts, checking conversations, flexibility with content coverage, reading non verbal clues, receiving formal feedback, acknowledging self-limitations, assigning individual work during class, sending students to the blackboard, and making suggestions about how to work.
	Student Support (Clarifying and Relating)	Instructors using this approach encourage students and boost their self-confidence. They place less emphasis on learning the content. • When using *Clarifying* approaches, instructors direct students to use resources available for them in the institution without adapting the pre-established structures of their classes to fit students' needs. • When using *Relating* approaches, instructors take into account students' needs, developing relationships among students and between students and the instructor.	Being available, showing empathy for students' life circumstances, being flexible with requirements, maintaining informal conversations with the students, knowing students' names, praising students, using humor[a], and using personal stories.

Notes: a. "Using humor" was classified into either Traditional or Student Support according to the content. If using humor was used as a strategy to produce a short break in the lecture or if it had some reference to the content, it was classified as Traditional. On the other hand, if using humor was used to create a more personal or close relationship with the students, it was classified as Student Support.

Table 3

Coding System for Complexity of Questions in Classroom Transcripts

Teacher Questions
Routine: Students are expected to know the answer to or know how to procedurally figure out the answer (from previous classes or courses).
• T: If I'm talking about negative pi over 2, which direction am I going first of all?
• T: And then 135 in terms of radians?
• T: If I had this function, how long is the period?
Novel: The information required for students to figure out the answer can be expected to be known (because of what has been done in the prior lesson or during the lesson), but the answer or how to use the procedure is not known. These questions often require an explanation that makes connections between known information. Novel questions included also those that required students to figure out the answer with information that has not been discussed in the class. This category includes open-ended questions seeking students' opinions.
• T: If you look at a picture here, what kind of symmetry would you say the sine wave has?
• T: What about cosine? How would cosine compare?
• T: Why is it sometimes that if the light is getting old that you're able to see it flicker?
• T: Now why doesn't the dishwasher vibrate or why don't we see those vibrations?
• T: What do you think?
Student Questions
Routine: Questions that look for a direct answer. There is no evidence of conflict regarding understanding.
• F: It needs to be in radians right? not in degree mode?
• F: So are the *x* intercepts now at pi?
Novel: These questions are about the 'how' and 'why' of a mathematical process. Student inquires about the nature of mathematics or about connections beyond mathematics.
• M: So does the L cancel?
• M: Why do you write one over root 2 instead of root 2 over 2?
• F: Now I just did it because a-squared plus b-squared equals c-squared. Is that how you do it?
• F: Why is 8 divided by 0 undefined?
• M: Doesn't shifting affect whether it would be sine or cosine?
• M: Would it be the same thing if you did just one pi?

Table 4

Coding Examples for each Teaching Approach Category

Framework Categories	Coding Examples
Traditional Distancing	*Covering the material fast*. Because this is content heavy class so I don't want to get bogged down by, I need to be able to move quickly in this class and so I need to make sure that they have everything. So this way I know that they've gotten it all, you know what I mean, because it's fast. I mean this is one of those classes you go fast, you do the whole book and it has a very broad spectrum. I mean everything from beginning algebra through trig, problem solving, conics, I mean it covers a lot. (Elizabeth, p. 3)
Traditional Adapting	*Reading the body language*. I also use, I mean I try to gauge body language, facial expression of course. It's pretty easy to tell when they're lost. It's not as easy to tell when they're not. I mean if they're understanding, sometimes it's hard to tell that yeah they get it, they get it, but when they're really stumped it shows on their faces. And that's a universal I know it's me, right? (Elizabeth, p. 1-2)
Meaning Making Clarifying	*Discussing and Guiding.* Writing assignments, yeah, I mean to a degree. I, on my projects I often ask them to you know basically after they've done some number crunching to write for me what their, what their outcome was, what they found, like on that survivor project they had to write, I gave them about yeah many lines and told them to write it out, tell me, not just in a sentence but clarify it for someone who you know is going to be reading this, whether or not these people are going to survive, why or why not. (Erik, p. 4)
Meaning Making Relating	*The coaching role.* To motivate them to learn or to come or I mean there's different motivation. I try and make it so that they want to come. I try and acknowledge reasons why they wouldn't and that I understand why you wouldn't want to do this or participate in this or come to this or whatever, but I believe, I kind of put myself, not so much an authority role as like a coaching role. (Elizabeth, p. 2)
Student Support Clarifying	*Resourcing.* We have a math resource center that has a least twenty or thirty computers in it for the students. We have at least two other labs. We have two different places where students can go to get free tutoring, which is just amazing. […] I have a lot of single mothers in my classes and you know we have a day care facility on campus. You know and so we have a lot of people that want to see them succeed and to take someone and show them that

Framework Categories	Coding Examples
	they don't have to be stuck in this dead end retail job, that they wanted to be a nurse when they were twelve or fourteen and they can still do that, that their decisions affected their lives but they weren't, they didn't permanently doom them. (Erik, p. 6-7)
Student Support Relating	*The math isn't the problem*. [For remedial students,] the math isn't the problem. In this class you can tell them, "oh go see a tutor or meet me in my office," and mostly we can clear up most of the problems in class, I mean any questions or problems they have I'm happy to talk about with them in class. I tell them I don't want to move to the next thing until you're ready, but you have to tell me when you're ready. (Elizabeth, p.2)

Table 5

Examples of Coding of Framing Talk Strategies

Code	Emmet Class Observation 1
Talking about examination, Following the book	T: Right now, **if anybody takes the [departmental] exam right now you should be able to do 13 out of 15 questions.** You cannot do two questions because **they're from chapter 8, we haven't got to chapter 8.**
	M: What's chapter eight?
Talking about examination	T: Chapter eight is (inaudible). But once we start eight next week **you should be able to do the entire [departmental] exam**. If you want to take it ahead before Nov 15th, let me know. Everyone who has taken it so far you tell me.
	F: (inaudible)
	T: Sorry.
	F: Do we get the results back?
	T: Yes. And students finish earlier. That's because the review is supposed to be on Tuesday and they have similar questions. Those tests will have some questions that are just like the LEE exam.
	M: This is November 15th, right?
	T: November 15th, yeah.
	F: That's why the next test you're going to give us was very, very easy, right, it had a lot of problems?
	T: You did not like the last one?
	F: No.
	T: (laugh)
	(several talking)
	T: Yeah we'll be able to get...
	F: You don't want us to do bad.
Informal Conversation	T: No. (inaudible) Thanks. (11 seconds) I don't have chalk. So I requested this one in particular.
	M: Did you look on the back to see where it's made?
	T: Yeah made in France.
	M: (inaudible)
	T: No I'm not being...
	M: Particular.
	T: Particular, but this is not (inaudible). This chalk here I can't use. It breaks fast, it breaks too fast and...
	M: I thought that was the French chalk.
	T: No, no this one is. This is the one I have and I've been saving it, it's tiny, this is how

	much I have left.
Assigning homework	T: Ok. Good so we have two more (inaudible). Ok. There are a lot of applications in this section. We’re not going to be able to do all of them. **I’ll leave the rest of them for you to do.** And if you have any questions you can ask. Now we’re going to start the next thing and then take a little break. Next section that we’re doing is proportions. The section on inequalities we’ll do it last. That’s the section that’s not on the test, it’s going to be on quizzes and homework. Section four is going to be on everything. And section four (inaudible).
	F: That’s our midterm then, I mean as our final, section four? It’s going to be on everything?
Talking about examination Following the book Connection with real context	T: **No not the final. Just the next test**. On the final you’d have the new stuff from chapters ten and nine and part of six. Ok. We mostly define proportion and let’s take a little break and after the break we’ll do some exercises on proportion and do some more work on proportions. (writes on board 8 seconds) There are (writes on board 4 seconds) (writes on board) direct proportions and inverse proportions. We’ll start with direct proportions (writes on board 13 seconds) **This section does not give you, shouldn’t give you that much trouble.** It doesn’t involved drawing any graphs, doesn’t involved finding any slopes, just solving equations. And you’ve done a lot of that. So direct proportion, if you have two quantities y and x, the definition of direct proportion is this, y varies directly as x if the next line is true, if $y = k$ times x. I’ll explain to you what this means, where k is a constant, it’s a number. (writes on board 8 seconds) It means y is related to x by this equation here: y = k times x. k is just a number. y and x are both variables and they can represent anything. (pause 10 seconds) I’ll give an example of a direct proportion. For example (pause 4 seconds) **let *x* be the amount of taxable income**. (writes on board 6 seconds) Ok, and y is tax (writes on board 4 seconds) to the state of Michigan. (writes on board 6 seconds) Ok. Is the tax owed proportional to the taxable income? Before you answer this question, before you decide whether it’s a direct proportion or not, this is a way to think about this. If one quantity increase, if x increases, does y increase? The answer is yes. The answer is yes then that’s a direct proportion, it’s a simple as that. Now let’s say somebody has $50,000 of taxable income, the amount of tax, income tax that they will pay to the state of Michigan will be a certain amount, if they make $100,000 would they pay more or less?
	M: More.
	T: More.
	M: More money

Table 6

Frequency and percent of instructors and students' novel questions per class period

Instructor	Total Instructor Questions per class period[a]	Novel Questions by Teachers[b]	Total Students Questions per class period[a]	Novel Questions by Students[b]
Evan	46	26%	4	45%
Ernest	99	27%	25	38%
Emmet	44	33%	8	43%
Elijah	90	12%	18	9%
Elliot	89	16%	39	16%
Edwina	17	12%	6	26%
Elrod	109	43%	36	33%
Elizabeth	73	35%	8	25%
Edward	85	28%	14	54%
Earl	123	21%	13	50%
Emily	92	14%	28	4%
Elena	176	16%	27	0%
Erin	148	18%	4	0%
Erik	163	3%	10	17%

Notes: a) A class period is 85 minutes long. b) Because some instructors were observed more than once the percentages of questions was obtained by averaging the number of questions over all lessons observed.

Table 7

Examples of Novel and Routine Questions by Instructors and Students

Question Code	Elrod, Statistics
Instructor Novel	**T:** Or (inaudible) anywhere almost. Ok, I'm talking population distributions. Say the population of age is not, it is normal distribution. In a population income is not a normal distribution. Which way is it skewed? (pause 4 seconds) To the right.
	M: There are a bunch of people here and a lot...
Instructor Routine	**T:** Right. It looks as we have a mean of what? National average income, 30-35, who knows. If I put Bill Gates on the distribution, he will fall past Clark Road.
	(laughter)
Instructor Novel	**T:** And he's probably not even the richest guy, officially he's just (inaudible). So I said everything in nature's always like this, how do you explain this one? (pause 4 seconds)
Student Routine	**F:** An outlier that you normally don't account for, right?
	T: Well outliers are actually quite typical in income distribution.
Student Novel	**F:** But when you standardize this, when you do that and you're only concerned with the three standard deviations from the mean, that would be one of the far outliers?
	T: I'm glad you brought up that question. Standardization doesn't change where all these stand. You standardize the distribution. This score is going to be pretty high.
Student Routine	**F:** Right, but what I'm saying is most of the data would be centered around the mean within three standard deviations and that percentage, that variable would be, like you said earlier really minute, right?
Instructor Novel Instructor Novel	**T:** But my question is why do we have some crazy outliers in this distribution and not in most others? (pause 6 seconds) What's unique to this distribution that it allows extremes, extreme outliers? (pause 8 seconds)
	Erin, Arithmetic
Instructor Routine	T: […] If I take 1 1/3 + 2 1/3 I have 1 1/3 cups sugar + 2 1/3 cup sugar, when I'm combining two different recipes, what do I have total?
	Several: 3 2/3.
Instructor Routine	T: 3 2/3. Tell me how you got 3 2/3? What did you do to get 3 2/3? T, what did you do?
	M: Added everything.
Instructor Novel	T: Ok, what do you mean you added everything?
	M: The 2 and the 1, the 1 and the 2 I added that and I had 3 wholes. Then the 1/3 I added both those together, they had the same denominator, add the 2.
	(writes on board (6 seconds))
Instructor Novel Instructor Novel Instructor Routine	T: What do you think about his process? He went through and looked for completely filled in pies and there were three of them and then he went through and looked at the parts and identified that they were cut in the same size pieces, so he could just say ah ha I've got two parts out of pies cut in thirds, does that make sense? So if you use that strategy, number two, the second one has a shading typo, what's the shading typo? (writes on board (5 seconds))

Instructor Routine	M: ¾. T: Yes. The 1 ¾ is only showing a shading of 1 ¼, so go ahead and fix that shading. on board (10 seconds)). Let's use that strategy again. Let's use T's strategy and tell me what kind of things you come up with. Start with the whole parts. <u>How many whole parts do you have?</u> Several: 3.

Table 8

Teaching Approaches and Complexity of Mathematical Questions

	From Interviews[a]			From Clasroom Observations[b]				
				Framing Talk			Mathematical	
Instructor	Traditional	Meaning Making	Student Support	Traditional	Meaning Making	Student Support	Total Instructor Questions per class period	Instructor Novel Questions
Evan	X			◕	○	○	46	◔
Emmet	X			◕	◔	○	44	◔
Ernest	X			◑	◔	◔	99	◔
Elijah	X			◕	○	◔	90	○
Edwina	X	X					17	○
Elliot	X	X		●	○	○	89	○
Elrod	X	X		◕	◔	○	109	◑
Earl	X	X	X	◕	◔	○	123	◔
Edward	X	X	X	◑	◔	○	85	◔
Elizabeth	X	X	X	◑	◑	○	73	◔
Emily	X	X	X	○	◔	◑	92	○
Elena		X	X	◑	◔	◔	176	○
Erin		X	X	◔	◑	◔	148	○
Erik		X	X	◔	◔	◑	163	○

Notes: a. Each X represents that more than 10% of the codes in the interview belongs to that category. Thus, in order to be labeled as Traditional only, instructors needed to have less than 10% of codes in each of the other two categories. The 10% threshold is meant to acknowledge that instructors in general tend to follow more than one approach as they teach and to avoid simplistic labeling of their approaches. b. Circles represent percentages of codes for framing talk strategies by teaching approach and percentages of novel questions, using the following convention:

○ 0-19% ◔ 20-39% ◑ 40-59% ◕ 60-79% ● 80-100%

Figure 1. *Instruction as interaction* (Adapted from Cohen, Raudenbush, & Ball, 2003)

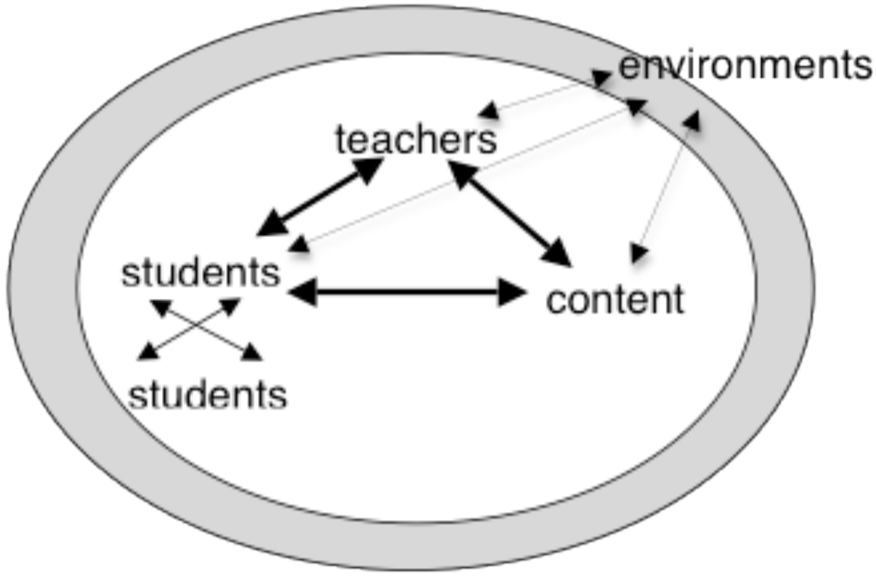
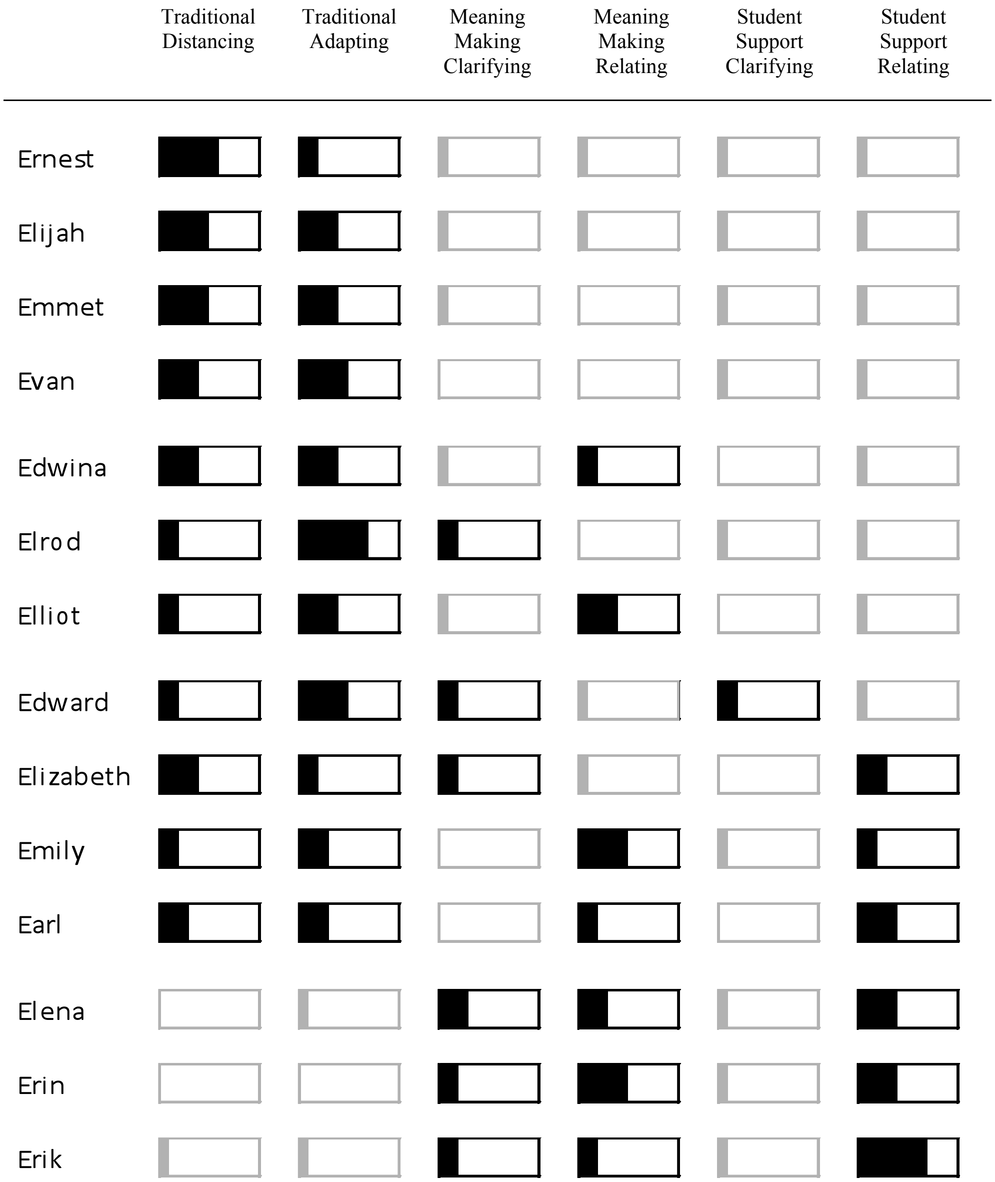


Figure 2: *Percentage of codes for teaching approaches described by instructor*



Note: For any given instructor, the shaded area in each block represents the percentage of codes by tenths in a particular teaching approach category out of the total of the instructor's codes. Blocks that represent less than 10% appear grayed.

Figure 3. *Classification of instructors by three main approaches to teaching*

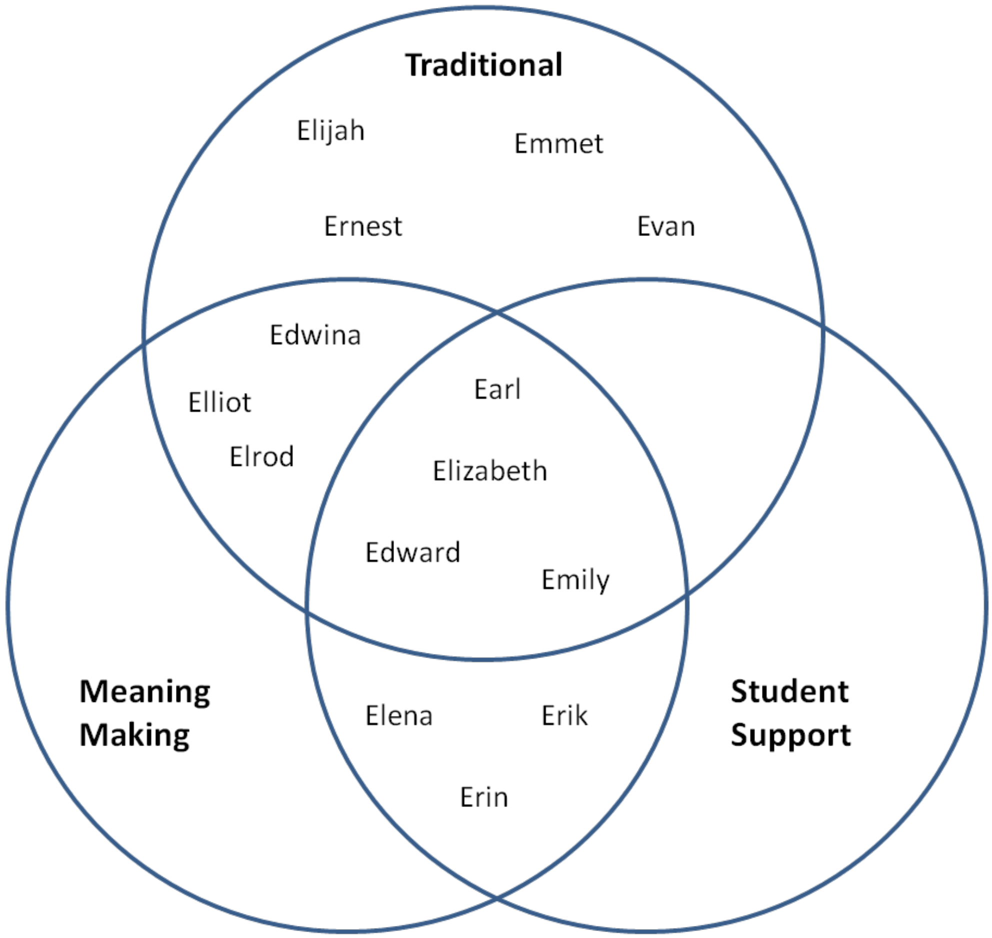


Figure 4. *Percentage of codes by category (Total of codes = 389)*

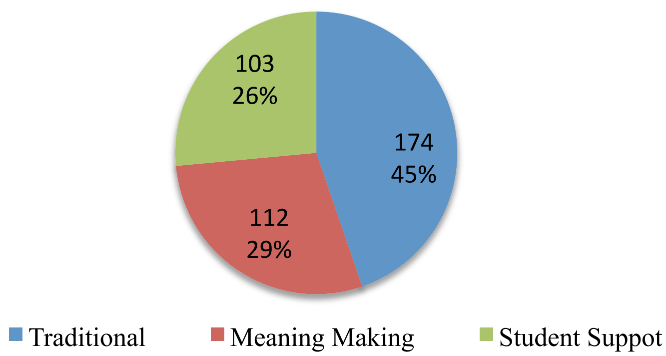


Figure 5: *Frequency of framing talk strategies by teaching approach*

Instructor	Traditional	Meaning Making	Student Support
Evan	◕	○	○
Emmet	◕	◔	○
Ernest	◑	◔	◔
Elijah	◕	○	◔
Elliot	●	○	○
Elrod	◕	◔	○
Earl	◕	◔	○
Edward	◑	◔	○
Elizabeth	◑	◑	○
Emily	○	◔	◑
Elena	◑	◔	◔
Erin	◔	◑	◔
Erik	◔	◔	◑

Note: Circles represent percentages of codes for framing talk strategies by teaching approach, using the following convention: ○ 0-19% ◔ 20-39% ◑ 40-59% ◕ 60-79% ● 80-100%

Appendix A: Interview Protocol

The interview protocol used for this study was Adapted from the interview protocol developed by Stan Goto and Larry Forman (March 16, 1993) and was used with permission from N. W. Grubb (July, 2007).

Teaching practices (what they do)

1. How do you use different forms of instruction- e.g. lecture, small groups, worksheets, technology? (Note responses to similar question on Instructor/Class Information Form.)
2. How do you measure what the students are learning?
3. What do you do to motivate your students?
4. What do you do to help your students in and out of the classroom?
5. What kinds and uses of materials, e.g., textbooks, do you employ?
6. What kinds of assignments do you give?
7. Do you have writing assignments? What types?

Conceptions and philosophies of teaching (reflect on what they do)

8. How do you define good teaching?
9. What are your goals for the students?
10. How have you arrived at your views?

Personal influences on teaching

11. How have outstanding instructors (you have had) influenced how you teach?
12. What impact does the surrounding business and/or disciplinary community have on how and what you teach?

Instructor perceptions of students

13. Why are your students there? Why do they enroll in your course?
14. What kinds of students show up in your class?
15. What are some important issues with your students? What external forces impinge upon your students? What do your students need from you as an instructor?
16. What kinds of attitudes do your students exhibit toward your class and toward education in general when they enter your class? Are they prepared for class (having done all the assignments)? How motivated are they for your class?
17. What kinds of cognitive or affective changes do you see in your students during the semester?
18. What is it in your teaching that causes these changes?

Collegial influences on teaching

19. What kinds of exchanges do you have with your colleagues in your department? In other departments?
    Probe: Do you talk about teaching?
    Follow-up: What exchanges occur between academic and vocational and remedial disciplines?
20. What exchanges do faculty as a whole have with one another? How frequently?

** What would improve the climate of collegiality?

21. Have you ever taught collaboratively? How common is it in your department? In other departments?
    If yes:
    What are the pros and cons of collaborative teaching compared with solo teaching?
    What kinds of results do you see with collaborative teaching?
22. What forms of contact do you have with other departments?

Institutional influences on teaching

23. What resources and facilities are available for you to use in your teaching?
24. How does the administration influence effective or innovative teaching? For you? For colleagues? For the institution as a whole?
25. What are the significant factors/criteria used in hiring new instructors? In promoting instructors? In acquiring sabbaticals, travel/conference funding?
    (If teaching isn't mentioned:) Is teaching skill a criteria for hiring?
26. Are there campus-wide programs related to teaching (e.g., writing across the curriculum, critical thinking across the curriculum)
27. Have you participated in faculty/staff development activities? What difference has it made for you, other faculty, the campus as a whole? How do faculty feel about the existing faculty/staff development programs?
28. What additional steps might the administration take to support innovation and effective teaching?
29. What are some important issues going on in the institution or the community at large that affect your teaching?