Student Participation in Mathematics Lessons Taught by Seven Successful Community College Instructors

Vilma Mesa

University of Michigan, Ann Arbor,
Michigan, USA
<vmesa@umich.edu>

Abstract

This paper presents results of a qualitative study describing classroom participation in pre-college mathematics classes taught by seven successful community college faculty members. The analysis reveals high levels of student participation coupled with low complexity, which can result in detrimental opportunities for students to learn mathematics. The multiple and competing functions and the diversity of the community college setting makes delivering high quality mathematical instruction more difficult. This paper discusses implications for further research and for practice.

Key words: community colleges, instruction, classroom participation, cognitive complexity

Introduction

A higher education degree benefits the society at large in terms of income, health, and civic behavior (Baum & Ma, 2007). The changing nature of the global economy has resulted in the need for many adults to improve their academic preparation (McCabe, 2000; Roberts, 1986). The rising costs of higher education in the United States have made the community college a natural, and in many cases only, option available to adults for completing postsecondary studies (Dowd, et al., 2006). Indeed, nearly half of the undergraduate population in the United States is enrolled in a two-year college (Baum & Ma, 2007). At the same time, national completion and transfer rates for students in these colleges are low (22 percent and 18 percent, respectively, Dowd, et al., 2006; Knapp, Kelly-Reid, & Whitmore, 2006), thereby creating pressures on administration and faculty to increase the number of students who complete their studies. Because mathematics is an almost universal requirement in community colleges and the needs for remediation are high (Boylan & Saxon, 1999; Parsad, Lewis, & Greene, 2003) math departments spend considerable resources making sure students are ready to take on college work (Lutzer, Rodi, Kirkman, & Maxwell, 2007) yet the effectiveness of math remediation remains unclear (Bahr, 2008; Bailey, 2009; Ignash, 1997; Mazzeo, 2002).

One area that can play a significant role in understanding the opportunities that community college adult students have to earn a higher education degree is instruction itself. Yet, there is little empirical information about the quality of mathematics instruction in two year colleges (Grubb & Associates, 1999; Mesa, 2008). In this exploratory study, I describe the teaching practices of seven successful mathematics instructors at a community college in terms of the level and complexity of student participation. In particular I answer the question "*What are the characteristics of classroom participation in community college mathematics?*" by describing patterns of student participation, types of questions asked by instructors, and the level of complexity of the participation. In spite of high student involvement in the lessons, the analyses revealed that the complexity of that involvement was low, which might limit all students', and in particular adults, opportunities for completing a college degree.

I start by describing the community colleges in the United States and by reviewing literature about classroom participation in undergraduate settings that oriented the study, then I present the methods used to collect and analyze the data and the findings. I conclude with implications for further research.

Background

Junior colleges, currently known as community colleges, emerged in the United States in the early 20th century to fulfill three educational functions: transfer to a four-year college, vocational education for workers, and general education to complement a vocational terminal degree (A. M. Cohen & Brawer, 2003; Labaree, 1997). With time, these institutions have added two other functions, enrichment of the adult community and retraining workers displaced by disappearing industries (Labaree, 1997; Mesa, 2008). A transfer student can obtain a terminal associate's degree, which roughly corresponds to the first two years of a university program. Currently there are about 1,150 two-year colleges in the nation, enrolling near 10 million students, with about 66 percent of them taking classes for credit (Blair, 2006; Dowd, et al., 2006). In the school year 2001-2002, 53 percent of all undergraduate students in the U.S. were enrolled in two-year colleges. The average age of a community college student is 29 years with over 15 percent being 40 years or older. More women (58 percent) than men are enrolled and 33 percent are ethnic minorities. In 2001-2002, 61 percent of the students took a part-time course load, 80 percent were employed, and 41 percent were employed full time. Last, but not least, community colleges have an open-door admission policy with mandatory placement testing in reading, writing, and mathematics for first-time students. All these features combined make of the community college a very distinct setting from four-year institutions in the United States.

Literature Review

The current body of literature on adults learning mathematics point to curriculum and instruction as important pieces that can have a significant impact on their motivation to learn mathematics (Benn, 1997, 2001; Duffin & Simpson, 2000; Gal, 2000; Miller, 1999; Miller-Reilly, 1997; Safford, 2000). The literature documents the need for realistic mathematics curriculum and for instructional approaches that honor what students bring into the classroom: their academic, personal, and work experiences. These all inform what they can do and instructors who capitalize on them can see important changes on students' motivation towards the subject. These approaches are justified theoretically by a social constructivist theory of learning, which establishes that individuals learn by becoming participants of a community of practice in which knowledge is created and shared among its members (Wenger, 1998). Empirical studies comparing learning in classrooms and discipline requirements can be credited with the push for suggesting that classrooms resemble more the practices of those who generate knowledge in those disciplines. Examples of what students need to be do as they learn content include scientific method in the sciences and conjecturing, proving, and justifying in mathematics (Cobb, Wood, Yackel, & McNeal, 1992; Cochran, 1997; Minstrell, 2001; Schoenfeld, 1989; Stephan & Rasmussen, 2002). Such approaches appear promising with adults as well (FitzSimons & Godden, 2000).

A main implication of these studies is that classrooms must create opportunities for students to participate actively in the learning process (Bransford, Brown, & Cocking, 1999; Miller-Reilly, 1997). Some empirical evidence from analysis of large longitudinal and cross sectional data sets (e.g., National Study of Student Learning) support the notion that "good teaching practices" (such as increased student-faculty interactions, peer-to-peer interactions, and assigning challenging work) as reported by students have a significant positive, albeit small, effect on outcomes such as mathematical knowledge and critical thinking (Cruce, Wolniak, Seifert, & Pascarella, 2006; Kinzie, Gonyea, Shoup,

& Kuh, 2008; Pascarella, Cruce, Wolniak, & Blaich, 2004; Pascarella, Wolniak, Pierson, & Terenzini, 2003; Seifert, Drummond, & Pascarella, 2006; Seifert, Pascarella, Colangelo, & Assouline, 2007). This study complements findings from those studies, as it provides evidence from classroom activity that shows the necessity of promoting instructional practices that can foster substantial student learning. Differently from studies conducted in the higher education and in the adult learning mathematics community, in this study I do not focus on a specially designed course nor on what students say is important but on the observed practices in mathematics classes that might have a sizable proportion of adults, and analyze the opportunities that all students have for learning mathematics, in particular attending to students' participation. For this purpose I reviewed pertinent literature, and I organized it under three different, yet complementary, perspectives: who participates, what opportunities instructors give their students to participate, and the complexity of such participation.

Who Participates?

Studies in higher education have uncovered patterns of participation that suggest that some groups, women and minorities in particular, are excluded from it and highlight the role that instructional practices have on students' participation. The "chilly climate" hypothesis, for example, refers to patterns of interaction that occur in college classrooms that prevent females or minorities from participating actively (by asking questions or offering answers) and that lead them to leave or change degrees for which they are highly qualified (Hall & Sandler, 1982; Williams, 1990). Fassinger (1995, 2000) reports evidence that females in general participate at lower rates than males (independently of the discipline) but there is mixed support for how much such behavior depends on the instructors' gender. Some evidence suggests that both male and female students participate more with female instructors.

Aspects such as student confidence, class size, and level of student-to-student interaction are more critical than gender or participation grade in determining how much students participate. Fassinger also found that no instructor factors could be associated with different student participation. Likewise, classes in which participation was high (measured as students offering an average of twelve or more interventions in a given class) had "more cooperative, supportive, and respectful classroom dynamics; [patterns of interaction were] more inclusive, less teacher-centered, more tolerant of student input, their members [were] more confident, and their professors seen as more approachable and supportive" (Fassinger, 2000, p. 45). These studies relied on students' self-reports of participation, which might over or under-estimate the actual participation occurring in the classroom. Studies in K-12 mathematics education highlight the fundamental role that the teacher plays in establishing an environment in which all students can actively participate in the construction of mathematical knowledge (Cobb, et al., 1992; Hiebert & Wearne, 1993; Lampert, 2001). Substantial work has been conducted with the participation of children who are not proficient in the English language (Moschkovich, 1998). In all of these studies, the emphasis is on making sure that all students are included in the learning process.

What Opportunities Are There for Participating?

Instructors have at hand several options for increasing student participation. One way is to ask questions for which teachers expect students to provide a response or to assign class time for students to work individually or with others in specially crafted activities. Associated with asking questions is providing ample time for students to think about the question and to supply an answer. The literature reports that instructors of undergraduate classrooms tend to ask questions for which little wait time is given (Duell, Lynch, Ellsworth, & Moore, 1992; Tobin, 1987). On average, instructors wait less than three seconds when they ask a question that requires an answer, such as "Are there any questions?"

With such little wait time it is argued, students are not encouraged to voice an answer or contribution and therefore opportunities for participation are shut down. In addition, increased wait time (three seconds or more) has been systematically associated with higher student participation and increased complexity of the students' responses (Duell, et al., 1992).

Providing time during class in which students solve problems or share their thinking with peers has shown to have an impact on students' learning measured as increases in correct responses to difficult items (Caldwell, 2007; Crossgrove & Curran, 2008; Martyn, 2007); thus, instructors are advised to provide such opportunities in their daily plans (Angelo, 1991; Angelo & Cross, 1993). As this paper demonstrates, asking questions and giving students adequate opportunities to answer them might be necessary but certainly not sufficient for ensuring high student participation or participation that is conducive to learning by involving students with challenging content.

What is the Complexity of Student's Participation?

The mathematics education community agrees that high participation is useful when it is accompanied by interesting and challenging mathematics (Blair, 2006; D. K. Cohen, 1990; Doyle, 1988; Schoenfeld, 1988; Silver, Mesa, Morris, Star, & Benken, 2009; Stein, Grover, & Henningsen, 1996). Efforts to improve mathematics instruction have attended to the central role that mathematics instructional tasks play in daily lessons in providing opportunities for students to learn mathematics. For example, the *Professional Standards for Teaching Mathematics* (NCTM, 1991) claims that students' learning of worthwhile mathematics depends to a great extent on their teachers using "mathematical tasks that engage students' interests and intellect" (p. 1). Such tasks, when implemented well in the classroom, help develop students' understanding, maintain their curiosity, and invite them to communicate with others about mathematical ideas. Research on instructional practices in K-12 mathematics classrooms has found that daily mathematics instruction usually involves teachers and students engaging in cognitively undemanding activities, such as recalling facts and applying well-rehearsed procedures to answer simple questions (Porter, 1989; Stake & Easley, 1978; Stigler & Hiebert, 1999; Stodolsky, 1988). Although research shows that although it is not easy for teachers to use cognitively demanding tasks well in mathematics classrooms (Stein, Grover, & Henningsen, 1996), the regular use of cognitively demanding tasks in ways that maintain high levels of cognitive demand can lead to increased student understanding, development of problem solving and reasoning skills (Stein & Lane, 1997), and greater overall student achievement (Hiebert et al., 2005).

The three questions, who participates, what opportunities are there for participation, and what is the complexity of the participation, provide entry points to describe classroom participation in community college mathematics classrooms and focus on specific aspects of that participation that can be modified to expect a change in instruction that involves students more actively with the content. I investigate the main research question of this study—*What are the characteristics of classroom participation in community college mathematics?*—by studying patterns of student participation, types of questions asked by instructors, and the level of complexity of mathematical activities conducted in the classroom.

Methods

This study is part of a larger research agenda investigating the impact of changing classroom participation on college mathematics instructors' practice and students' learning. The setting for the study is a large suburban community college in Michigan with an approximate enrollment of 12,000 students and an average retention rate of 50%. The college has two satellite campuses. The mathematics department has 16 full time and 75 part time instructors and offers an average of 22 different courses per term, including developmental math (e.g., fundamental math, beginning and intermediate algebra), courses for professional degrees (e.g., business, health, and education), and pre-college and college level courses for the science, technology, engineering, and mathematics track (e.g., college algebra, college trigonometry, and pre-calculus calculus, linear algebra, and differential equations). Like other community colleges across the U.S., it offers students the opportunity to complete a general education diploma (GED, the equivalent to a high-school diploma).

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 the teaching. In addition, the department had recently appointed a very dynamic department chair who was committed to improve teaching in the department. Moreover, like other colleges in the state, the faculty felt pressure to increase passing rates in their courses. These three reasons made this college special, but representative of other colleges that have good conditions for experimenting with alternatives to teaching that can increase passing rates.

The focus of attention for the study was the instructional practices of seven instructors who volunteered to participate in this exploratory study, four part-time and three full-time. According to their chair, they were 'successful' because their sections filled up first, their end-of-term student evaluations were consistently high with scores at or above 4.7 on a 1 to 5 scale, and their passing rates were above average in the department. Because this study was exploratory and because observing classes could be stressful to faculty, I chose to work only with faculty who volunteered. I assumed that willingness to participate also reflected interest in improving practice and genuine concern for students' learning, attitudes that were confirmed with the interviews. Selecting 'good' instructors aids in showing how good practice is conceived and gives hints for the need and possibilities for change. One complication of selecting volunteers is that it is difficult to control for the content they teach. Because content might play a role in how instruction was enacted, the possibility of having different courses represented in the sample was welcome.

Finally, I chose to focus on instructional practices of faculty, rather than on students' learning because instructors have the greatest responsibility for shaping students' opportunities to learn. Even in environments in which students can have a say on what needs to be learned, the instructor's role in deciding how to orchestrate that learning is crucial (Ball & Bass, 2003; Cobb, et al., 1992; D. K. Cohen, 1990; Davis, 1996).

Data Collection

The two sources of data for this study were interviews with the instructors and classroom observations. One- to two-hour long interviews were conducted both before the observation (to gather instructors' views of instruction and learning, awareness of context, and institutional support for their work) and after the observation (with findings of the analysis to obtain each instructor's input regarding the accuracy of the representation and their explanations for why certain patterns emerged in the data).

Each instructor was observed at least three times in order to obtain a characterization of students' classroom participation patterns and of the nature of questions asked. After each class, instructors commented on events that happened during the class or told the observer if the lesson observed was representative of other lessons in the term. In subsequent observations, the observer also asked for comments on events that had departed from the previous observation (e.g., calling students by name to answer questions or sending students to the board) to determine what counted as 'normal' or 'standard' practice and what as extraordinary. The classes were audiotaped and extensive field notes were taken about what the students and the instructors were doing, who was saying what, and what was written on the board. I assumed the role of non-participant observer. Because of the wider range of students who take classes in the college, I was usually mistaken for another student. Institutional Review Board regulations did not require consent from students to participate, because there were minimal risks for them and my main focus was on the instructors.

The interviews were transcribed noting pauses in speech with their length in seconds. After each observation, a summary noting important events that could be revisited later was written. After three observations were conducted, the audiotape of the class thought to be most representative of each instructor's style was transcribed, noting pauses in speech and time at which instructors and students intervened.

Data Analysis

I strived to generate a realistic account of what was happening in the classroom (Creswell, 2005) regarding participation. Because of my interest in describing such participation with mathematical activity, I limited my analytical approaches to applying frameworks that could describe salient characteristics of the mathematics classes observed; thus other methods such as grounded theory or relational coding were not applied in this study. The interview transcripts were analyzed thematically (Bazerman, 2006) to create a profile of each instructor that summarized their perceptions of the students, the college, and of teaching and to corroborate practices observed during instruction. The main sources for classroom participation analysis were the transcript of each class, the corresponding field notes, and the summary of each lesson. I focused on four aspects: students' turns, teachers' questions, lexical complexity, and cognitive complexity of mathematical activities.

'Turns' are segments in the transcript when the instructor and the students, male or female, speak. A turn corresponded to the full speech given by a speaker before being interrupted by another speaker. The turns were tallied to get a sense of the amount of participation in each class. Pauses after questions were also counted and their average length calculated. Field notes provided information about which students participated, allowing me to obtain a measure of how widespread the participation was and how it was distributed by gender (see Appendix 1).

Each instructor turn was parsed to identify questions asked. First, I searched for all question marks (?) in the transcript and located the full sentence that ended with it. Then I looked for instances in which the instructors did not finish a sentence but for which there was an expectation for students to complete it. Those sentences were also marked as questions. Next, I read the transcript searching for all instances in which students intervened and read instructor's preceding turn to determine whether a question had been asked. Those instances were marked as questions as well.

The coding system for the questions was developed for this particular study. The questions were classified into the following categories:

- Question Answered in which the instructor asked a question for which students immediately provided a response.
- Question Wait in which the instructor asked a question and waited three seconds or more until a response was given.
- Questions No-Wait in which the instructor asked a question and waited two seconds or less for a response.
- Rhetorical Question for which no answer was expected from students.
- Sentence-Right? in which the instructor made a statement and immediately followed it by "right?" or "OK?"

The first two categories of questions allowed for determining the proportion of questions that were actually answered by the students. The next three categories identified questions for which instructors were not expecting an answer.
Figure 1 below provides examples of each of these categorizations.

Question Answer

EH: Everybody's good with that answer?
M: No.

F: No because I'd lost you back here. Where did you get that, that extra 3?
EH: <u>Which extra 3?</u>
F: I don't know, you seem to have cancelled...
M: You have to multiply everything by the 3.

EH: Everybody gets multiplied by the lowest common factor. (Lines 674-680)

Question Wait

EY: <u>What is it, what are questions in 2.1</u>? (pause 5 seconds) <u>Yeah so that was page 116-117</u>… <u>Any questions on that? Anything you want to see?</u> (Lines 74-76)

Question No-Wait

ET: $2. So it'd be $2 plus... and then you add to it $1.50/mile. Now if you traveled *m* miles, <u>if the total number of miles you traveled, how much would the initial cost be?</u> 1.50 times *m*, 1.50 multiplied by the number of miles, that's what they want, the total cost. So if you use this formula, this formula will give you the total number of miles, I'm sorry, the total cost if you traveled *m* miles in New York in that particular situation. (pause 4 seconds) <u>Any questions?</u> Next they're asking you how much do we have to pay for a 30 mile ride. (Lines 84-91)

Rhetorical Question

EA: Now notice how if I was mean I could have not asked you about number three and I could have just said probability of a matched pair, <u>then you would have had to think yourself about ok what does a matched pair mean?</u> Well that means either I get blue, blue or I get black, black. And you would have to set up the problem yourself and I think that's why probability comes difficult because the wording, you have to dig deep into the wording to find out what's really being asked. So let's spend a little bit more time on this conditional probability because I don't think we've done enough with this. (Lines 436-444)

Sentence-Right?

EK: For instance, we would like to see our income rise 300%, but we certainly wouldn't want to see inflation rise 300%, <u>right</u>? (Lines 109-111)

Figure 1: Examples of questions instructors asked. Numbers in parenthesis correspond to lines in the transcript.

To determine complexity, I performed three analyses. First, I computed a measure of lexical complexity by dividing the number of words that instructors and students spoke by the number of turns they took. This measure gave an estimate of the average length in words of individual contributions. Second, because in the lessons observed students usually provided answers that were short (one or two words long) or not very elaborated, I created a second measure of lexical complexity of students' participation by tallying students' turns that were one, two or three words long.

Third, I characterized mathematical activities by their cognitive complexity. Anderson and colleagues (Anderson, et al., 2001), proposed a revision of Bloom's taxonomy (Bloom, 1994) that provides a framework for analyzing the type of knowledge (factual, conceptual, procedural, and metacognitive) that can be elicited in an activity as well as the different cognitive processes that students might engage when working on the activity (remembering, understanding, applying, analyzing, evaluating, and creating). Whereas the different types of knowledge are complementary—that is, one needs all of them in order to ensure an adequate knowledge of a subject—the cognitive processes differ in terms of the demand they impose on students and the amount of resources required. There is a hierarchy between the processes with remembering, understanding, and applying being less demanding and therefore less complex than analyzing, evaluating, and creating.

In order to determine cognitive complexity using this framework, each transcript was parsed into mathematical activities; that is, the different examples and problems that the class worked on. Four criteria were used to reliably parse the transcript into mathematical activities (see Figure 2).

One activity deals with one topic: The same topic usually means the same concept (e.g., mutually exclusive or direct proportion). **One activity deals with one situation/problem**: If the problem is of the same topic but the form is different (e.g., asking to fill a table vs. asking to draw a graph), then we parse it into another activity. **One activity has one goal**: If the problem is the same but the goal/perspective to deal with the problem is different (e.g., find the slope vs. interpret the slope), then we parse it into another activity. **One activity deals with one set of numbers:** If the problem is of the same kind but numbers of the problem change, we parse it into another activity.

Figure 2: Criteria used to parse the transcripts into mathematical activities for coding cognitive complexity.

Text not related to mathematical content (e.g., questions about tests or due dates) was not coded for cognitive complexity. Next, each mathematical activity was located on a 4x6 grid that combined the four different types of knowledge elicited (factual, conceptual, procedural, and metacognitive) and the six different types of cognitive processes (remember, understand, apply, analyze, evaluate, and create), as shown in table 1 below. Note that an activity could be placed into more than one cell. In Appendix 2, I provide excerpts exemplifying how activities were classified.

Table 1: Definitions of the categories of the cognitive complexity coding scheme (Source, Anderson, et al., 2001)

Knowledge Dimension	Cognitive Processes Dimension
***Factual Knowledge*—**Basic elements students must know to be acquainted with a discipline or solve problems in it, including knowledge of terminology and of specific details. ***Conceptual Knowledge*—**Interrelationships among the basic elements within a larger structure that enable them to function together. It involves knowledge of classifications and categories, of principles and generalizations, and of theories, models, and structures. ***Procedural Knowledge*—**How to do something, method of inquiry, and criteria for using skills, algorithms, techniques, and methods. It includes knowledge of subject-specific skills and algorithms, of specific techniques and methods, and of criteria for determining when to use appropriate procedures. ***Metacognitive Knowledge*—**Knowledge of cognition in general as well as awareness of one's own cognition. It includes strategic knowledge, knowledge about cognitive tasks (including appropriate contextual and conditional knowledge), and self-knowledge.	***Remember***: Retrieve relevant knowledge from long-term memory, including recognizing and recalling. ***Understand***: Construct meaning from instructional messages, including oral, written, and graphic communication. It involves interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining. ***Apply***: Use a procedure in a given situation. It involves executing and implementing. ***Analyze***: Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose. It involves differentiating, organizing, and attributing. ***Evaluate***: Make judgments based on criteria and standards. It involves checking and critiquing. ***Create***: Put elements together to form a coherent or functional whole and reorganize elements into a new pattern or structure. It involves hypothesizing, designing, and producing.

Reliability and Validity

Inter-rater agreement for the coding process was established using two transcripts. One random transcript was given to an undergraduate research assistant to determine the reliability of turn, question, and mathematical activity parsing. The assistant received training for parsing and coding the transcript. Identifying turns in these transcripts was relatively simple because there were no overlaps or interruptions in the dialog. The agreement was above 90% for turns and questions and near 80% for activity parsing.

Then, a new random transcript was parsed and coded for cognitive complexity. The inter-rater reliability in the coding was also high (Cohen's $\kappa > .75$); most difficulties occurred when distinguishing between understanding and applying; the coding system was specified better to make explicit the classification. In some cases we used a 'generous' coding, assigning an activity to more than one cell when in doubt. Member-checking was used with all participants to establish the validity of the coding and of the interpretations. In all cases, except one, the participants agreed with the coding. The disagreement corresponded to the assignment of three activities (out of 25) to different cells in the cognitive complexity grid. All instructors agreed with the interpretations of the data and provided reasons for some of the findings of the study. These reasons are included as needed, in this manuscript.

Results

Table 2 below shows characteristics of instructors who participated in this study. The seven instructors (three females and four males) in the sample were teaching a variety of courses, mostly developmental mathematics. The non-developmental courses included statistics and a general college math course intended for non-science, technology, engineering or mathematics majors. The participants represent a range of experiences and academic background. The classes analyzed ranged in length from one hour to about an hour and a half, and averaged 22 students.

Table 2: Characteristics of instructors in the sample and of the classes observed

Instructor	# Years of Experience	Academic Background	Level of Math Class Observed	Length (minutes)	Class Size (Female – Male)
EA	20	Math Educ., BA, MA	College	59	10 – 5
EH	7	Engineering, BS	Developmental	84	14 – 11
ED	2	Ed. Psychology, PhD	College	92	13 – 14
EY	2	Math, BS, German, BA,	Developmental	100	8 – 12
ET	16	Physics, PhD	Developmental	85	8 – 8
EK	2	Math Educ, BA	Developmental	99	10 – 4
EN	19	Math Educ., BA, MA	Developmental	100	4 – 10

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

Who Participates?

One interesting feature observed in these classes was the high number of turns students took. As seen in table 3 below, students in these classes contributed more frequently than those reported in other studies in higher education, which could be expected given that this was not an average sample of faculty selected. Comparing class size with the number of students who spoke, we see that the majority of the students, male and female, participated in these classes. Also, we see that more women than men participated, both in absolute and in relative terms. The sample is too small for making claims about the relationship between instructors' gender and student participation, but it appears that in this sample instructors' gender did not play a role in how many or how much students (female and male) participated in the classes.

The ratio of female turns to the number of speaking women was similar to the ratio of male turns to the number of speaking men, except in two classes (EK's and EN's), which suggests that in these two classes the males who spoke tended to contribute more individually than the women who spoke. Thus, even though more females than males participated in these two classes, males tended to be more vocal than females, corroborating the perception that males tend to be more active than females (Fassinger, 1995, 2000; Hall & Sandler, 1982).

Table 3: Frequency of Turns by Instructor and Student Gender

Instructor	# Instructor Turns	# of Student Turns		Class Size		# Speaking Student		# Turns per Speaking Student	
		Female	Male	Female	Male	Female	Male	Female	Male
EA	209	140	78	10	5	8	4	18	20
EH	225	153	48	14	11	10	3	15	16
ED	205	91	22	13	14	4	6	23	20
EY	197	104	53	8	12	6	3	14	20
ET	183	111	61	8	8	6	4	19	15
EK	186	68	77	10	4	9	3	7	26
EN	156	29	124	4	10	4	5	7	25

Note: Shaded entries correspond to part-time instructors.

What Opportunities Are There for Participating?

The total number of questions that each instructor asked, together with the frequency by each category is given in table 4 below. As shown, these instructors asked a large number of questions in their classes, with the minimum being over 100 questions and the maximum 228. In an analysis of 550 lectures in 10 different courses, Pollio (1989 as cited in Menges & Austin, 2001, p. 1140) found that the number of questions ranged from 0 to 50, with an average of 21; more than one third were yes/no questions, and near 70% were not answered by the students. The figures in this study differ substantially from Fassinger's (2000) and Pollio's (1989) reports on college students' participation. Also, instructors waited at least three seconds in a considerable percent of those questions (from 16% in EA's class to 29% in EN's class) and in almost all the cases in which no wait time was given, students answered over 40% percent of the questions posed, the exception being in EY's class, in which only 22% of the questions without wait time were answered by the students. She provided wait time for almost one fourth of the questions she asked.

Table 4: Number and percent of each form of questioning observed in each class

	N	Question Wait	Question Answer	Question No-Wait	Rhetorical Question	Sentence-Right?
EA	148	16%	80%	0%	3%	1%
EH	105	19%	43%	4%	15%	18%
ED	135	20%	67%	0%	8%	4%
EY	210	23%	22%	15%	12%	30%
ET	115	23%	46%	10%	17%	3%

EK	179	28%	57%	0%	9%	6%
EN	228	29%	50%	3%	7%	11%
Average	160	23%	51%	5%	10%	12%

Note: Shaded entries indicate part-time instructors.

On average, instances of questions that required an answer, namely Question Wait and Question Answer, constitute nearly 75% of the questions that these instructors asked with the lowest percent being in EY's class (45%) and the highest in EA's (96%). The high percentage of questions in which instructors paused for more than three seconds waiting for an answer is markedly higher than what reports in higher education suggest (Ellsworth, Duell, & Velotta, 1991). In fact, in these classes questions in which instructors did not wait for an answer were the exception rather than the norm. Post-interviews with instructors indicated that they tend to rely on visual inspection of students' faces and body signals to determine whether to wait for an answer or not. For example, ET said,

> I told them on the first day, ask any questions you want, the only stupid questions are the ones you take home with you without asking… with this class they were, the day you came, I mean they were already used to, I was used to their face. So usually if I asked, "are there any questions," right away they raised their hands. If I don't see the hand like within four seconds or something... That means there's no question. (…) But once I get used to the students' face and I know that if I don't say anything they'll just be quiet, they don't have any questions, I move on. In fact Wednesday, (…) that was only our third meeting, when I asked them "are there any questions?" I would stop and I would scan the entire room, back and forth, maybe for ten seconds, twelve seconds, something like that before I move on. But once I get used to their responses, like if they have a question and they'll respond within two or three seconds, then I make it like four or five. I'm not counting the seconds, but it's automatic, once you get used to that face. (Lines 291-301)

In addition to giving wait time after asking a question, the instructors also paused to locate problems or examples in the textbooks, to redirect the class to a new section, or to allow students to work independently on an example or a problem. Table below presents descriptive information about wait time in seconds. As can be seen, instructors' wait time after a question was above three seconds on average. These relatively long pauses contribute to explaining the high participation rates observed. When instructors ask many questions and provide sufficient wait time for students to think and answer, it is more likely that students will respond or make a contribution to maintain the flow of the conversation. Also, pausing for making transitions is a useful tool to help students redirect their attention to the new section. Giving time also allows the instructors to know if students are ready to move on. Giving time for students to work on their own also gives instructors the opportunity to see how their students are working and for students to make sure they know what they are supposed to do on their own. In general, the classes had a steady but calm rhythm and these pauses served pedagogical purposes that contributed to that rhythm.

Table 5: Descriptive Information about Wait Time in Seconds in the Sample

Instructor	All Instances			# Question Wait		Other Instances	
	Min wait	Max wait	Mode	*n*	Mean wait	*n*	Mean wait

	time	time	wait time		(SD)		(SD)
EA	2	113	5	28	5.79 (2.85)	2	79.00 (48.08)
EH	3	20	3	21	3.76 (1.00)	22	9.95 (3.94)
ED	2	23	4	22	3.64 (0.49)	54	5.56 (4.52)
EY	2	11	3	48	3.42 (5.24)	39	9.77 (6.47)
ET	3	23	3	33	4.64 (1.62)	13	14.00 (4.78)
EK	2	106	3	50	3.12 (0.63)	48	17.34 (23.35)
EN	3	70	4	52	7.29 (3.99)	13	28.86 (14.33)

Note: Shaded entries indicate part-time instructors.

Rhetorical questions or statements in the form Sentence-Right were less prominent in these classes but all instructors formulated them during teaching.
Figure below illustrates Rhetorical and Sentence-Right statements. Rhetorical questions (Figure a) show train of thought or ways of thinking about problems. Sentence-Right statements (Figure b), on the other hand, seem to align the students with what instructors wanted to say.

ET: Now to find the slope we can line them up like this, this point, or we can put 102, 124 on top and 100 and 128 under it. ***Does it make any difference which way we calculate it?*** It shouldn't. It should get the exact same slope. (lines 154-157)

EN: ***What do you think about this process?*** He went through and looked for completely filled-in pies and there were three of them and then he went through an 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 [for] number two… How many whole parts do you have? (lines 128-138)

EK: 1/3. So I can write this as 33 1/3% (pause 2 seconds) ***Isn't that weird?*** It is kind of weird. So using the same idea, let's take (writes on board 3 seconds) 2.3 and write 2/3 as (pause 4 seconds) (lines 378-381)

(a)

ED: What exactly as you think about it, how much can you get into debt? (**M:** Infinite.) ***Not really because eventually people will stop lending you money***, ***right***? (lines 151-154)

EY: And they [fraction bars] work really well on an overhead, not so well here, but I will pull them out anyway. ***This is considered a whole, right?*** Whole. This would be a half. And I have two of them. ***You can see that 2 halves make one whole, right?*** ***So that would be 1 is the same as 2 halves, right?*** (lines 299-303)

EH: ***3 and x – 2 are like two factors, right?*** So you just multiply those two together. (writes on board 5 seconds) (lines 656-657)

(b)

Figure 3: Examples of (a) Rhetorical Questions and (b) Sentence-Right? statements in the corpus.

What is the Complexity of Students' Participation?

Table 6 shows the number of turns and words instructors and students said, the average number of words per speaker turn, and the percent of students' turns that were one to three words long. As reported in other studies of instruction (e.g., Hiebert & Wearne, 1993), teachers speak more than their students. The ratio of number of students' words to the number of turns provides a measure of the length in number of words of the turns. In these classes, this ratio ranged from three to seven words, which indicates that contributions offered by students tended to be of low lexical complexity. Although the average sentence length was about four words, in five classes more than 50% of the students' responses were sentences one to three words long.

Table 6: Number of Turns, Words Uttered, Average Length of Turns, and Percent of Turns that were One to Three Words Long

	Number of Turns		Number of Words Stated		Average # of Words per Turn		Percent of Students' Turns 1 to 3 Words Long
	Instructor	Students	Instructor	Students	Instructor	Students	
EA	209	218	6,011	867	29	3	63%
EH	225	201	6,169	1,078	27	5	41%
ED	205	113	8,096	1,499	39	7	50%
EY	197	157	9,688	665	49	4	50%
ET	183	172	8,906	704	49	4	46%
EK	186	145	8,766	650	47	4	55%
EN	156	153	9,350	750	60	5	55%

These numbers suggest that when instructors ask questions, their students respond with short answers, which in turn suggests that the questions might be focusing on recalling factual knowledge or filling in steps in procedures done on the board.
Figure 44 below presents an example of such questioning.

> **ET**: Mark?
>
> **M**: -10 over (5 – 3).
>
> **ET**: Over (5 – 3). Ok. So 18 - 10 (writes on board 3 seconds) And then you still, in the numerator you have 5 - 10. Ok, we need *y* in the numerator and the *x* is in the denominator and you subtract. 18 – 10, 5 – 10. 18 – 10 is?
>
> **M**: 8.
>
> **ET**: 5 – 3 is?
>
> **F**: 2
>
> **ET**: Then you divide 8 by 2 you get 4 and that's the slope. This is how you calculate slope. This is part of what you did last time. What we're going to do today is applications of this, of slope, real life applications of slope and slope calculations. (Lines 15-32)

Figure 4: Example of questions that required short answers from students.

The instructors worked on an average of 30 activities in their classes (from 15 in EH's class to 37 in EA's). The codification of the types of knowledge and cognitive processes that these activities elicited (shown in Table below) revealed that instructors placed more emphasis on basic cognitive processes (such as remembering, understanding, and applying factual and procedural knowledge) than on the more advanced processes with all types of knowledge. Few activities required metacognitive knowledge or expected students to analyze, evaluate, or create. Lessons strongly emphasized the application of procedures. This result is consistent with the K-12 mathematics education literature, which characterizes mathematics classrooms as places in which the cognitive demands of tasks students perform is not high (Silver, et al., 2009; Stein & Lane, 1996; Weiss, Pasley, Smith, Banilower, & Heck, 2003). In the observed classes, instructors made an effort to assist students in remembering, understanding, and applying facts, concepts, and procedures more frequently than engaging them in higher order cognitive activities.

Table 7: Frequency (and Percent) of Activities Classified by Type of Knowledge Elicited and by Cognitive Process Required.

	Remember	Understand	Apply	Analyze	Evaluate	Create	Total
Factual knowledge	41 (10%)	46 (11%)	18 (4%)	1 (0%)	3 (1%)	1 (0%)	110 (27%)
Conceptual knowledge	8 (2%)	43 (11%)	5 (1%)	-	-	-	56 (14%)
Procedural knowledge	38 (9%)	59 (15%)	109 (27%)	1 (0%)	3 (1%)	-	210 (52%)
Metacognitive knowledge	7 (2%)	7 (2%)	11 (3%)	-	-	-	25 (6%)
Total	94 (23%)	155 (39%)	143 (36%)	2 (0%)	6 (1%)	1 (0%)	401 (100%)

Note: An activity could be classified as belonging to more than one cell.

Instructors' Perceptions

Participant interviews suggest that the kind of students who take these classes together with the instructor's previous teaching experiences with these students can explain these findings.
First, instructors tended to speak sympathetically about the students, in particular the adults in developmental classes, highlighting their high anxiety levels and their low confidence in their ability to do mathematics. All instructors, when interviewed, expressed that one of their goals was to infuse confidence and reduce these students' anxiety towards mathematics and talked about different strategies used to accomplish these goals. Involving students with the material during class was one such strategy. It consisted of either assigning homework during the session so students could practice or connecting the material to what they were doing outside of college, as stated below:

> These are students that (…) I don't know if they've really talked about math much, ever, other than to say I hate it. So my goal is to get them talking about math and to get them comfortable talking about math in a situation that's not threatening. So they, I think they respond well in that it, some of them it helps them just to see that they're not the only ones struggling with a concept. Sometimes it really helps them to teach another student, if I have them explain to your neighbor how you got this problem, you know that's very educational. And I've been doing that, I've done that a little more in my, I haven't done that so much in [math class] yet, I've done that a little more in algebra two, but we've done some of it. So it's, it's the communication about math that they just, I think that helps a lot and I've seen them, just builds their confidence more than anything, which they really need (EY, initial interview, lines 61-68)

Instructors reacted negatively towards lecturing, because they believed that one reason their students were taking classes at the community college was that they had unsuccessfully experienced such teaching in their K-12 education. Thus, the instructors felt compelled to try something new. Getting students talking in class was very important and consequently, they strived for creating environments in which participation was part of their daily work, as stated below:

> I launch the day's lesson, which usually involves as short of a lecture as I can get away with (EA, initial interview, lines 61-62)

> I'm a big believer in experiential learning; I'm doing those small discoveries together. Like I put a question up on the board, let them think for a few seconds and they are

> coming up with the answer. And of course they don't have the right answer for the first time, but we think through as a group (ED, initial interview, lines 288-291)

> I don't do any, very little just straight lecture where I'm just giving them information because [I'm] often [saying] "tell me what you think, tell me what you know" … or "if I put these problems up what are you noticing?" (EN, initial interview, lines 146-149)

Instructors did not appear surprised by the emphasis on factual and procedural knowledge or by the little emphasis on higher order thinking of classroom activities. They felt that mathematics was mainly "a procedural activity" (EH, data interview, line 600) that required a vast amount of factual knowledge and suggested that course level was an important factor in explaining findings on knowledge and cognitive processes, as stated below:

> I think in calculus they have more experience, they have more, with equations, with solving, with moving terms and manipulating, so in calculus they can take any form and work with it. But in algebra they don't, in introductory algebra especially, … which is this class, they're just beginning, so we give them forms that are ready or take as few steps as possible, as little effort as possible. (ET, data interview, lines 265-270)

All participants shared ET's sentiment. Instructors indicated that unevenness in the mathematical preparation that their students bring to initial classes combined with the little time students have to study deter faculty from proposing more demanding activities:

> They need a lot of opportunity for practice from me. Depending on the level, most students will only do what is assigned (…). They have the kids to get to bed, they have the dinner to make, they have the work to go from midnight to 8:00 am, so if I assign twelve problems by goodness they're going to do twelve problems whether they understood any of them or not. So I need to make sure my assignments are pretty well crafted and tweaked so that they're given opportunities, things like practice tests, review sheets for tests, lists of exactly what type of problem is going to be on the test. They really crave that. They're not able to write their own note cards from scratch for a test. I won't do note cards obviously but I will give them a list of exactly the types of problems, you will solve a system in two variables, you will, you know, for elementary math it might be you will add and subtract in base three and base five, you will be able to explain the place value in base twelve and what the digits are. So they can make their own note cards from that but they need structure and as I said before, they need pretty much every class period there to be a task that they know if they're not there they'll miss and they'll miss points because there's too many competing pressures, yeah. (EA, Initial Interview, 445-462)

Because the content was seen as basic and elementary, faculty believed that their students needed to learn and practice facts and procedures before being able to pursue more advanced processes. And because the courses are lock-step, faculty felt pressured to ensure proficiency with such basic content. In this scenario, faculty saw their primary obligation as assisting students in advancing through the requirements in their department and saw the reinforcement of basic skills as necessary. The lock-step nature of these courses allowed them to assume that in higher courses they could expect students to know the basic material and therefore have a different pace, as stated below:

> I just change the pace… If I'm teaching calculus, yes I teach them differently, differential equations I teach them differently because there are a lot of things that we expect them to know so I don't have to go over them. (ET, Data Interview, lines 317-319)

At the same time instructors felt that their students needed to be acquainted with more conceptual and metacognitive knowledge and to be exposed to activities that demanded more advanced cognitive processes, they felt constrained in accomplishing that goal, in terms of their own limited knowledge in handling such activities with these particular group of students, as stated below:

> That's what I talk to my colleague at the end of class. Because I learned conceptually, that is how I learned math. And I've tried a lot of conceptual [activities] with this kind of students, but then they just give me this look, like 'what are you talking about?' but [my colleague] uses it in his introductory algebra class; that makes sense, … but [in this developmental course], conceptually explaining things, that is an area that I know I need to work on, if they can get the conceptual, then they will be much happier with it. (EY, Data Interview, lines 600-604)

> In my [lower level class] I need for them to learn all this rules and apply them. But if I try to use the more abstract, create kind of thing, their anxiety level shoots up, so to me it is very difficult to get them to do these more advanced work (EK, Data Interview, lines 700-705)

> I am thinking about these—analyze, create, evaluate—maybe I do these more in my assessments… I know the two hours go by so quickly, I wish I could give them, you know, tell them create a problem, invent the numbers, come up with the story, but you know a lot of times—you just can see their faces, it takes so much time… and… This is the tip of the iceberg, isn't it? (EN, Data Interview, lines 723-730)

Not only did instructors indicate limited student knowledge, they also indicated that using information or activities shown to be useful in other settings to deepen understanding actually created dilemmas in their own practice, as stated below:

> I try to do work with manipulatives but that's also a hard balance with adults. You know it works OK with students but to hand them little toys or little contraptions you sort of feel like, you know? This is a thirty-year-old person, I don't want to seem demeaning, I don't want to seem… you know? I had fraction strips yesterday and I was like am I going to give them these or can we just draw these models out and so I decided not to use them because I wasn't convinced enough that it was worth it versus… what are we doing with these little things? So that is a little bit tricky. (EN, Initial Interview, 162-167)

Thus, instructors indicated that the emphasis of low-cognitive processes that emphasize factual and procedural knowledge was necessary for the mathematics teaching they have to do, and at the same time recognized that this type of learning can be limiting. However, when asked about using other forms of knowledge and higher cognitive processes, they felt that they had neither the right students, tools, context, nor sufficient knowledge to be successful with them.

Discussion

The purpose of this study was to characterize participation in a select group of community college mathematics classrooms in order to understand the opportunities to learn mathematics that are available to the students; because of the high proportion of adults in these classes, the analyses can speak also about opportunities for the adults who share these classes.

It is important to highlight a main limitation of the study that influences the results and limits their application to different settings. The study had a small number of participants who volunteered for the study and who were invited because they were seen as successful in their department. It is possible that what is reported here is more idiosyncratic of the sample selected rather than representative of the department at large. Volunteering to participate in a study of instruction makes the sample very special. The faculty who participated wanted to know more about their teaching and to learn ways to reach their students better; such attitudes make them more receptive and open than what could be expected with a random sample. At the same time, findings from this select sample of faculty who are considered successful raises important questions about the learning opportunities that students might have in classes of less successful instructors.

In the seven classes observed the instructors rarely delivered content for long periods of time and the students made frequent contributions during class. The classes were mostly devoted to solve examples and problems on the board, with substantial input from the students. The students took notes, worked on their own or with other students, trying procedures, and asking and responding to the many questions that emerged. The wait time, the high number of questions these instructors asked, and the high proportion of questions for which an answer was expected, help to explain the high participation rate observed. Instructors indicated that it was very important for students to ask questions and they encouraged students to do so. In these community college classes, women and men participated actively with more women than men speaking in a given class. But, in general in this sample, females and males made comparable contributions. The findings of this preliminary exploration also indicate that a considerable number of students' answers were of a low lexical complexity. Students in general provided short unelaborated sentences that required low cognitive activity as corroborated by the analysis of the knowledge and cognitive demands of the activities, which showed a prominence of factual and procedural knowledge with basic cognitive demand processes. In sum, although quite interactive, these classrooms do not seem to be challenging students.

Two potential explanations for these findings—instructors' perceptions of their students and the level of the classes observed appear to play a role in these results. Instructors are aware of the sacrifices and efforts adult students make to attend community college classes and perceive these students as unprepared and therefore in need of substantial assistance. Thus, they are more willing to give them more opportunities to use the material during class because instructors have little hope that students will be able to devote time outside to do homework. Instructors therefore feel more compelled to reach out to students in class to make sure that each one succeeds. Because these students are perceived as unprepared or with high levels of anxiety, asking questions that students will be able to answer is very important to the instructors. This would justify using questions that activate knowledge that is easy to retrieve, giving both students and teachers a sense of "efficacy" (Herbst, 2003). If this is indeed the case, then we could hypothesize that with a different group of students—for example, students who had just successfully finished high-school or who do not need remediation—the classroom dynamics would change towards less interaction (because the students are better prepared) and more complex questions (because they can handle them).

The content of the courses observed corresponds to mathematics taught in grades 3 to 9. Such content is perceived as basic (students need to be proficient with the four arithmetic operations with different types of numbers, they need to recognize equations and formulas and be able to solve and use them as needed) and necessary to handle more advanced mathematics courses. Because the amount of time available to cover all this material is limited to about three 15-week long courses, it appears to be certainly more efficient to emphasize basic notions and procedural proficiency over applying, evaluating, or creating conceptual or metacognitive knowledge. Activities involving these more complex processes take time (in planning and deploying) and it is unclear that such investment pays off in the end, especially because the amount of content is quite large. As before, the possibility of seeing immediate rewards for the effort makes the emphasis on procedures more enticing both for the students and the faculty. I am not suggesting that this is an intentional decision, rather the conditions in which this type of teaching happens help to determine these outcomes.

There are at least two ways to investigate whether this perception of the content and the complexity of using more cognitive demanding activities with this content is a factor at play. Similar to work by Stein and colleagues (Stein, et al., 1996; Stein, Smith, Henningsen, & Silver, 2000), one possibility is to encourage faculty in developmental courses to infuse higher-order activities in instruction and then study their deployment in classrooms. Do faculty maintain or increase the cognitive level of the activity or do they tend to reduce it in order to maintain a sense of efficacy in the classrooms? What types of obstacles are there for implementing these activities? And what do students perceive and learn when using such activities? Given that students are considered important players in the learning situation, listening to how they understand the activities is very important. Because there are both adult and non-adult students in these courses, it would be important to determine the differences that deploying these tasks make. We can anticipate that implementing these activities might be at odds with students' perceptions of what mathematics is (Benn, 1995). Some action research projects were started with this model by a number of community colleges in California (Rose Asera, personal communication, February, 23, 2009, see also Asera, 2008) and they provide evidence of change in instructors' practices.

A second possibility is to apply these analyses to non-developmental courses to determine whether indeed there is less student participation and more challenging activities—which would corroborate that instructors perceive the non-developmental student as more capable of handling the content. Following instructors who teach both types of courses could provide evidence that instructors change their teaching practice depending on the level of the content that they teach. Because adults take college level courses in community colleges, it would be important to determine whether in more advanced classes they have more opportunities to learn the mathematics that will ensure their success once they transfer to a four-year institution.

Conclusion

Involving all students, specially adults, with the material of the mathematics classroom is an important practice that might help them overcome their mathematics anxiety and develop a sense of self-efficacy that will help their chances of success. However, as we have seen the students in these classes were engaged at low levels of lexical and cognitive complexity, emphasizing limited aspects of mathematical knowledge which might be detrimental as they attempt to succeed in more advanced work. At the same time, instructors' perceptions of their students and the content they teach works against the possibility of having classrooms in which students can be engaged at higher level of cognitive activity. The findings from this study suggest important avenues for future work, both in terms of faculty development and in terms of research.

First, faculty's willingness to participate and learn more about their own teaching—they volunteered and they teach at a *teaching* institution—are promising signs that instruction can become less instructor-centered in college settings. The faculty felt responsible for their students' success in the lock-step math courses the college offered and felt that involving students was crucial, given the students and material they were teaching. At the same time their perception that higher-level cognitive processes might not work with adults and the basic math content could be addressed by preparing faculty workshops in which activities that use higher-level processes (such as analysis, creation, and evaluation) with this basic content are modeled and tried out. Simultaneously, attention to the need for developing metacognitive and conceptual knowledge is crucial.

But before being able to do this work, it is fundamental to investigate which activities could be used for such purposes. The participants in this study, who were aware of K-12 reform-oriented practices, were reasonably skeptical about the appropriateness of those methods for the adults they were teaching in their higher-education institution. It is not clear that the methods will work as transparently in community colleges. In addition, most of the faculty felt concerned with passing rates. Their instructional approach was successful as their students were moving on as they were supposed to do; therefore attempts to change such instruction would not be welcome unless the new approaches demonstrate improvement over what they already know how to do well.

Other research includes determining the extent to which the patterns of participation observed in this study with faculty who are considered successful are representative of what could be observed in classes taught by other instructors. Norton Grubb's work (Grubb & Associates, 1999) suggests that the variation of instruction within colleges is quite substantial, and it might be possible that the findings reported here are outliers in the landscape of participation in community college math classrooms. Thus, systematic analyses of mathematics instruction within and across colleges are needed. Such work is important as we create faculty development that is tailored to the needs of the faculty that we serve.

Finally, a closer look at the type of knowledge potentially activated during the interaction is fundamental because what matters most is what the students learn and the quality and permanence of that learning. Because community college classrooms have a wide range of students in each class—they can be adult, college-age, full-time employed, with families, or low-income—what instructors do in each classroom is of paramount importance, *all of the time*. It is fundamental to determine how feasible is it to sustain classrooms that encourages students to participate at high levels of cognitive demands and with richer types of knowledge given the time constraints for teaching a vast amount of content, the limited amount of time that faculty have for planning such activities, and the limited amount of time that students have for learning the material.

Acknowledgements

Portions of this work were delivered at the International Congress of Mathematics Education in Mexico July 2008 and at the Annual Meeting of the American Educational Research Association in San Diego, April 2009. Thanks to Alice Cheng and Hee Joo Suh for assistance with this research. This work is supported in part by the National Science Foundation through award DRL 0745474. Opinions are those of the author.

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., et al. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing*. New York: Longman.

Angelo, T. A. (1991). Ten easy pieces: Assessing higher learning in four dimensions. In T. A. Angelo (Ed.), *Classroom research: Early lessons from success* (Vol. 46, New Directions for Teaching and Learning, pp. 17-31). San Francisco: Jossey-Bass.

Angelo, T. A., & Cross, P. K. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). San Francisco, CA: Jossey-Bass.

Asera, R. (2008). *Change and sustain/ability: A program director's reflections on institutional learning. Strengthening pre-collegiate education in community colleges*. Stanford, CA: The Carnegie Foundation for the Advancement of Teaching (Available from: http://www.carnegiefoundation.org/programs/index.asp?key=26).

Bahr, P. R. (2008). Does mathematics remediation work? A comparative analysis of academic attainment among community college students. *Research in Higher Education, 49*, 420-450.

Bailey, T. R. (2009). Challenge and opportunity: Rethinking the role and function of developmental education in community colleges. *New Directions for Community Colleges, 145*(Spring), 11-30.

Ball, D. L., & Bass, H. (2003). Toward a practice-based theory of mathematical knowledge for teaching. In B. A. Davis & E. Simmt (Eds.), *Proceedings of the 2002 Annual Meeting of the Canadian Mathematics Education Study Group* (pp. 3-14). Edmonton, AB: CMESG/GCEDM.

Baum, S., & Ma, J. (2007). *Education pays 2007: The benefits of higher education for individuals and society*. New York: The College Board.

Bazerman, C. (2006). Analyzing the multidimensionality of texts in education. In J. L. Green, G. Camilli & P. B. Elmore (Eds.), *Complementary methods in education research* (pp. 77-94). Mahwah, NJ: Erlbaum.

Benn, R. (1995). Mathematics: Certaintly in an uncertain world? In D. Coben (Ed.), *Proceedings of the second international conference of Adults Learning Maths* (pp. 20-25). London: Goldsmiths College, University of London.

Benn, R. (1997). Reading, writing, and talking about mathematics. In D. Coben (Ed.), *Proceedings of the third international conference of Adults Learning Maths* (pp. 24-29). London: Goldsmiths College, University of London.
Benn, R. (2001). All for one and one for all: Citizenship and maths education. In M. J. Schmitt & K. Safford-Ramus (Eds.), *Proceedings of the seventh international conference of Adults Learning Maths* (pp. 155-159). Cambridge, MA: National Center for the Study of Adult Learning and Literacy and Harvard University Graduate School of Education.
Blair, R. (Ed.). (2006). *Beyond crossroads: Implementing mathematics standards in the first two years of college*. Memphis, TN: American Mathematical Association of Two Year Colleges.
Bloom, B. (1994). Reflections on the development and use of the taxonomy. In L. W. Anderson & L. A. Sosniak (Eds.), *Bloom's taxonomy: A forty-year retrospective, Ninety-third yearbook of the National Society for the Study of Education* (pp. 1-27). Chicago: University of Chicago Press.
Boylan, H. R., & Saxon, D. P. (1999). *Outcomes of remediation*. Boone, NC: National Center for Developmental Education.
Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.
Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *CBE Life Science Education, 6*(1), 9-20.
Cobb, P., Wood, T., Yackel, E., & McNeal, B. (1992). Characteristics of classroom mathematics traditions: An interactional analysis. *American Educational Research Journal, 29*, 573-604.
Cochran, J. P. (1997). What's 'common' in a common core: How course structure shapes disciplinary knowledge. *Journal of Classroom Interaction, 32*, 45-55.
Cohen, A. M., & Brawer, F. B. (2003). *The American community college* (4th ed.). San Francisco: Jossey-Bass.
Cohen, D. K. (1990). A revolution in one classroom: The case of Mrs. Oublier. *Educational Evaluation and Policy Analysis, 12*, 327-345.
Creswell, J. W. (2005). *Educational Research: Planning, conducting, and evaluating quantitative and qualitativ research* (3rd ed.). Upper Saddle River, NJ: Pearson.
Crossgrove, K., & Curran, K. L. (2008). Using clickers in nonmajors- and majors-level biology courses: Student opinion, learning, and long-term retention of course material. *CBE Life Science Education, 7*, 146-154.
Cruce, T. M., Wolniak, G. C., Seifert, T. A., & Pascarella, E. T. (2006). Impacts of good practices on cognitive development, learning orientations, and graduate degree plans during the first year of college. *Journal of College Student Development, 47*, 365-383.
Davis, B. A. (1996). *Teaching mathematics: Toward a sound alternative*. New York: Garland.
Dowd, A., Bensimon, E. M., Gabbard, G., Singleton, S., Macias, E., Dee, J. R., et al. (2006). *Transfer access to elite colleges and universities in the United States: Threading the needle of the American dream*: Jack Kent Cooke Foundation, Lumina Foundation, Nellie Mae Education Foundation.
Doyle, W. (1988). Work in mathematics classes: The context of students' thinking during instruction. *Educational Psychologist, 23*, 167-180.
Duell, O. K., Lynch, D. J., Ellsworth, R., & Moore, C. A. (1992). Wait-time in college classes taken by education majors. *Research in Higher Education, 33*, 483-495.
Duffin, J., & Simpson, A. (2000). Understanding their thinking: The tension between the cognitive and the affective. In D. Coben, G. E. FitzSimons & J. O'Donoghue (Eds.), *Perspectives on Adults Learning Mathematics* (pp. 83-99). Dordrecht, NL: Kluwer.
Ellsworth, R., Duell, O. K., & Velotta, C. L. (1991). Length of wait-time used by college student given unlimited wait-time intervals. *Contemporary Educational Psychology, 16*, 265-271.
Fassinger, P. A. (1995). Understanding classroom interaction: Students' and professors' contributions to students' silence. *The Journal of Higher Education, 66*, 82-96.
Fassinger, P. A. (2000). How classes influence students' participation in college classrooms. *Journal of Classroom Interaction, 35*(2), 38-47.
FitzSimons, G. E., & Godden, G. L. (2000). Review of research on adults learning mathematics. In D. Coben, G. E. FitzSimons & J. O'Donoghue (Eds.), *Perspectives on Adults Learning Mathematics* (pp. 13-45). Dordrecth, NL: Kluwer.
Gal, I. (2000). Statistical literacy: conceptual and instructional. In D. Coben, G. E. FitzSimons & J. O'Donoghue (Eds.), *Perspectives on Adults Learning Mathematics* (pp. 135-150). Dordrecth, NL: Kluwer.
Grubb, N. W., & Associates. (1999). *Honored but invisible: An inside look at teaching in community colleges*. New York: Routledge.
Hall, R. M., & Sandler, B. R. (1982). *The classroom climate: A chilly one for women?* Washington DC: Project on the Status and Education of Women, Association of American Colleges.
Herbst, P. (2003). Using novel tasks in teaching mathematics: Three tensions affecting the work of the teacher. *American Educational Research Journal, 40*, 197-238.

Hiebert, J., & Wearne, D. (1993). Instructional tasks, classroom discourse, and students' learning in second-grade arithmetic. *American Educational Research Journal*, *30*, 393-425.

Ignash, J. M. (1997). Who should provide postsecondary remedial/developmental education? *New Directions for Community Colleges*, *100*, 5-20.

Kinzie, J., Gonyea, R., Shoup, R., & Kuh, G. D. (2008). Promoting persistence and success of underrepresented students: Lessons for teaching and learning. *New Directions for Teaching and Learning, 115*(Fall), 21-38.

Knapp, L. G., Kelly-Reid, J. E., & Whitmore, R. W. (2006). *Enrollment in postsecondary institutions, Fall 2004; graduation rates, 1998 & 2001 cohorts; and financial statistics, fiscal year 2004* (NCES 2006-155). Washington, DC: US Department of Education; National Center for Education Statistics. Retrieved Dec 2, 2007, from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2006155.

Labaree, F. D. (1997). *How to succeed in school without really learning: The credentials race in American education*. New Haven & London: Yale University Press.

Lampert, M. (2001). *Teaching problems and the problems of teaching*. New Haven, CT: Yale University Press.

Lutzer, D. J., Rodi, S. B., Kirkman, E. E., & Maxwell, J. W. (2007). *Statistical abstract of undergraduate programs in the mathematical sciences in the United States: Fall 2005 CBMS Survey*. Washington, DC: American Mathematical Society.

Martyn, M. (2007). Clickers in the classroom: An active learning approach. *EDUCAUSE Quarterly*, *30*(2), 71-74.

Mazzeo, C. (2002). Stakes for students: Agenda-setting and remedial education. *Review of Higher Education, 26*, 19-39.

McCabe, R. H. (2000). *No one to waste: A report to public decision-makers and community college leaders*. Washington DC: Community College Press.

Menges, R., & Austin, A. (2001). Teaching in higher education. In V. Richardson (Ed.), *Handbook of Research on Teaching* (4th ed., pp. 1122-1156). Washington DC: American Educational Research Association.

Mesa, V. (2007). *Developing a survey for collecting data about textbook use in introductory undergraduate mathematics courses*. Unpublished raw data. Ann Arbor, MI: University of Michigan.

Mesa, V. (2008). *Mathematics instruction in community colleges: A literature review* (Unpublished manuscript). Ann Arbor, MI: University of Michigan.

Miller, B. (1999). The effect of gender and fluency in English on the mathematical confidence and achievement in a realistic mathematics course. In M. v. Groenestijn & D. Coben (Eds.), *Mathematics as a part of lifelong learning, the fifth international conference of Adults Learning Maths* (pp. 190-203). London: Goldsmith College, University of Londong.

Miller-Reilly, B. (1997). Exploration and modelling in a university mathematics paper: Perceptions of adult students. In D. Coben (Ed.), *Proceedings of the third international conference of Adults Learning Maths* (pp. 117-122). London: Goldsmiths College, University of Londong.

Minstrell, J. (2001). Facets of students' thinking: Designing to cross the gap from research to standards-based practice. In K. Crowley, C. D. Schunn & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 415-443). Mahwah, NJ: Erlbaum.

Moschkovich, J. (1998, April). *Classroom participation of English learners in mathematical discussions.* Paper presented at the Annual Meeting of the American Association Educational Research, San Diego, CA.

Parsad, B., Lewis, L., & Greene, B. (2003). *Remedial education at degree-granting post-secondary institutions in Fall 2000 (NCES 2004-010)*. Washington, DC: National Center for Education Statistics.

Pascarella, E. T., Cruce, T. M., Wolniak, G. C., & Blaich, C. F. (2004). Do liberal arts colleges really foster good practices in undergraduate education? *Journal of College Student Development*, *45*, 57-74.

Pascarella, E. T., Wolniak, G. C., Pierson, C. T., & Terenzini, P. T. (2003). Experiences and outcomes of first-generation students in community colleges. *Journal of College Student Development*, *44*, 420-429.

Pollio, H. R. (1989). *Any questions now?* (Teaching-Learning Issues No. 66). Knoxville, TN: University of Tennessee.

Roberts, G. H. (1986). *Developmental Education: An historical study*: ERIC Document 276 395.

Safford, K. (2000). Algebra for adult students: The student voices. In D. Coben, G. E. FitzSimons & J. O'Donoghue (Eds.), *Perspectives on Adults Learning Mathematics* (pp. 235-255). Dordrecth, NL: Kluwer.

Schoenfeld, A. (1988). When good teaching leads to bad results: the disasters of "well-taught" mathematics courses. *Educational Psychologist*, *23*(2), 145-166.

Schoenfeld, A. (1989). Ideas in the air: Speculations on small group learning, environmental and cultural influences on cognition and epistemology. *International Journal of Educational Research, 13*, 71-88.

Seifert, T. A., Drummond, J., & Pascarella, E. T. (2006). African American students' experiences of good practices: A comparison of institutional type. *Journal of College Student Development, 47*, 185-205.

Seifert, T. A., Pascarella, E. T., Colangelo, N., & Assouline, S. G. (2007). Effects of honors programs participation on experiences of good practices and learning outcomes. *Journal of College Student Development, 48*, 57-74.

Silver, E. A., Mesa, V., Morris, K., Star, J., & Benken, B. (2009). Teaching for understanding: An analysis of mathematics lessons submitted by teachers seeking NBPTS certification. *American Educational Research Journal, 46*, 501-531.

Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal, 33*, 455-488.

Stein, M. K., & Lane, S. (1996). Instructional tasks and the development of student capacity to think and reason: An analysis of the relationship between teaching and learning in a reform mathematics project. *Educational Research and Evaluation, 2*(1), 50-80.

Stein, M. K., Smith, M. S., Henningsen, M., & Silver, E. A. (2000). *Implementing standards-based mathematics instruction*. New York: Teachers College Press.

Stephan, M., & Rasmussen, C. L. (2002). Classroom mathematical practices in differential equations. *Journal of Mathematical Behavior, 21*, 459-490.

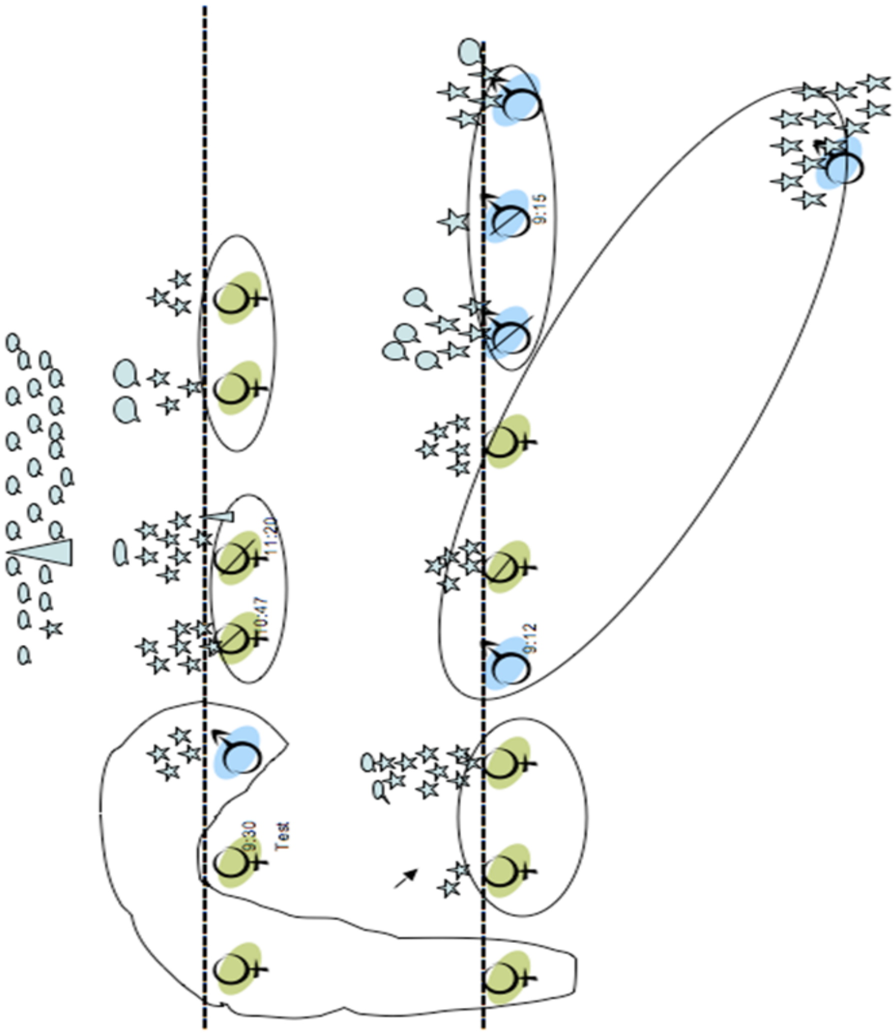
Tobin, K. (1987). The role of wait time in higher cognitive level learning. *Review of Educational Research, 57*, 69-95.

Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). *Looking inside the classroom: A study of K-12 mathematics and science education in the United States*. Chapel Hill, NC: Horizon Research Inc.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*: Cambridge University Press.

Williams, D. (1990). Is the post-secondary classroom a chilly one for women? A review of the literature. *The Canadian Journal of Higher Education, 20*(3), 30-42.

Appendix 1



Map of EA's class, showing a portion of the number of questions asked (bubbles) and answers provided (stars), as well as the gender of the participants. The curved lines show how students organized themselves into work groups.

Appendix 2

Examples of activities from the corpus categorized according to knowledge and cognitive processes.

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual knowledge	**EY**: What is whole number in fraction form? Number 8, what's 8 as a fraction? S: 8 over 1 **EY:** Put t over 1. (625-628)	**ED**: Somebody put this statement in an application: 'I graduated in the top 60% of my high school class' (pause 9 secs) What is he trying to say? S: He is dumber than half, dumber than half of the students **EY:** He is quite far below average is what he is trying to say (201-205)	**EH:** So I can take the 5 out and a 5 out of here. And also the ys. Three of them here… **S**: Five **EH**: So I have five left over in then numerator. (24-27)	**ED**: I'm building a distribution based off of sample means, not individual scores. So I'm using the same scale and plus the first sample mean, the second one, the third one, I keep on doing this for a while (writes on board 7 seconds) and this is what I notice. (pause 8 seconds) What do I notice?	**ED**: Are you satisfied with this answer? **S:** No. **ED**: Why? **S**: You need to subtract from 1.	**ED**: I am going to give you a mirror image of this problem (writes on board 16 seconds). What is a z score at, just make a up a number that makes sense given the problem. **S**: -.9
Conceptual knowledge	**ET**: Why do we use the point slope form in this situation? Do we have the slope of this line? **S:** No. **ET:** d, look at these numbers. **S:** Yes. **ET:** We do have this from part, there it is, part a. 3. We already calculated it. So $m = 3$. Do we have the slope of this? (211-217)	**ET**: what is the interpretation of the 2 and the 4? … What does 2 mean as far as this is concerned? **S:** inaudible **ET:** the slope has to do with the steepness of the line, how steep is the line (40-44)	**ET**: now if you traveled *m* miles, how much would the initial cost be? S; inaudible **ET**: 1.50 times *m*, 1.50 multiplied by the number of miles, that's what they want the total cost (84-87)			

Appendix 2

	Remember	Understand	Apply	Analyze	Evaluate	Create
Procedural knowledge	**EH**: So question says, perform indicated operations of fractions. All right, so first step always with something like this? **S**: Rewrite it **ET**: Rewrite it. (7-11)	**EK**: Can 316% of all Americans vote for a candidate? **S**: No **ET**: No, what's the maximum number? Yeah, only 100%. Right. That's all of them (85-88)	**EH**: All right. So it's a fraction, follows the same rule, right? Lowest common denominator which is? ($x + 6$), (x -5). (writes on board 7 seconds) This one gets an $x + 6$ (write on board 4 seconds) All right, so distributive property. (writes on board 2 seconds) on top. (writes on board 11 seconds) (375-379)	**EH:** All right, so when you check your answer everything looks good? No. What's the problem? **S:** Because if you do 2 - 2 you're going to get a 0 in the denominator and you can't... **EH:** Oh man, wait a minute. So if I plug my answer back in what happens? 2/0 + 2/3 = 2/0. Hum, that doesn't sound good. That sounds really bad. We've got two undefineds in this one, it's like the double undivided. (**Laughter**) **EH:** I don't know what to call it. It just popped in my head. (690-698)	**EY**: A. brought up a good question. She says when you multiply by a fraction you get a smaller number, I'm a little confused. Yeah it's multiplication and you end up with a smaller answer. Normally you're used to when you multiply you get a bigger number, right? Multiply stuff, it multiplies it gets bigger, doesn't necessarily work with fractions. Just be careful, your answer might not intuitively make sense right away if you think of like for half, it could mean half of that, half is going to be smaller. (577-583)	
Metacognitive knowledge	**EN:** Any thoughts on that strategy (pause 3 seconds) It feels pretty good. It feels like it's a nice follow on from what we just did with adding mixed numbers, agreed? Cool (571-573)	**EN:** Again this is my bias, I think this is less work than converting to improper, getting common denominators, subtracting, converting back to mixed numbers and reducing. Somewhere in there you're going to make a math mistake, potentially, so you just need to be careful if that's your method of choice. (775-779)	**EN:** doing the picture sort of cuts to the chase and gives you an idea about that lowest common denominator, right? So if I make my new denominators, (writes on board (3 seconds) how many times larger did I make the first fraction's denominator? **S**: (inaudible) **EN**: So I have to change this by the same factor, so what should this be? (41-44)			