

**Research Commentary: Moving from anecdote to evidence:
The need for a research agenda in community college mathematics education**

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Moving from Anecdote to Evidence:

The Need for a Research Agenda in Community College Mathematics Education

Mathematics education research has, until recently, focused primarily on issues of teaching and learning in K-12 mathematics. In 1999, the Research in Undergraduate Mathematics Education Special Interest Group of the Mathematical Association of America [RUME] was “formed for the purpose of encouraging quality research in undergraduate mathematics education (RUME) and its application to teaching practice”¹. Although community college mathematics intersects both K-12 and undergraduate mathematics, there are phenomena specific to community college mathematics that remain largely under investigated. For example, one of the missions of community college mathematics is to help students obtain the knowledge and skills needed for college readiness. As a result, community college mathematics teachers often find themselves re-teaching mathematical content that students have presumably encountered in previous mathematics courses, yet little is known about how students arrive at an understanding when they are re-introduced to the material. Another group of students, those with an interest in majoring in science, technology, engineering, and mathematics (STEM) and who complete two years of course work at community colleges encounter serious challenges as they transition to university programs (Dougherty & Hong, 2006; Dougherty & Kienzl, 2006). Community colleges also prepare students for vocational work; yet the distinct mathematical needs of these students is not well understood. Research questions within the context of community college mathematics certainly overlap with research at both K-12 and four-year

¹ http://sigmaa.maa.org/rume/Site/About_SRUME.html

mathematics education, but the community college context presents itself as a unique setting worthy of investigation.

In addition, the number of students enrolled at community colleges is making up a large and growing proportion of the undergraduate population nationwide (Lutzer, Rodi, Kirkman, & Maxwell, 2007). As these growing numbers of community college students encounter difficulties in developmental and college-level mathematics courses that can become barriers to transfer and degree completion (Attewell, Lavin, Domina, & Levey, 2006; Bahr, 2010), the proposed research agenda has the potential to influence persistence and completion rates for almost half of undergraduates in the United States.

Members of the Research Committee of the American Mathematical Association of Two-Year Colleges (AMATYC) hosted Working Group sessions at the 14th and 15th Conferences on RUME (February 2011, 2012 Portland, Oregon; Sitomer, Ström, Yannotta, & Mesa, 2011). The sessions brought together over 20 researchers and practitioners interested in investigating questions of mathematics teaching and learning in community colleges. Our initial goal was and has continued to be to outline a research agenda to further our understanding of phenomena that are particular to this educational setting. Advancing this work will inform investigations of undergraduate education at large in the long run.² Participants of the working group sessions included community college faculty-researchers, university researchers, and graduate students in mathematics and higher education.³ The sessions engaged participants in three types of activities:

² There is an emerging body of scholarship among community college faculty. In 2008 AMATYC chartered its own research committee, *Research in Mathematics at Two-Year Colleges* (RMETYC), which comprises community college mathematics education researchers and practitioners. In 2009, the RMETYC committee recognized the need to start the work of outlining a research agenda to better guide the future of research in community college mathematics education. AMATYC publishes a journal, the *MathAMATYC Educator* that features research conducted in two-year colleges.

³ A full list of participants as well as a list of reactors to this document appears at the end of the document.

(1) presentation of historical underpinnings of research movements in mathematics education; (2) discussion of ongoing research in specific areas that are fundamental for community colleges; and (3) guided discussion with the goal of establishing a research agenda for this work. We see this agenda as a tool to spark new collaborations between researchers and practitioners, between mathematics education research and research in higher education, and between these communities and policy makers. In addition, we anticipate that the agenda will generate new knowledge and methodologies to examine the complexity of teaching and learning of mathematics at community colleges. The ultimate goal of research carried out under this agenda is the improvement of mathematics teaching, learning, and curriculum in the community college setting. The working group proposed four research strands of research that we viewed as critical for understanding mathematics teaching and learning in community college mathematics: instruction, students, curriculum, and technology (including e-Learning).

The impetus for this research agenda is twofold. First, we believe that unless we understand the conditions in which teaching and learning of mathematics happens in community colleges, it will be difficult, if not futile, to attempt sustainable changes of current practices, especially given the highlighted attention to community colleges in the public discourse. Concerted and coherent research efforts might advance our knowledge base faster. Second, we believe that we, as researchers and practitioners directly connected with community college mathematics, have the responsibility of setting an agenda that truly reflects our concerns—not doing so would allow for others to impose problems and paradigms of research that are disconnected from the core of our work of ensuring that students learn authentic and valuable mathematics. The work on this agenda will require drawing from various existing theoretical frameworks and methodologies to examine the complexity of teaching and learning of

mathematics at community colleges. All in all, research framed by this agenda should lead to improving student success in mathematics in the community college setting—that is improving both students’ learning of mathematics and students’ progression through the mathematics curriculum.

In what follows we provide background information to contextualize the need for this agenda. In particular we provide information about community colleges in general and in relation to K-12 and tertiary education, and we provide a rationale for the need to attend specifically to mathematics teaching and learning within this setting. We then we introduce definitions for terms we use and describe our lens to understand the particular phenomenon of mathematics teaching and learning in community colleges and the four proposed strands specifically. For each strand, we describe how the major areas that we propose could be investigated and present possible questions that urgently need to be answered.

Background

Community colleges educate over 40% of all undergraduates in the U.S. (Aud et al., 2011; Dowd et al., 2006) and nearly 49% of all undergraduate *mathematics* students at U.S. colleges and universities (Rodi, 2007). Despite this, surprisingly little research exists on community college mathematics education. Historically, community colleges have assumed four functions: (1) academic transfer preparation, (2) terminal vocational certification, (3) general education leading to an associate’s degree, and (4) community education—all of them seeking to accomplish diverse aims: democratic equality, social mobility, and social efficiency (A. M. Cohen & Brawer, 2008). Current shifts in economic organization have even added a fifth function, that of re-training workers for a changing economy, which fulfills a social efficiency

aim. These multiple and competing aims and functions set the community college apart from their counterparts in four-year colleges and universities and, for some critics (e.g., Brint & Karabel, 1989; Labaree, 1997), result in unresolved tensions over the central aims of education in the United States.

Unlike four-year colleges and universities, community colleges operate with open access policies that create classrooms with full- and part-time students of all ages and backgrounds but sharing some common characteristics. For instance, a majority of these students are under-prepared, under-resourced, and have family or work obligations. In addition, the populations at many community colleges also have high concentrations of minorities and women, students with diagnosed and undiagnosed physical and cognitive disabilities and students are English language learners (Goldrick-Rab, 2007; Perin & Charron, 2006). Furthermore, in many states developmental coursework has been relegated to the community colleges, so that students who are in need of these courses must enroll first at the community colleges before they can transfer to a four-year institution. Also, in contrast to other higher-education institutions, faculty in community college are not expected to conduct research but to instead concentrate on *teaching* (Grubb & Associates, 1999). This results in heavy teaching loads (e.g., 4 to 6 courses for an average of 15 credit hours per term for full-time faculty) and more demands for doing administrative work (e.g., serving on college committees). In the same way that post-secondary researchers recognize community colleges as an institution type distinct from four-year colleges and universities, we argue that undergraduate mathematics education research needs to similarly distinguish community colleges as a unique research setting.

Four major differences exist between K-12 and community colleges as post-secondary institutions that often provide obstacles for researchers attempting to apply research findings

from K-12 education to post-secondary education. These differences include: (1) voluntary attendance and greater autonomy of post-secondary students, (2) high prevalence of re-learning for students in community colleges, (3) minimal training in teaching for post-secondary faculty and absence of systems that require continued faculty development, and (4) a culture of academic freedom that limits uniformity among college courses. These differences are largely unexplored in terms of their connection to teachers' ability to provide meaningful opportunities for students to learn and to students' ability to make steady progress in mathematics.

First, engaging in post-secondary education requires students to be more independent and self-motivated than is typically in K-12 school. Attendance in college is voluntary, so students can choose for themselves whether to persist in a course, a degree program, or a particular institution or not. Although faculty, departments, and institutions may have policies regarding mandatory attendance, there are no legal requirements for the students (or their parents) to enforce it. Students are often paying most of the courses that they take at community colleges, and may be more likely to see class attendance as something that may directly further their career and personal goals, and less likely to see it as the result of overt external coercion (except for possibilities of losing financial aid). This results in students attending to community colleges being older and usually more independent than high school students. In addition, they may enroll in fewer courses per term, and as a consequence, they may rarely have the same teacher or the same advisor from one term to the next; because their classes are typically scheduled for fewer hours per week and their courses are typically one semester long rather than a year long, they are less likely to have the same type of support network and may be less integrated into the institution than is typical in the K-12 environment or in four-year institutions.

Second, K-12 and post-secondary teaching and research start with the assumption that students are learning a concept (e.g., fractions, limits) for the first time. But the majority of community college students are more likely to have had a previous exposure to particular mathematical concepts and to have a gap in formal schooling. So they are, in essence, relearning material to which they were already exposed. Testing companies have seen here an opportunity for creating placement tests that help colleges in making decisions about which courses fit better the students they enroll. As open access institutions, community colleges tend to rely solely on placement tests for making placement decisions. Information on the content validity of these tests is proprietary and anecdotal information suggests that in spite of the results of the test, there can be a very wide range of knowledge and skills that students bring to the same level course (Bos, Melguizo, Prather, & Kosiewicz, 2011) and even among “re-learners,” students may be placed in a mathematics course for a variety of different reasons (e.g., unfamiliarity with testing process, deficiencies in one content area, poor mathematical reasoning skills). More so than in the K-12 setting, a teacher may know little about what prerequisite concepts and skills a student may bring to a mathematics course.

Third, community college faculty, on average, have attained higher degrees in mathematics or in mathematics education than secondary school teachers, and are more likely to have mathematics rather than mathematics education degrees (Blair, 2006; Lutzer et al., 2007). Although some research universities have programs for preparing future faculty, a large portion of faculty are untrained in teaching (Speer, Gutman, & Murphy, 2005; Speer & Hald, 2008). This lack of knowledge on teaching can be problematic, specially when dealing with groups of students that are have important deficiencies in mathematics. The knowledge to be able to deploy adequate teaching sequences goes beyond the disciplinary content knowledge. Furthermore, in

contrast to many K-12 teacher requirements, few higher education institutions have ongoing formal professional development requirements, with community colleges notoriously lacking sustained programs for promoting teaching excellence (Grubb & Associates, 1999). Faculty development at post-secondary institutions is often perceived as something that faculty members are expected to do on their own in the same way that they might be expected to conduct disciplinary research independently.

Fourth, these differences in faculty training in teaching and instructors' autonomy in higher education lead to a certain lack of uniformity in curriculum and teaching. Whereas K-12 schools have a requirement to follow local, state or national standards (e.g., the Common Core Standards) explicit regulations concerning which content to focus on and the best methods for delivering this content is not necessarily standardized in post-secondary education. In an attempt to maintain some commonality, some post-secondary mathematics departments may have a unified syllabus for designated classes, a policy for single textbook use, and yet others may have common assessments (including final exams). However multiple visions within a department (Burn, 2006) and a strong tradition of academic freedom can still make uniform change difficult in community colleges. The assumption that faculty members are autonomous and responsible for what happens in the classroom tends to be unwavering in post-secondary institutions. This assumption is largely tied to the notion of academic freedom, and it implies that policies to reform content or instruction cannot be imposed on the faculty in the same way as they are in K-12 settings. To make things more complex, nearly 75% of faculty at community college is hired as part-time, to account for fluctuations in college enrollment. These faculty members less likely to be fully integrated within the institution, to receive less support for teaching, and to be less informed about departmental policies (Grant & Keim, 2002; Roueche, 1996).

These strong differences between the students, teachers, and institutional culture at community colleges versus K-12 schools imply that previous theories developed for K-12 mathematics education will likely not extend to community college mathematics without significant adaptation and revision. And the development of new theories for community college mathematics, or the adaptation of current K-12 mathematics theory will require a significant investment in new research projects that focus on some of the topics outlined in this agenda.

The Role of Mathematics

National attention on community colleges has provided a necessary spotlight for investigating mathematics education. President Obama's (2010) White House Summit on Community Colleges was preceded by a flurry of papers related to community college mathematics (e.g., Bailey, 2009; Rosenbaum, Stephan, & Rosenbaum, 2010; Stigler, Givvin, & Thompson, 2010), authored by people outside the field of mathematics education research and with little to no experience teaching mathematics at community colleges (Gonzalez, 2010; The White House, 2011).⁴ This scholarship refers to aspects of community colleges that, even though important (e.g., economic considerations, access, retention) leave unexplored the one aspect that may determine students' success: their experiences in their mathematics classroom (Mesa, 2007).

Seen as an important component for adult literacy, mathematics is one of the required subjects that nearly all community college students encounter. Some reports, however, suggest that the failure rates in mathematics courses taught at community colleges range from 30% to 70% for developmental and college preparatory courses and from 30% to 55% for college

⁴ A flurry of activity in the White House blog also pointed out the lack of attention to instruction. See for example <http://communitycollege.ideascale.com/a/dtd/Where-are-the-teachers-/77657-10450>.

mathematics courses (Bahr, 2010; Bailey, Jeong, & Cho, 2010; Waycaster, 2001). These failure rates have negatively impacted on the potential to increase our future educated work force by deterring students from further mathematics study that may be necessary for accomplishing their educational goals and our society's work demands. Although individual and institutional characteristics (e.g., prior achievement, ethnicity, family support, financial aid, learning centers, ratio of full- to part-time instructors, etc.) factor into these rates (Bradburn, 2002; Feldman, 1993), it is essential to also understand the impact of mathematics instruction that may contribute to these results, as well as what is possible in community college mathematics classrooms to reverse those trends. For example, it has been proposed that teacher-centered classrooms may be a significant barrier to students persistence in mathematics in post-secondary education (Williams et al., 2009), but it is unclear which of the many aspects composing teacher-centered classrooms is mostly responsible for generating such barriers and how they operate in this new context.

Calls for increasing scientific literacy have been heard at least since the Sputnik scare in the late 50s (Kilpatrick, 1992). In 1996, the advisory committee to the National Science Foundation's Directorate for Education and Human Resources (1996) pointed out that although the United States' basic research in science, technology, and mathematics is world-class, "most of its population is virtually illiterate... Undergraduate SME&T [science, mathematics, engineering, and technology] education is typically still too much of a filter that produces a few high-qualified graduates while leaving most of its students 'homeless in the universe'" (p. iii). Although community colleges are seen as playing a significant role in increasing the number of

students who could pursue STEM degrees in four-year institutions, the staggering figures of failure in mathematics may doom this possibility to failure.⁵

The need for augmenting a STEM work force is not just felt in the transfer function of the community college. Indeed, new jobs requiring some preparation beyond high-school exist now in white-collar offices, education, health care, and high-tech companies, “the signature occupations and industries of the often-cited ‘new knowledge economy’” (Carnevale, Strohl, & Smith, 2009, p. 23). In 1973, only 38% of office workers had some post-secondary education, whereas in 2009, 69% of them did: nearly 40% of all workers had at least a bachelor’s degree, 10% had an associate’s degree, and over 20% had some college but not a degree “making office work one of the most highly educated job sectors” (p. 24). Similar trends had been documented in the education and healthcare sectors. In the technology sector, roughly 86% of workers have postsecondary education: “more than half have at least a bachelors degree, 16% an associate’s degree, and nearly 20% some college but no degree.” More dramatically, even in the factory sector, where the jobs have been shrinking since 1960, the new technology and high-performance work processes allow manufacturers to be more productive using fewer but more skilled workers: whereas in 1973 “only 12% of factory floor workers had any college, [in 2009 the percentage was higher] than 36%, with about 6% having a bachelor’s degree or more, 8% an associate’s degree, and 17% some college but not degree” (p. 24).

Last, but not least, mathematics has been seen as an important element of literacy; a fundamental right that allows full participation in a democratic society (Steen, 2001). Being able

⁵ Research in higher education consistently shows that community college students who successfully remediate and transfer do as well as community college students who do not need to do remediation (Bahr, 2010; Bailey, 2009). In addition, the economic impact, an often cited argument against remediation (Melguizo, Hagedorn, & Scott, 2008) suggests that the difference is negligible in practical terms. However numerous studies suggest that only about 1 in 4 students who first attend a community college transfer to a four-year college (see e.g., Dougherty & Kienzl, 2006).

to operate in a world that is increasingly demanding more quantitative knowledge, “to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of the individual’s life as a constructive, concerned, and reflective citizen” (OECD, 2006, p.72) is becoming mandatory.

In sum, mathematics is a fundamental subject that most students will encounter as they prepare for further education in STEM disciplines, work in careers that provide both a living wage and the potential for professional development and advancement, and to participate fully in a democratic society. The many distinguishing characteristics of the American community college (open access, diversity of student population, small classes) put community college mathematics departments in a position to play a significant role in preparing students for each of these roles. It is our conviction that a research agenda to guide the examination of teaching and learning mathematics at community college will help us better understand that ways that community colleges are preparing students to succeed

Four Strands to Advance Research in Mathematics Teaching and Learning in Community Colleges

Before describing the four strands of research, we present definitions that are used throughout this document. These definitions clarify our use of terms and provide a common language as we engage in this work. We define instruction, authentic mathematical content, curriculum, environments, and student success.

Instruction. We define instruction as the interaction between teachers and students with authentic mathematical content, embedded in particular contexts and evolving over time (D. K. Cohen, Raudenbush, & Ball, 2003, see Figure 1).

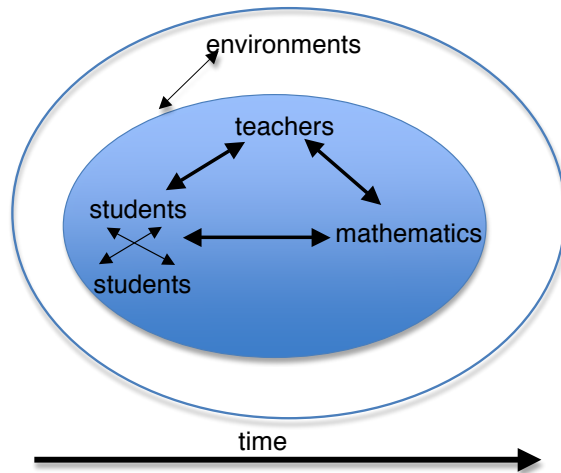


Figure 1: Instruction as interaction Adapted from Cohen et al. (2003), p. 124.

Figure 1 highlights that it is during the day-to-day work in the classroom that all aspects of instruction coalesce to create opportunities for students’ learning through the use of authentic mathematical content and specific teaching practices. This definition allows us to investigate instruction by attending to either individual elements—teachers (what they say, think, and do for planning, enacting, and assessing instruction), students (how and what they learn), mathematics (how it is organized and presented) and environments (how they influence what happens in the classroom)—or to the combination of all these elements. The arrows make evident that what matters is the way in which these elements come together in the classroom.

Authentic Mathematical Content. Besides mathematical concepts, algorithms, and skills, authentic mathematical content includes the disciplinary practices of problem solving, modeling, and reasoning (Blair, 2006; National Council of Teachers of Mathematics, 2000). By reasoning we mean constructing and evaluating both mathematical and statistical arguments, defining, axiomatizing, conjecturing, proving, and describing or using mathematical structures (C.

Rasmussen, Zandieh, King, & Teppo, 2005). In this document we use mathematics, content, and authentic mathematical content interchangeably.

Curriculum. Curriculum is notoriously difficult to define; in this document we see curriculum as more than “textbooks” or the course sequences students take. We use a definition of curriculum from Mesa, Gómez, and Cheah (in press) who combined two traditions of curriculum work in mathematics education (Rico, 1997; Travers & Westbury, 1989). Mesa and colleagues propose that curriculum can be conceptualized as having four dimensions and three levels. The dimensions—conceptual, cognitive, formative, and social—each deals with four fundamental and interrelated questions: “what is knowledge what is learning, what is teaching, and what is useful knowledge” (Mesa et al, in press; see also Rico, p. 386). The levels include the documents that describe each dimension of curriculum (i.e., the intended curriculum), what teachers and students experience in the classroom (i.e., the implemented curriculum), and what students can demonstrate through performance on examinations and other assessments (the attained curriculum, see also Travers & Westbury, p. 8; see Figure 2).⁶

⁶ Here we note that other conceptualizations that take the larger contexts in which curriculum is enacted (e.g., Beyer & Liston, 1996; Lattuca & Stark, 2009) can be embedded within this definition.

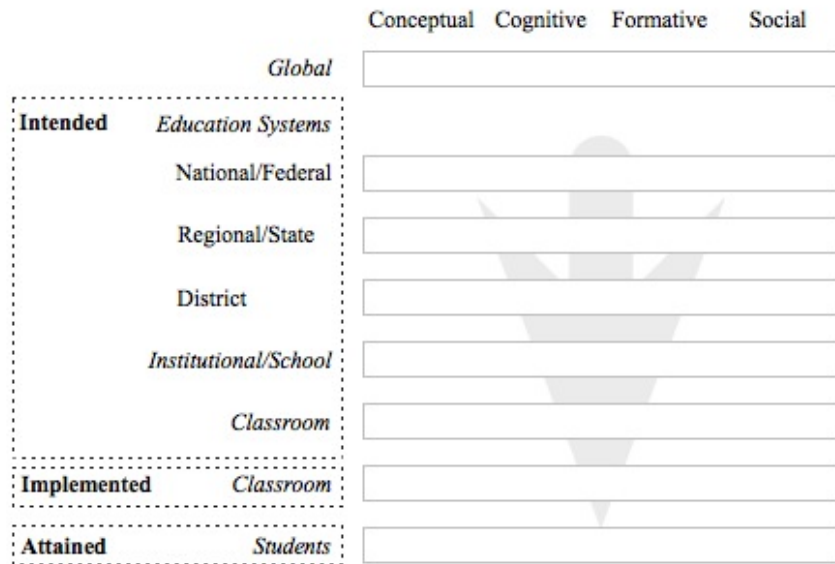


Figure 2: Levels and dimensions of curriculum (Mesa, Gómez, Chea, in press).

Environments. By environments we mean the conditions, factors, and forces within or exogenous to the community college setting that can influence the college and those within it.

Student success. Student success is to be understood as composed of two possibly interrelated aspects: that students learn the material that teachers and departments intend them to learn and that students make steady progress towards accomplishing their academic goals. We believe that by separating learning from progress we can attend to different and important elements of students' experience in college. Given our definition of authentic mathematical content, our vision of student learning of mathematics requires for students to demonstrate mathematical proficiency in the five strands described by Kilpatrick, Swafford, and Findell (2001): procedural fluency, conceptual understanding, strategic competence, adaptive reasoning, and productive disposition. We see student proficiency in these areas as fundamental for demonstrating learning of authentic mathematical content. The second element of success, progress, refers to passing the courses that students take as required by their academic goals.

With these definitions we are ready to present the four strands of research, which we view as critical for advancing our understanding of mathematics teaching and learning in community colleges:

- *Strand 1: Community College Mathematics Instruction.* In this strand we propose work that advances our understanding of mathematics instruction in community colleges. Specifically we propose to investigate teacher knowledge and the nature of classroom interaction, seeking to define faculty development that can be effectively delivered in this particular context, so that mathematics instruction can support students' success.
- *Strand 2: Community College Mathematics Students.* In this strand we propose work that seeks to create a knowledge base of students' understanding of mathematical notions that can inform instructional design; parallel to this we propose investigating the attitudes, motivations, and expectations that students bring to the classroom, and how these are connected to their success.
- *Strand 3: Community College Mathematics Curriculum.* This strand proposes work on different levels of curriculum (intended, implemented, attained), the organization of mathematics programs, the organization of topics within mathematics courses, and the implementation of curriculum in the classroom and their connections to students' success.
- *Strand 4: Technology and Mathematics e-Learning in the Community College.* This strand proposes work that seeks to understand the role and impact of technology—in particular, classroom technology, on-line homework systems and systems for course management, and on-line distance mathematics education—in supporting community college students' success.

In proposing these four strands, we focus primarily on the *teaching* and *learning* of *authentic mathematics* in community colleges. This research agenda is not comprehensive; it

does not map all of the possible research that can be conducted on this phenomenon in this setting. We are purposefully leaving out some aspects that are crucial to the successful operation of mathematics departments in community colleges (e.g., funding, student support programs, and impact of state policies regarding transfer or vocational certification) because we want to understand better what happens in the classroom in community colleges. This also justifies the four areas that we have proposed as all are tied to the definition of instruction making it central to the investigations proposed. We believe that this work will give us insights about whether and how recommendations for reform in the community college can take place and what programs for faculty professional development should look like.

In what follows, organized under each strand, we propose main areas that are fundamental to generate insights that can move us forward to gain a better understanding of how to support mathematics instruction at community colleges with an eye towards ensuring students' success.

Strand 1: Community College Mathematics Instruction⁷

Three areas are fundamental to advancing our understanding of mathematics teaching at community colleges, instructors' knowledge of community college mathematics for teaching (MKT), classroom interaction, and faculty development. Instructors' knowledge of mathematics for teaching encompasses more than disciplinary knowledge; besides knowledge of the content that is taught, it includes knowledge that is fundamental for teaching mathematics (e.g., knowledge of paradigmatic examples, of typical students' misconceptions, or of questions to

⁷ Vilma Mesa, Laura Watkins, Carla van de Sande, Taras Gula, Tim Whittemore contributed to the discussion of this strand.

assess students' understanding). Investigations of teachers' knowledge in elementary education have demonstrated a connection between three elements: mathematical knowledge for teaching (a specialized form of teachers' mathematical knowledge), teachers' enactment of practice, and students' achievement as measured as performance on standardized tests (Hill, Rowan, & Ball, 2005). Teachers who have high scores on test of mathematics knowledge for teaching enact high quality instruction and their students make significant gains in standardized tests (Hill et al., 2005). A main question for those of us interested in instruction at community colleges is the extent to which this connection can be replicated in this setting. The hypothesis that a certain kind of teachers' knowledge matters for what happens in the classroom and what students can learn needs to be tested within the constraints of community colleges. One survey study conducted with community college mathematics faculty in Michigan (Andersen, 2011) found a gap between what instructors say they know about teaching practices that engage students in discussing mathematical content (e.g., cooperative and inquiry-based learning) and what they actually enact in their classrooms; more specifically, Andersen found that knowledge plus a favorable instructor attitude are not enough to predict an instructor's use of those practices, although, unsurprisingly, an unfavorable attitude will predict non-use. The existence of this knowledge-attitude-practice gap suggests that community college instructors face constraints in their teaching that are worth investigating, in particular, because they can be directly related to students' learning of authentic mathematical knowledge and progress to achieve their goals.

A second area that is fundamental to understand instruction, and is connected to the previous area, relates to classroom practice—that is, understanding the norms and the quality of the interactions that occur in the day-to-day work of teachers, how interactions evolve over time, the rationality of teachers' decisions (Herbst & Chazan, 2011), and the extent to which classroom

practice varies by factors such as students' level, type of course (e.g., remedial, vocational, college), or characteristics of the instructor (e.g., gender, status), or college (e.g., size, location). This knowledge can shed light on what elements are fundamental for facilitating students' learning and progress and what can be used to assist faculty in supporting mathematics students. Some studies of classroom interaction in community college mathematics reveal high levels of interaction but limited opportunities for high cognitive demand work (Mesa, 2010). Studies that link classroom interaction patterns to students' learning and progress would be fundamental to support the connection between classroom practice and student success.

While research results are important for the field, they are necessary as long as they can inform of teachers' practice. We see faculty development as the vehicle for this process. Considering that mathematics departments in community colleges require full-time instructors to teach many courses per semester and that they depend on large numbers of adjunct faculty to accommodate fluctuating student enrollment patterns,⁸ one area of urgent attention relates to investigating what could be the nature of programs for faculty development that could support all faculty as they teach mathematics. On-line platforms, participation in programs such as the Project ACCESS (Advancing Community College Careers: Education, Scholarship, and Service),⁹ creating learning communities, or participating in action research projects, need to be systematically studied in order to determine their impact on teachers' knowledge, their classroom practice, and more importantly on student learning of mathematics and in progress to achieve their academic goals.

⁸ The ratio of full-time to part-time instructors in this setting is nearly 1 to 4 in mathematics departments (Lutzer et al., 2007).

⁹ The program has been modeled after the very successful MAA's NExT (New Experiences in Teaching, <http://archives.math.utk.edu/projnext/>). See <http://www.access.amatyc.org/home.htm>

Strand 2: Community College Mathematics Students¹⁰

Three areas related to students are fundamental to advancing our understanding of mathematics teaching at community colleges: community college students' understanding of mathematical notions, their attitudes and motivations, and their expectations of mathematical work in a community college classroom.

Research in mathematics education at all levels has shown that knowledge of typical students' conceptions is a powerful tool that can increase instructors' awareness of how their teaching can support students' learning (Fennema, Franke, Carpenter, & Carey, 1993; C. L. Rasmussen & Marrongelle, 2006). The model of instruction that we use assumes that learning occurs all the time, and suggests that the challenge is to make such learning happen in such a way that privileges a view of mathematics as an evolving body of knowledge that is logical and makes sense. A study by Stigler and colleagues (Stigler et al., 2010) has revealed that community college students who have successfully remediated basic mathematics courses lack number sense, and that they rely on procedures that have little to no connection to representations or to real world situations. In another study, in community college pre-algebra courses, revealed poor understanding of subtraction and its relation to negative numbers and to the opposite of addition and in general a weak sense of structure in mathematical statements (Lande, 2011). Collecting information on how community college students understand mathematics notions is crucial: it can inform practice and it can inform faculty development, in the same way it has informed K-12 teaching. Moreover, this work can be foundational to help us understand how to adapt ideas designed for children to the adult learners that populate community colleges, in particular,

¹⁰ April Strom, Elaine Lande, and Heejoo Suh contributed to the discussion of this strand.

because in this setting many students are re-learning material, rather than learning it for the first time.

In parallel to what students understand, learning how students' motivation towards mathematics influences their success is crucial. Studies in educational psychology research conducted with elementary, middle- and high-school students have established a link between students' motivation and their academic success (Anderman & Midgley, 1997; Friedel, Cortina, Turner, & Midgley, 2010; Kaplan & Midgley, 1999; Middleton, Kaplan, & Midgley, 2004; Patrick, Anderman, Ryan, Edelin, & Midgley, 2001), but the body of work with community college students is minimal. In an exploratory study of students' goal orientations, Mesa (2012) found that community college mathematics students indicate having achievement goals orientations that are consistent with an interest in mastering the content rather than an interest in performing well, that they expect their teachers to press them to do challenging work, and that they tend to avoid engaging in self-handicapping behaviors that can be detrimental to their progress. Their instructors, however, held different views, portraying their students as more preoccupied with performance, pressing teachers to reduce the complexity of the work, and continuously engaging in behaviors that were detrimental to their progress. This suggests a potential mismatch that could be counterproductive in the classroom. Results like these suggest that the relationship between student motivation and success can be more complex in this setting, and that it merits further investigation.

The third piece that is instrumental to understand student success is students' attitudes. Andersen's (2011) and Cox's (2009a, 2009b) studies in mathematics and English respectively, indicate that faculty have experienced students' resistance to instructional practices that are student-centered. Likewise, Sitomer's work (2012) suggests that community college adult

students avoid using their own correct knowledge of mathematical strategies in the context of their mathematics classrooms: similar to the candy sellers in Brazil (Saxe, 1988) these adults create a separation between the mathematics they learn in college and their own knowledge of mathematics in everyday life. Students' attitudes and expectations about mathematics and about its instruction (including norms and involvement) can be barriers to implementing practices that could support students' learning and progress, given our belief of the importance of engaging students with authentic mathematical content. Thus learning what students' attitudes are can inform instruction (e.g., what steps can faculty take in their mathematics classes to ease students into a more pro-active role in learning mathematics) and programmatic work (e.g., programs for both faculty and student development that can be geared to align better what students bring and what they need to do in order to be successful in mathematics) and can result in mathematics classrooms that are more conducive to students' learning and progress.

Strand 3: Community College Mathematics Curriculum¹¹

There are at least three levels in which mathematics curriculum needs to be understood as we situate it in community colleges. The first is at the programmatic level: the sequence of courses that students take to advance their undergraduate mathematical education at a community college. This level includes placement tests. The second is at the course level—that is, the organization of topics within specific courses and the instructional materials that are intended to support student success—learning and progression through the curriculum. The third is at the classroom level, where the intended, enacted, and achieved curriculum come together (Kilpatrick, 1997). We propose investigations at each of these levels.

¹¹ Ann Sitomer, Helen Burn, Kelly Mercer, and Sergio Celis contributed to the discussion of this strand.

The undergraduate mathematics curriculum for the first two years of college for math-intensive majors typically includes at up to three courses of calculus, and may include additional courses in linear algebra or differential equations. For the general education and students in non-mathematically intensive majors, there is presently no clear vision of what the common undergraduate mathematics curriculum should be (David Bressoud, personal communication, January 2012). Other majors and programs for service-oriented or vocational careers may require students to take quantitative literacy courses. This lack of vision squarely affects the courses that comprise the bulk of the community college mathematics curriculum—that is, the curriculum that would successfully prepare students to take these courses: the pre-college courses (college algebra, trigonometry, precalculus¹²) and developmental or remedial courses (typically arithmetic, beginning algebra, and intermediate algebra). Bold initiatives such as Quantway and Statway¹³ have sought to create alternative pathways, with the latter leveraging the national trend towards requiring more students to take an introductory statistics course. Myriad additional initiatives are underway nationwide to reorganize the offerings in the developmental curriculum.¹⁴ Behind these efforts is the intention of proposing a curricular sequence that will be more effective in helping students transition through the mathematics curriculum (e.g., from remediation to college preparatory courses and then through college level courses), and for those students pursuing a baccalaureate degree, transitioning from courses in the two-year program to courses in the four-year program. We know little about what makes these transitions easier or difficult and what curricula (course sequences at least) should look like to support students’

¹² In some states, these courses carry college credit that will transfer to a university, although some university programs may not use those credits as part of any given major.

¹³ www.carnegiefoundation.org/quantway and www.carnegiefoundation.org/statway

¹⁴ http://www.devmathrevival.net/?page_id=8

success. Community colleges, where the bulk of curricular redesign is being conducted, provide a fertile ground for conducting this research.

At the course level we have scant information about the characteristics of course curricula for community colleges and their intended impact on classroom practice and student success. Research on course curricula (e.g., instructional materials such as textbooks) is particularly important given the potential influence they have in shaping faculty course planning (Lattuca & Stark, 2009; Mesa & Griffiths, 2012). A study of college algebra textbooks used in both community colleges and four-year colleges in Michigan revealed that the quality of the textbook examples is low: the vast majority of examples emphasize procedures without connections to concepts of ideas, favor numeric and symbolic representations over graphical and verbal representations, and seek numeric answers only rather than solutions with explanations (Mesa, Suh, Blake, & Whittemore, in press). These findings raise questions about the opportunities for teaching and learning authentic mathematics that these textbooks offer to instructors and students. Other materials defining the intended curriculum (e.g., syllabi, examinations) also offer a fertile field of study.

Last, but not least, learning more about the implemented curriculum, for example, what supports instructors need to successfully use instructional materials in everyday work is fundamental to understanding students' success and to developing programs of community college faculty development in mathematics. As various mathematics education researchers have documented, the materials teachers use as they teach undergo transformations that can be conducive or detrimental to students' learning of mathematics (Silver, Smith, & Nelson, 1995; Silver & Stein, 1996; Stein, Grover, & Henningsen, 1996; Stein & Lane, 1996). These transformations are a natural process of teaching (Brown, 2009; Mesa & Griffiths, 2012;

Remillard, 2005). Thus, the mathematics curriculum that instructors and students experience may have little connection to what authors of textbooks or those interested in bringing more authentic mathematical content to the classroom intend. The diversity of courses taught and of students taking these courses offers an opportunity to understand the different ways in which instructors adapt materials in their classroom and the implications of these adaptations on students' success.

Strand 4: Technology and Mathematics e-Learning in Community Colleges¹⁵

There are three areas that merit substantial attention under this strand: classroom technology, on-line homework systems and systems for course management, and on-line distance mathematics education.

One area of research relates to the use of technology in the classroom. Both the National Council of Teachers of Mathematics (NCTM) and the American Mathematical Association of Two-Year Colleges acknowledge the important role that technology plays in the teaching and learning of mathematics (NCTM, 2003) for “technology changes not only *how* mathematics is taught, but also *when* and *what* mathematics is taught” (Blair, 2006, p. 55). Andersen (2011), citing Huber and National Center For Postsecondary Improvement (1998), indicates that “over eighty percent of community college faculty report that their department has experimented with the use of technology in instructional practice” (Andersen, 2011, p. 20). Indeed, graphing calculators appear to be ubiquitous (nearly 80% of two-year-college Calculus I courses use them, a larger percentage than in four-year institutions, around 50%; Lutzer, 2007, p.25). Despite studies that investigate how graphing calculators (or computer algebra systems) are being used (e.g., Doerr & Zangor, 2000; Hennessy, Fung, & Scanlon, 2001), it is unclear to what extent

¹⁵ Mark Yanotta, Ann Sitomer, Keith Nabb, and Claire Wladis contributed to the discussion of this strand.

these technologies increase students' awareness of connections between representations or introduce misconceptions through its use (Bossé & Nandakumar, 2004; Buchberger, 202; Child, 2002; Drijvers, 2000; Guin & Trouche, 1999; Hoyles & Noss, 1992; McCallum, 2003) or more importantly or how instructors capitalize on these tool while teaching. Other technological tools, accessible both within the classroom and to students outside the classroom, include games and applets that can be used in classroom for teaching or by students to practice skills, on-line video-based tutorials (e.g., Khan Academy¹⁶), free graphing tools (e.g., Geogebra¹⁷), computational knowledge engines (e.g. Wolfram Alpha⁴), and hand-held devices that are also part of students' everyday lives (e.g., smart phones). Yet, it is not known under which conditions they are effective tools that positively influence community college students' success. Pea (1985, as cited in Sherman, 2011) makes the distinction between technological tools as amplifiers and as reorganizers. As amplifiers, these technologies can be used to perform accurately and efficiently procedures that would be both tedious and time consuming. As a reorganizers, the tools can support a shift to something different or beyond what the technology was doing for them (p. 4). Sherman uses this distinction as one lens on technology use in middle school and high school mathematics classrooms and provides an example of investigation of how this knowledge translates into understanding the affordances of the plethora of emerging technological tools are being used in community college classrooms and by students outside the classroom. Not only do these devices hold greater potential than graphing calculators and alleviate some of the restrictions of syntax associated with CAS, they also differ from these technologies in that they are better integrated into students' lives outside of the mathematics classroom. However, little is

¹⁶ www.khanacademy.org/

¹⁷ www.geogebra.org/

⁴ www.wolframalpha.com/

known about how community college students use these newer technological-based aids outside or class and what motivates students to turn to these aids (e.g., is classroom instruction insufficient to support students' understanding?).

Various technologies supporting instruction delivery and students' learning and assessment are playing a significant role in mathematics teaching that merits further studying as they permeate all aspects of classroom work. Anecdotal information suggests a widespread use of course management systems (e.g., ALEKS) and of curricula that allow teachers to generate homework and tests, and students to complete these assessments on-line, often with built-in examples and tutorials. The quality of these systems or whether they make a difference in students' learning of authentic mathematical content and progress in their mathematics curriculum has not been systematically investigated. Faculty descriptions suggest that these systems reinforce procedural fluency and that they fall short of helping students make connections to mathematical ideas. Studies on their impact attend mostly to students' progress but not to students' learning (Trouba, 2012).

Finally, an important area for investigation is on-line learning. In these courses students interact with the instructor regularly on-line to answer questions and solve problems. Some courses may have a face-to-face requirement for instruction or testing. The varied work and life commitments of students attending community colleges make these distance options very convenient, allowing for more students to take courses at their own time and pace. This convenience may account for the exceeding growth rate in on-line learning at community colleges compared to the growth rate at other types of institutions (Allen & Seaman, 2007). It is critical for us to better understand how to effectively teach mathematics on-line in particular because enrollments in on-line courses are expanding rapidly and taking up an ever-increasing

proportion of higher education offerings as a whole, especially at community colleges. The Sloan Foundation recently reported national on-line enrollment growth rates to be 21% annually, over ten times the 2% yearly growth rate in higher education as a whole, and more than 30% of college students now enroll in on-line courses (Allen & Seaman, 2007). In particular, more community college students take courses on-line than students at other types of post-secondary institutions: in a recent nationally-representative poll of 1,434 community colleges, over 60% of students reported taking at least one course on-line (Pearson Foundation, 2010). National data on the number of mathematics courses taken on-line is scarce, since this information is not included in any of the larger NCES or NSF datasets, however Lutzer (2007) reports that compared to four-year institutions, two-year institutions offer more distance learning courses in calculus and statistics:¹⁸ less than 1% in four-year institutions of calculus and statistics sections are offered in distance learning modality, compared to over 5% of sections of calculus and 8% of sections of statistics offered at two-year colleges. In one study of a large urban community college enrolling over 20,000 degree-seeking students, several thousand of which enroll in on-line courses each semester, approximately one-eighth of all courses offered on-line were in mathematics (Wladis, Hachey, & Conway, 2012). There is very little research that looks at what actually happens “inside the classroom” in on-line mathematics courses more generally, much less in on-line mathematics courses at community colleges in particular. This has been an issue not only for mathematics taught on-line, but for the study of on-line courses more generally. What studies do

¹⁸ In the Lutzer (2007) report, “Distance learning courses are defined as those in which at least half of the students receive instruction in a situation in which the instructor is not physically present” (p. 76). More recent literature uses Allan and Seaman’s (2010) standards for classifying on-line courses. Fully on-line courses are defined as those courses where at least 80% of the course takes place on-line, hybrid courses are defined as courses where 30-79% of instruction takes place on-line, face-to-face courses are those in which less than 30% of the instruction takes place on-line. Fully on-line courses seem to be by far the most common of these two modes of instruction at community colleges (Instructional Technology Council, 2010; Jaggars & Xu, 2010).

exist have typically looked primarily at passing rates and have been mainly case studies or small in scale, often conducted by an instructor on his or her own students in a single class or two (Jaggars, 2011; Means, Toyama, Murphy, Bakia, & Jones, 2010). It is unclear how mathematics learning and teaching occurs in the on-line environment, and the extent to which faculty are knowledgeable about effective teaching strategies in this mode of instruction. It would be useful to know what the typical interaction patterns in on-line mathematics lessons are and to what extent the type of learning that occurs is comparable with courses taught in a more traditional face-to-face format. It is also important to know for which students this mode of teaching is most effective and whether or not this mode of instruction is better suited to some courses than others. Knowing this can help students, instructors, and community colleges as they make the case for mathematical education that helps students learn mathematics and successfully progress to achieve their goals.

Coda

In proposing this agenda we hope to have made clear areas in urgent need of attention from various communities: post-secondary mathematics instructors, the mathematics education research community, the higher education research community, and faculty and those involved in faculty development. We believe that tackling these pressing issues requires approaches that are multi-pronged and multi-tiered and that call for multiple perspectives and methodologies, and above all collaboration between representatives of all these areas. Researchers cannot continue to be detached from practitioners, practitioners cannot afford to be unaware of research results that can enhance their work, and policy makers cannot afford to institute policies that do not attend to the work and needs of these two key constituencies. There is a role for all of us concerned with the well being of our community colleges, the students who attend these institutions, and their

success, both in mathematics classes and in using mathematics in future academic work, careers, and as participants in a democratic society.

Appendix:

Participants in the 2011 and 2012 RUME Working Groups and Reactors to the Document

2011 Participants: Tyler Blake (Heritage High School), Helen Burn (Highline Community College), Sergio Celis (University of Michigan), Taras Gula (George Brown College, Canada), Elaine Lande (University of Michigan), Kelly Mercer (Portland Community College), Vilma Mesa (University of Michigan), Carla van de Sande (Arizona State University), Heejoo Suh (Michigan State University), Ann Sitomer (Portland Community College), Susan Stein (Portland Community College), April Ström (Scottsdale Community College), Laura Watkins (Glendale Community College), Tim Whittemore (University of Michigan), Mark Yannotta (Clackamas Community College), Nissa Yestness (Northern Colorado State University).

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Invited Reactors: Maria Andersen (Muskegon Community College), Ann Austin (Michigan State University), Peter Bahr (University of Michigan), Tom Bailey (Community College Research Center), Rikki Blair (AMATYC), David Bressoud (Macalester College), Rob Farinelli (American Mathematical Association of Two-Year Colleges and Community College of Allegheny County), Tim Fukawa-Connelly (University of New Hampshire), W. Norton Grubb (University of California, Berkeley), Erich Hsu (San Francisco State University), Sean Laursen (Portland State University), Karen Marrongelle (Oregon University System), Tatiana Melguizo (University of Southern California), Vanessa Morest (Norwalk Community College), Ricardo Nemirovsky (San Diego State University), Chris Rasmussen (San Diego State University), Jim Roznowski (American Mathematical Association of Two-Year Colleges and Harper College), and Mike Shaughnessy (National Council of Teachers of Mathematics and Portland State University).

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