Two-Year College Mathematics and Student Progression in STEM Programs of Study

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Executive Summary

In spite of the strident pursuit of standards-based reform of two-year college mathematics, implementation of reform has been slow and uneven. National studies show more students are enrolling in two-year college mathematics, but a substantial portion of them are at the pre-college level, and many of these students never reach college-level mathematics courses. A host of issues need to be addressed to improve two-year college mathematics and prepare more students for STEM-related careers. Specific recommendations to support this important goal are:

Take a P-20 approach to reforming the entire mathematics curriculum. Without a strategic, collaborative endeavor, it will continue to be difficult for two-year colleges that are caught between K-12 education and higher education to implement and sustain meaningful change.

More research is needed on the teaching and learning of two-year college mathematics. Finding ways to support two-year college faculty to engage in professional development that reinforces innovative pedagogies is important. Included in this list is contextualized teaching and learning, technologies, and college placement and related assessments that need to be linked closely to classroom instruction.

More research is needed on the students who enroll in two-year college mathematics. More information is needed about how diverse learners, especially women and minorities, experience their initial mathematics courses (pre-college and college level) and how these experiences influence their subsequent enrollment, completion and career decisions.

More and better data are needed to support practitioner engagement in active research on mathematics education. Many two-year faculty would appreciate and benefit from opportunities to engage in active research that helps them to understand how mathematics education impacts the learning of diverse students, and then employ these pedagogical strategies in their classrooms.
Introduction

There is wide consensus that mastery of mathematics is essential to progressing into and through STEM programs of study, yet many students are unsuccessful at navigating the normative mathematics course sequence (Cullinan & Treisman, 2010) that is fundamental to their advancement into STEM-related careers. Recent concerns about international competition and the struggling economy have focused attention on this important issue and renewed concerns about the challenges that many students, particularly women and minorities, face succeeding in mathematics coursework (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2010). Resolving this problem is an urgent priority if the nation is to see growth in student enrollment and success in STEM programs of study, in the placement of graduates in STEM-related careers, and in the prosperity of the global economy.

This paper examines the influence of the two-year mathematics curriculum on students’ progression into and through STEM programs by drawing upon extant literature, materials on the Internet, and personal communication with two-year college mathematics experts and practitioners. It documents the expansive developmental mathematics curriculum offered by two-year colleges and provides insights into the college-level mathematics courses offered by these institutions, a subject that has received relatively modest attention in the literature. The paper begins with a brief historical perspective and then proceeds to address such questions as, What is the status of two-year mathematics courses, Who teaches them, and How are they taught? What standards-based reforms are associated with two-year college mathematics, What curricular and pedagogical innovations are capturing the attention of mathematics reformers, and What do we know about the impact of these reforms on student enrollments and student success? This paper concludes with recommendations for future research, policy and practice on two-year college mathematics that is intended to enhance student progression through STEM programs of study and into STEM-related careers.
Perspectives on Mathematics Curriculum in the Two-year College

A useful framework for understanding two-year mathematics curriculum comes from Cullinane and Treisman (2010) who label the mathematics curriculum in the United States the “normative mathematics course sequence” (p. 7-8), which they claim is ubiquitous to the P-20 (Primary through grade 20) education system. The normative mathematics course sequence begins with basic arithmetic, which is followed by pre-algebra, algebra, and intermediate algebra, and extends to calculus and other calculus-based courses. Geometry may be part of the sequential mathematics continuum, or it may be omitted, to the detriment of students’ advancement into calculus and mathematics-based sciences such as physics. Because this framework represents the dominant schema for which mathematics is taught and for which student competence is assessed in the United States, I use this framework as the basis for discussing the literature reviewed in this paper. Later, in my discussion of two-year college mathematics reforms, I again cite the work of Cullinane and Treisman (2010) who are studying alternatives to the normative mathematics course sequence. First, however, I provide a very brief historical foundation for this paper and then move to contemporary developments in two-year college mathematics.

Liberal arts and sciences courses, including mathematics courses, have been part of the two-year college curriculum since creation of junior colleges in the early 1900s. A. Cohen and Brawer (1982) observed that, by the time two-year colleges arrived on the U.S. higher education scene, the academic disciplines were already “codified” (p. 284) by the rest of the educational system. Junior colleges that emerged to fill the void between high schools and universities adopted the prevailing curriculum structure advocated by the mathematics discipline and were therefore from the start caught in-between the K-12 sector and the four-year college sector. To this end, A. Cohen and Brawer (1982) observed that, “the liberal arts [courses of two-year colleges] were captives of the disciplines; the disciplines dictated the structure of the courses; [and] the courses encompassed the collegiate function” (p. 285). To facilitate the acceptance of college credits at the university level, two-year colleges reproduced the curriculum as well as the pedagogical methods used by universities to which their students sought entry.
Transfer was born from these early replication efforts. A landmark study of junior colleges conducted at mid-20th century by Medsker (1960) confirmed the lengths to which two-year colleges mimicked university curriculum to enhance students’ ability to transfer. He noted, “the junior college forfeits its identity and its opportunity to experiment in the development of a program most appropriate for it” (p. 53). Looking back to the start of the comprehensive curriculum of the two-year college, A. Cohen and Brawer (1982) cited findings from a very early study of 58 junior colleges conducted in 1921 and 1922 by Koos (1924, p. 29) that showed liberal arts, sciences and humanities courses dominated the early junior college curriculum, with three-fourths of all courses representing these disciplines. Across a broad array of the liberal arts and sciences, mathematics represented about 8% of all course offerings. Whereas mathematics was not as dominant as English, communications and the sciences, it was nearly universally offered in the two-year college curriculum. By the late-1950s, a national survey conducted by Medsker (1960) of 230 two-year colleges in 15 states confirmed mathematics courses were ubiquitous to two-year college curriculum, but still, only a relatively modest proportion of students enrolled in them. In fact, only about one-quarter of two-year colleges required their students take at least one mathematics course to meet general education requirements Medsker’s study was also important because it was one of the first to document the prevalence of pre-college courses in reading, writing and mathematics, foreshadowing a phenomenon that would continue to grow to the present day.

Several decades subsequent to Medsker’s study, A. Cohen and Brawer (1987) studied two-year college curriculum and found remarkably similar findings about mathematics course-taking. Their analysis showed 9% of total course enrollments in the liberal arts, sciences and humanities curriculum was in mathematics, and again reflective of Medsker’s results, the survey revealed a high proportion of mathematics courses were at the pre-college1 level. Subsequent studies conducted by A. Cohen, Brawer

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1 Consistent with other literature on two-year college mathematics (see, for example, Blair, 2006), I use the term pre-college to refer to mathematics courses offered below the college level, including courses often referred to as developmental and remedial education courses.
and colleagues, including A. Cohen & Ignash (1992), documented growing enrollment in mathematics, with the largest enrollments in Introductory and Intermediate Mathematics courses that are at the lowest level of the normative mathematics course continuum and below the college credit threshold. However, though enrollments were more modest in courses beyond the Introductory and Intermediate Mathematics level, it is very important to note that two-year colleges were then and continue now to offer a substantial array of mathematics courses at the college level, including advanced mathematics and statistics.

Table 1. Mathematics Student Enrollment Figures and Class Size

<table>
<thead>
<tr>
<th>Mathematics and Computer Sciences Courses</th>
<th>Student Enrollments</th>
<th>Average Class Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introductory and Intermediate Mathematics</td>
<td>786,100</td>
<td>24</td>
</tr>
<tr>
<td>Advanced Mathematics</td>
<td>87,700</td>
<td>20</td>
</tr>
<tr>
<td>Mathematics for Other Majors</td>
<td>99,700</td>
<td>23</td>
</tr>
<tr>
<td>Statistics and Probability</td>
<td>69,000</td>
<td>27</td>
</tr>
</tbody>
</table>


Concerns about the lack of student preparation for college-level of mathematics has been documented since the 1960s and 1970s, including an early report of the Association for Mathematical Association of Two-Year Colleges (AMATYC) on developmental courses offered by 91% of two-year colleges in the United States (Baldwin & others, 1975) and linking remediation to problems with high school students’ academic preparation. In a national survey conducted in the early 2000s, Greene and Foster (2003) found only 32% of all high school graduates demonstrated the level of competence needed to enter college coursework, meaning remediation in mathematics is a necessity for a large proportion of students who enter the two-year college. Among all learners, Greene and Foster identified Hispanics and African Americans as “seriously underrepresented in the pool of minimally qualified college applicants” (p. 3), and they attributed their lack of preparation to inadequate K-12 education rather than “financial aid or affirmative action policies” (p. 3). Their research is representative of a handful of studies that point to the
uniquely important role that community colleges play to address inadequate student preparation and still maintain a robust transfer function that prepares students to matriculate to the university level to support baccalaureate attainment (Arbona & Nora, 2009).

Another important aspect of two-year college mathematics curriculum that has relevance to this discussion pertains to the rise of non-liberal arts curriculum, a trend that began in the 1970s (A. Cohen & Brawer, 1987). Since much of mathematics course-taking in the two-year colleges relates to the majors that students choose in non-mathematics subjects, it is important to understand the ways mathematics is used to fulfill general education requirements. A. Cohen and Ignash (1994) identified the emergence of occupational-technical fields of study (many having STEM-related content) beginning in the 1970s, and they documented the growth of technical education, trades and industrial education, and other programs of study offered by two-year colleges that require various levels and forms of mathematics. Whereas the offering of liberal arts and sciences courses has been relatively robust over the years, the expansion of technical education shifted course enrollments to about 45% non-liberal arts and sciences courses compared to about 55% liberal arts, sciences, and humanities courses by the early 1990s. One implication of this trend is that the teaching of mathematics, which had been the purview of the mathematics discipline, spread to other instructional units. This trend and other critical aspects of the two-year mathematics curriculum, student enrollments in mathematics course sequences from pre-college to college level, and pedagogical approaches are examined in the next section.

**Contemporary Two-year College Mathematics**

Most of what we know about two-year college mathematics in the U.S. comes from a few large-scale national surveys. These studies include gathering and reporting descriptive information about the presence of mathematics courses in the curriculum, the content and instructional strategies associated with all levels of the mathematics curriculum, the backgrounds and expertise of two-year mathematics faculty (full- and part-time), and the instructional strategies these instructors use. Emphasizing the curriculum and instructional delivery primarily, these surveys so not provide information about the students who
enroll in two-year college mathematics. We therefore know very little about student demographics and students’ prior preparation in mathematics and their college majors, interests and aspirations for further study of mathematics or STEM-related programs of study, indicating an important area deserving further research that is mentioned in the recommendations section of this paper.

The fullest depiction of the curricular landscape about two-year college mathematics is the national inventory of the mathematics curriculum in U.S. higher education that is conducted every five years and supported by the Conference Board of Mathematical Sciences (CBMS). The CBMS2005: Fall 2005 Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States is the last published installment of the national inventory results on the two-year college mathematics curriculum (Lutzer, Rodi, Kirkman, & Maxwell, 2007). Fortunately, however, preliminary results of the CBMS national inventory on two-year college mathematics that was conducted in Fall 2010 were shared with me to update this paper (E. Kirkman & R. Blair, personal communication, December 4, 2011).2 Taken together, these two reports (as well as reports associated with prior CBMS surveys) provide the most detailed description of two-year college mathematics curriculum in the U.S., including trends in student enrollments, courses, faculty, and instructional practices.

Table 2 reveals fall enrollments in mathematics and statistics courses at a 5-year interval from 1975 to 2010, with the highest enrollment being the most recent count in Fall 2010 (E. Kirkman & R. Blair, personal communications, December 4, 2011; Lutzer et al., 2007). As of Fall 2010 enrollments in public two-year colleges in the U.S. reached an all-time high of 2,096,000. This enrollment figure represents about a 26% increase from 2005, and it is also noteworthy that the 2005 enrollment figure was about the same percentage higher than 2000. Thus, enrollment growth from 2000-2010 is especially impressive when one takes into account that enrollment figures prior to 2000 included both private and public two-year colleges; 2000 and thereafter the enrollment figures reflected public two-year colleges.

2 I want to express my sincere appreciation to Ellen Kirkman and Rikki Blair for their generosity in sharing preliminary tables from the forthcoming CBMS2010: Fall 2010 Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States.
only. These statistics are also impressive because they suggest, in relation to mathematics enrollment in four-year colleges and universities, two-year college mathematics enrollments are critical to the overall postsecondary education system: *Two-year college mathematics enrollments make up 42% of all postsecondary mathematics enrollments.* These figures take into account dual enrollment, which has been growing over the last decade (Waits, Setzer, & Lewis, 2005); however, they do not take into account mathematics courses taught outside of mathematics disciplinary units, including centralized pre-college education units that are responsible for teaching pre-college mathematics classes. Therefore, these figures almost certainly underestimate enrollments in pre-college mathematics (Arithmetic, Pre-algebra, Elementary Algebra, Intermediate Algebra, and Geometry) and possibly other mathematics-related courses taught on two-year college campuses, suggesting the actual enrollment in two-year college mathematics may be higher still.

Table 2. Enrollments in Mathematics and Statistics Courses in Mathematics Programs in two-year Colleges on 5-year Interval from Fall 1975 to Fall 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Mathematics and Statistics Enrollments in two-year Colleges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 1975</td>
<td>864,000</td>
</tr>
<tr>
<td>Fall 1980</td>
<td>953,000</td>
</tr>
<tr>
<td>Fall 1985</td>
<td>936,000</td>
</tr>
<tr>
<td>Fall 1990</td>
<td>1,295,000</td>
</tr>
<tr>
<td>Fall 1995</td>
<td>1,456,000</td>
</tr>
<tr>
<td>Fall 2000</td>
<td>1,347,000</td>
</tr>
<tr>
<td>Fall 2005</td>
<td>1,739,000</td>
</tr>
<tr>
<td>Fall 2010</td>
<td>2,096,000</td>
</tr>
</tbody>
</table>


Table 3 shows the percentage enrollment in two-year college mathematics courses by type of course by the year the survey data were collected. *Looking at the overall curriculum delivered by two-year college mathematics units, the preponderance of enrollment is at the precollege course level, with a*
persistent percentage of 57% of all enrollments in mathematics units at the pre-college level for the last two decades. Other survey results reveal only modest changes in the distribution of enrollment across the mathematics curriculum since 1990, with a small but persistent decline in enrollment in pre-calculus (college algebra and trigonometry) courses since 1995, a slight drop but also fluctuation in calculus enrollment from 1990 to 2010, and a modest increase in enrollment in statistics courses since 1990 and in other mathematics courses since 1995, including classes for non-mathematics majors (e.g., mathematics for liberal arts and mathematics for elementary school teachers).

Table 3. Percentage Enrollment in two-year College Mathematics Courses, by Type and Year

<table>
<thead>
<tr>
<th>Public two-year College Mathematics Enrollment, by Course Type</th>
<th>1990</th>
<th>1995</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of enrollment in precollege courses</td>
<td>57%</td>
<td>56%</td>
<td>57%</td>
<td>57%</td>
<td>57%</td>
</tr>
<tr>
<td>Percentage of enrollment in pre-calculus (college algebra, trigonometry)</td>
<td>19%</td>
<td>21%</td>
<td>20%</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>Percentage of enrollment in calculus (mainstream calculus I, II, &amp; III; non-mainstream calculus I &amp; II; differential equations)</td>
<td>10%</td>
<td>9%</td>
<td>8%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Percentage of enrollment in statistics</td>
<td>4%</td>
<td>5%</td>
<td>5%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Percentage of enrollment in other mathematics (linear algebra, discrete mathematics, mathematics for liberal arts, mathematics for elementary school teachers, etc.)</td>
<td>10%</td>
<td>9%</td>
<td>10%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>


The national inventory of mathematics also examined faculty and instruction, which is an important issue for two-year colleges where part-time faculty are well documented and an important part
of the teaching workforce (Townsend & Twombly, 2008). The Fall 2005 survey reveals the extent to which part-time faculty are engaged in mathematics instruction (Lutkin et al., 2007), with the percentage of two-year college mathematics sections taught by part-time faculty being 44% (though a percentage was not apparent in preliminary results from the Fall 2010 survey, it is clear that part-time faculty numbers remain high in the 2010 CBMS survey.) Part-time faculty members are most evident at the pre-college level, with 56% of these sections being taught by part-time faculty, and part-time faculty are least involved in teaching of mainstream calculus and advanced mathematics compared to other courses in the two-year mathematics curriculum, with only 12% and 9%, respectively.

These results suggest students taking the advanced college-level mathematics curriculum are most likely to be taught by a full-time faculty, a finding that seems to recognize the importance of advanced mathematics curriculum being taught by professionally trained mathematics specialists as well as the need to align standards with disciplinary requirements that support student progression (transfer) to the university. Noting this advantage, there is little evidence to suggest students who take even the most advanced two-year college mathematics courses intend to continue their study of mathematics at the university level as mathematics or STEM majors. Looking at all the CBMS data for 2005, Lutkin et al. (2007) concluded that few two-year college students intend to transfer to the university and major in mathematics at the 4-year college level, a point that is reiterated in other national studies.

The Fall 2005 CBMS survey data report on instructional approaches that provide insights into how two-year mathematics curriculum courses are taught (Lutkin et al., 2007). These data show over three-quarters of on-campus sections of college algebra and trigonometry, two courses core to the mathematics curriculum for many transfer students, are taught using the standard lecture method. The standard lecture method was less evident in precollege course sections such as arithmetic (64%) and more evident in mainstream and non-mainstream calculus, elementary statistics, differential equations and technical mathematics (calculus), ranging from 81% to 93%. Given that calls for reform of mathematical pedagogy have been made for many years (see, for example, Wubbels & Girgus, 1997 and the authors of
two-year college standards-based reform mentioned in the next section), it is perplexing that so little change has occurred in the teaching of such important two-year college mathematics courses.

Looking at both instructional and outreach methods in the Fall 2005 and Fall 2010 CBMS surveys (E. Kirkman & R. Blair, personal communications, December 4, 201; Lutzer et al., 2007), Table 4 shows nearly universal use of placement testing by the two-year colleges, although the preliminary finding from CBMS2010 showing a 7% drop from 2005 to 2010 deserves further study. Blair indicated she and her colleagues are still exploring the reason for this drop, but point out that all of the 90% of two-year colleges that report diagnostic teaching report requiring placement testing for all incoming students. These results also show an increase in K-12 outreach opportunities and undergraduate research, but a decline in honors sections and special programs to encourage women and minorities to enroll in two-year college mathematics. In terms of the use of distance and online learning, the CBMS surveys show relatively modest use of online instruction, with most courses showing less than 10% of the sections using online learning systems.

Given the dearth of information about student enrollments and outcomes in mathematics, results of a national study by Horn and Li (2009) on postsecondary awards (credentials) below the baccalaureate level provide some insights into the scope and status of degree attainment. Most importantly, this research shows only .5% of all subbaccalaureate awards conferred in 2007 by Title IV postsecondary institutions (public community colleges as well as private for-profit institutions that award credentials below the baccalaureate level and also participate in the federal financial aid) are in mathematics and science fields. Whereas this statistic is alarmingly low, it represents a 11.5% increase from 1997 to 2007. Also, in spite the fact that females earn a majority of all subbaccalaureate credentials, enrollments in mathematics and science by males and females shifted toward males, from 46.9% in 1997 to 50.3% in 2007. Results on subbaccalaureate awards were not disaggregated by discipline and race; however, Horn and Li’s study confirms that most subbaccalaureate awards are conferred to Whites. Among minority groups, Hispanics showed the largest increase (75%) in overall subbaccalaureate conferred awards from 1997 to 2007;
followed by African Americans, with a 54% increase; and Whites with an 11% increase only. Results of national studies by Tsapogas (2004) and Dowd, Malcom and Bensimon (2009) also report the tendency of Hispanics to use the two-year college to pursue science and engineering degrees, though again, these results were not specific to mathematics.

Table 4. Various Instructional Approaches Used in the Two-year College Mathematics Curriculum

<table>
<thead>
<tr>
<th>two-year College Mathematics Instruction</th>
<th>Fall 2005</th>
<th>Fall 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of two-year college mathematics programs requiring diagnostic or placement testing</td>
<td>97%</td>
<td>90%</td>
</tr>
<tr>
<td>Percentage of two-year colleges offering mathematics labs or tutorial centers</td>
<td>95%</td>
<td>UK¹</td>
</tr>
<tr>
<td>Percentage of two-year colleges offering K-12 outreach opportunities</td>
<td>25%</td>
<td>32%</td>
</tr>
<tr>
<td>Percentage of two-year colleges offering honors sections to mathematics students</td>
<td>24%</td>
<td>20%</td>
</tr>
<tr>
<td>Percentage of two-year colleges offering special mathematics programs to encourage minorities</td>
<td>15%</td>
<td>11%</td>
</tr>
<tr>
<td>Percentage of two-year college offering undergraduate research opportunities</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td>Percentage of two-year colleges offering special mathematics programs to encourage women</td>
<td>7%</td>
<td>6%</td>
</tr>
</tbody>
</table>


¹Preliminary data are being recomputed and therefore results are unknown at this time.

Given the need to reach more women, minorities, and other underserved student populations it is not surprising that professional mathematics groups have made recommendations to change mathematics education. Among various groups to respond to calls for reform, the American Mathematical Association of Two-Year Colleges (AMATYC) played an especially important leadership role, as this next section describes.
Reform of the two-year Mathematics Curriculum

Following a wave of reform agendas at the K-12 level, mathematics professionals associated with two-year college eagerly jumped into the discussions. For many years AMATYC has provided guidance to professionals who teach two-year college throughout the United States. Consistent with efforts to improve mathematics education at the K-12 level, most notably the National Council on Teachers of Mathematics (2010) reform agenda on Principles and Standards for School Mathematics, AMAYTIC’s Crossroads in Mathematics (D. Cohen, 1995) and the subsequent Beyond Crossroads (Blair, 2006) initiatives conceived the two-year college position on reforming mathematics curriculum and instruction in community and technical colleges. The premise of “crossroads” identified in the Crossroads in Mathematics (D. Cohen, 1995) is that more citizens need to be prepared for STEM-oriented careers, including the “mathematics, science, engineering, and technology” workforce, but many students who seek a postsecondary education are not adequately prepared to perform at the college level. With respect to college preparation in mathematics, the Crossroads in Mathematics report anchored college readiness in students’ needing the mathematics fundamentals as well as their needing to advance to studying calculus. A statement that captured the major focus of the Crossroads in Mathematics report is that:

More students are entering the mathematics "pipeline" at a point below the level of calculus, but there has been no significant gain in the percentages of college students studying calculus (Albers et al., 1992). The purpose of Crossroads in Mathematics is to address the special circumstances of, establish standards for, and make recommendations about introductory college mathematics. The ultimate goals of this document are to improve mathematics education and encourage more students to study mathematics.

The AMATYC taskforce associated with Crossroads in Mathematics called for a “flexible framework for the complete rebuilding of introductory college mathematics” (p. 5), emphasizing student growth in knowledge of mathematics by enhancing the meaning and relevance of mathematics, the importance of laboratory teaching of mathematics, the use of technology as essential to up-to-date curriculum, “balanced” content and instructional strategies that include “viable components of traditional instruction”, the contribution of mathematics to students’ educational and career options, and the inclusion of diverse students (p. 4-5).
The report also noted three related yet distinct sets of standards: standards for intellectual development, standards for content, and standards for pedagogy. Standards for intellectual development pertain to problem solving, modeling, reasoning, etc.; Standards for content address such topics as real numbers and basic properties, solving linear equations, whole number exponents, quadratic equations, etc.; and Standards for pedagogy include teaching with technology, interactive and collaborative learning, connecting with other experiences, and experiencing mathematics (D. Cohen, 1995). The approach taken in the *Crossroads in Mathematics* report was that all students should grow in their fundamental knowledge of the normative mathematics content, supplemented with probability and statistics.

AMATYC’s second standards document titled *Beyond Crossroads* (Blair, 2006) extended the goals, principles, and standards set forth in the earlier *Crossroads in Mathematics* report by calling for fuller and more strategic implementation of standards-based reform. *Beyond Crossroads* placed more emphasis on assessment of students’ learning and promoting quantitative literacy (a topic discussed more fully later in this paper); meeting the needs of diverse learners; promoting active learning and online learning; promoting professionalism among full- and part-time instructors; and recognizing and involving more stakeholders in implementation of mathematics reforms. This *Beyond Crossroads* report acknowledged the complexity of reforming two-year college mathematics in ways not addressed in the first *Crossroads in Mathematics* text to facilitate “student learning and the learning environment” and encourage faculty, departments, and institutions to improve all facets of two-year college mathematics education (p. 7). Whereas the normative mathematics course sequence was still dominant in the second *Beyond Crossroads* report, the content standards seemed to place more emphasis on the application of mathematics to solve problems and to collect, analyze and use data to help faculty make informed decisions and grow as professionals. Blair (2006) also observed that the *Beyond Crossroads* standards were intended to enhance access to college for undeserved students, noting that two-year college mathematics “holds the promise of opening paths to mathematical power and adventure for a segment of the student population whose opportunities might otherwise be limited” (p. 7).
*College Renewal Across the First Two Years* (CRAFTY) is a third initiative that has focused on improving two-year college mathematics, in this case by focusing on college algebra. CRAFTY recognizes that most college students enroll in college algebra to fulfill a general education requirement and never see the relevance of the subject to the rest of their college education. Very few of these students ever move beyond college algebra to enroll in calculus, a point consistent with the *Crossroads in Mathematics* report. CRAFTY is a subcommittee of the Committee on the Undergraduate Program in Mathematics (CUPM) at the Mathematical Association of America. The project looks at the introductory mathematics courses for the broad range of students who enroll in postsecondary education, most of whom will not be mathematics majors, and it solicits input from disciplinary groups (e.g., biology, engineering, computer science, etc.) on what mathematics departments can do to best prepare students for those disciplines. Ganter and Barker (2004) make recommendations on what reform of early college mathematics instruction should entail. CRAFTY encourages faculty to engage colleagues, college administrators, employers and other local business leaders “to improve the role of College Algebra in our educational system and in the effectiveness of the present programs” (Small, no page no.). The faculty is also encouraged to use small group projects and technology applications that engage students in the active use of mathematics to solve real-world problems.

A companion initiative to CRAFTY led by AMATYC, called “The Right Stuff” (funded by the National Science Foundation) opened the dialogue within the two-year college mathematics community to re-envisioning college algebra and redesigning curriculum to meet the needs of students enrolled in college algebra who might not be calculus bound. AMATYC also administered an initiative called Mathematics Across the Community College Curriculum (MAC3) (also funded by the National Science Foundation) that designed and shared materials that infused the mathematics curriculum with real-world problems and scenarios in collaboration with disciplines outside of mathematics (like science and economics) (R. Blair, personal communication, December, 8, 2011).
Together, these several initiatives – the two AMATYC standards-based reforms and the CRAFTY and MAC3 projects – represent primary strategies to improve two-year college mathematics curriculum in the U.S. All of these initiatives have contributed to a national conversation to reform the curriculum. At a time when mathematics course enrollments have grown at an impressive rate in the two-year college, particularly during the decade of the 2000s, strong consensus has emerged about the need to improve two-year college mathematics as a means of enhancing the STEM pipeline in the U.S. Given the importance of two-year college mathematics to the overall P-20 education agenda of the U.S., it is important to examine two-year college mathematics innovations to lay a foundation for recommending the next steps for research, policy and practice.

**Innovative Approaches to the Mathematics Curriculum**

Many innovations and reforms associated with two-year college mathematics are focused on pre-college mathematics education. In this paper, I acknowledge the critical role that pre-college mathematics plays in the overall postsecondary mathematics course continuum, but my primary goal is to review literature pertaining to college-level mathematics that has been overlooked because of the nation’s preoccupation with remedial education. Studies of the struggles that students face enrolling in and navigating the sequence of pre-college mathematics courses have been immensely important to understanding student success (or lack thereof) in mathematics courses and the larger STEM pipeline. Researchers such as Bailey, Jeong, and Cho (2009), Perry, Bahr, Rosin, M., and Woodward (2010), and many others have laid a foundation for understanding the critical issues associated with pre-college mathematics, but even they have called for more research on the entire two-year college mathematics curriculum, particularly mathematics beyond the pre-college level. Recommendations for rigorous study of mathematics teaching and learning at the classroom level where it may be possible to gain a fuller and more nuanced understanding of the content-based and pedagogically-oriented reforms that can have a positive impact on student outcomes (passing fundamental mathematics courses, matriculating to and
passing more advanced mathematics, and advancing to and through the STEM pipeline) need to be pursued in the future.

An important recommendation that emerged from the AMATYC standards-based reform reports, particularly the 2006 Beyond Crossroads report, that is consistent with the wider national and international conversations to emphasize quantitative literacy and quantitative reasoning as an element of or, in some cases, alternative to the normative mathematics course sequence. A leader in the dialogue about quantitative literacy, Steen (2001) argues that enabling students to use mathematics to solve real-world problems that are complex, ambiguous, and incomplete is the most important thing that college mathematics courses can do. She notes that “rarely will high school graduates be faced with problems that present themselves in the language of algebra” (1992, no date), but just because students don’t appreciate algebra in its traditional forms does not mean that it’s not applicable or useful to them. Steen notes that quantitative literacy is rooted in real data that are part of life's diverse contexts and situations. She believes pedagogy should change to encourage quantitative thought that can help learners “to understand the meaning of numbers, to see the benefits (and risks) of thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning” (2001, p. 58). Students who experience quantitative literacy are empowered to think independently, to ask smart questions, and to confront complexities and challenges with confidence, and, as Steen concludes, “these are the skills required to thrive in the modern world” (p. 58).

Given the importance of this topic, it is unfortunate that the literature on quantitative literacy and quantitative reasoning are disconnected from literature on contextualized teaching and learning, integrated academic and technical curriculum, and problem-based learning. Referring to this collection of curricular and instructional approaches, Perin (2011) described contextualization as the “practice of systematically connecting basic skills instruction to a specific content that is meaningful and useful to students” (p. 3). Her recent review of the literature includes findings of various types of contextualization employed in postsecondary settings, especially pre-college mathematics courses. Baker, Hope, and Karandjeff (2009)
have explored the wide range of definitions that are used for contextualized instruction and to their credit, they tied the practices associated with contextualization to theories of learning and pedagogical strategies. Among the recommendations made by Baker et al. is the importance of exploring alternative formats for delivering the normative mathematics curriculum.

Examples of other innovative mathematics curriculum formats that are being studied include modularization, which involves delivering instruction in manageable segments or “chunks” (Rutschow & Schneider, 2011, p. 25), rather than traditional, semester-long courses. Mostly applied to pre-college mathematics, this strategy of chunking the curriculum could be extended to college-level mathematics. When implemented properly, students can achieve success in shorter time periods than traditional courses, which also motivates them to persist to the next shortened segment. Bailey, Matsuzuka, Jacobs, Morest, and Hughes (2003) evaluated modularization in six NSF Advanced Technological Education (ATE) projects and four centers, and they noted that instructors praised the method for its flexibility and adaptability. The National Center for Academic Transformation (NCAT) Mathematics Emporium model, which Twigg (2011) described as a silver bullet, combines modularization with technology-supported instruction (G. Reese and C. Kirby, personal communication, October 18, 2011).

Another innovation that is being attempted in mathematics, particularly pre-college mathematics, involves compression of the curriculum, meaning compressing the amount of time it takes for students to complete mathematics course sequences, and accelerating them toward their next course or completion. Compression often requires scheduling courses more hours a day for shorter amounts of time, and pairing courses that complement one another, including pairing mathematics and science courses or pairing multiple mathematics courses (including pre-college and college level) to create an intensive learning experience. Though most of the research on compression and acceleration is focused on the pre-college level curriculum, this strategy may be useful to attempt with college level mathematics courses (e.g., college algebra and statistics). For example, two forms of acceleration were used by the FastStart program at the Community College of Denver, wherein FastStart accelerates students through the mathematics
course sequence by allowing students to enroll in a developmental course concurrently with a college-level course. Results from 11 student cohorts who began developmental mathematics at various levels revealed encouraging outcomes on retention and credit accumulation (Bragg, Baker, & Puryear, 2010).

Change of not only how mathematics is taught but what is taught is also important for mathematics reformers. One of the most notable efforts in this regard are the Carnegie Foundation for Learning and the Dana Center’s Quantway and Statway projects (Carnegie Foundation for the Advancement of Teaching, 2011a, 2011b) that are attempting to replace the normative pre-college mathematics courses with mathematics courses focused on quantitative literacy and statistics. Using an accelerated timeframe, the Quantway and Statway projects seek to prepare students for college level mathematics instruction. Statway and Quantway “enable developmental mathematic students in community colleges to complete an accelerated, transferable mathematics course in one academic year while simultaneously building skills for long-term college success” (Cullinane & Treisman, 2010, p. 4). The Statway course sequence assists students to develop statistical literacy and engages them in mathematical reasoning using data, and it provides them with college credit in statistics. Cullinane and Treisman hypothesize that the adoption of a statistics sequence such as Statway will support many more students to engage in mathematical reasoning, especially when the curriculum is institutionalized from K-12 education and to the postsecondary level.

These studies, along with very important research on the ways classroom teaching often relies on textbooks that reinforce the normative math course sequences and traditional pedagogies associated with that subject matter (see, for example, Kays, 2004; Mesa, 2010) provide a valuable backdrop for a discussion of the critical needs that lay ahead as two-year college mathematics educators delve more deeply into reform.

**Recommendations for Further Research, Policy and Practice**

In spite of strident pursuit of standards-based reform of two-year college mathematics, implementation of reform of the mathematics curriculum has been slow and uneven. National studies
show more students are enrolling in two-year college mathematics, but a substantial portion of these enrollments are at the pre-college level, and many of these students never reach college-level mathematics. Thus, the STEM pipeline appears to be widening at the start, which is encouraging, but it also seems to narrow rapidly as students attempt to advance to college-level mathematics, a prerequisite for pursuing STEM programs of study and STEM-related careers.

To facilitate the role that two-year mathematics can play in providing access to the STEM pipeline and preparing larger numbers of postsecondary students, mathematics instruction needs to be sufficiently engaging and useful to support their interest and commitment to pursuing a STEM program of study. A whole host of issues need to be addressed with respect to two-year college mathematics and the preparation of students who seek subbaccalaureate credentials and who desire to transfer to universities in STEM fields. Specific recommendations for research, policy and practice to support this goal are:

**A systemic, P-20 approach is needed to reform mathematics curriculum.** Recommendations offered by different professional groups and at different levels of the educational system are logical, reasonable, and substantive, and equally important, they offer a sufficiently consistent vision to allow for a multi-level yet coordinated P-20 approach. Without such a strategic, collaborative endeavor, it will be difficult for two-year colleges that are caught between K-12 education and higher education to engage in reform, except in isolated ways. Given the national imperative to enhance the STEP pipeline, and the critical role that mathematics needs to play in that work, this recommendation may be the most important of all to emerge from the *Summit on Realizing the Potential of Community Colleges as Pathways to STEM Education and Careers*.

**More research is needed to improve two-year college mathematics instruction.** Although numerous pedagogical strategies are emerging that offer promise to change the way mathematics is taught at the two-year college level, CBMS survey data confirm the prevalence of lecture-led, teacher-centered instruction rather than the sorts of contextualized, problem- and projected-based approaches that support quantitative literacy and quantitative reasoning. Finding ways to support two-year college faculty to
engage in professional development that reinforces innovative instructional reforms is important. Included in this list is the importance of helping faculty to adopt contextualized curriculum and instruction that draws upon students’ everyday life experiences in the workforce, their communities, and other aspects of their lives. Mathematics instructors also need to understand how to integrate technologies to deliver instruction in the classroom or from a distance. In any case, instructors need to understand what evidence-based practices are likely to benefit their students. Moreover, mathematics instructors need to understand how college placement tests can either impede or advance students through the mathematics curriculum. Involving faculty in decisions about assessment may help them to understand how college placement testing impacts student learning, and ultimately, improve student outcomes.

More research is needed on the students who enroll in two-year college mathematics, especially college level mathematics (college algebra and beyond), and how their experiences and performance in college level mathematics courses influences subsequent enrollment, completion and career decisions. Because two-year colleges are the gateway to postsecondary education for diverse learners, these schools have an important role to creating pathways that prepare students to advance to higher levels of postsecondary education. More research is needed to support the study of mathematics pathways, other than the normative mathematics sequence, and to understand how students “develop the ‘habits of the mathematical mind’ that are required to be successful in mathematics and science and engineering and technology courses” (R. Blair, personal communications, December 8, 2011). Students need to know what these new mathematical pathways look like and how they lead to STEM careers, and they cannot be expected to understand or navigate them on their own, without encouragement and support. Systemic change is needed to ensure that all students who have aspirations for STEM careers get the chance to learn mathematics in ways that fully and respectfully support their goals. If the nation expects more women and minorities to participate in STEM programs of study, fulfilling this recommendation is essential.
More and better data are needed to support practitioner engagement in active research on mathematics education at the local level, where two-year college mathematics faculty and other stakeholders engage in the teaching and learning process. Beyond participating in training, many two-year faculty would appreciate and benefit from opportunities to engage in active research that encourages them to try out new pedagogical strategies in the classroom and determine how they impact student learning.

The Equity Scorecard™ and Benchmarking projects of the Center for Urban Education at the University of Southern California provide valuable examples of ways that professional development of two-year college faculty can be integrated with action research to address equity issues for minority students who seek to participate in STEM programs (Baldwin, Bensimon, Dowd, & Kleiman, 2011). The Achieving the Dream initiative has established a strong track record of engaging practitioners in using data to improve pre-college mathematics (Rutschow et al., 2011). Lessons learned from this initiative and other newer ones, such as Pathways to Results in Illinois (Bragg & Bennett, 2011), offer the potential to improve two-year college mathematics and support student success in STEM programs of study.
References


Appendix A

Methods

This paper relies on existing literature available from a number of sources. Most importantly, academic databases were queried to identify peer-refereed articles as well as books, monographs, reports, papers and conference presentations on two-year college mathematics. Databases included in this review were ERIC, EBSCO, Education Full-Text, JSTOR, Dissertation Abstracts, and Sociological Abstracts. In addition Google and Google Scholar were queried to identify relevant documents and materials that appear outside of the traditional scholarly databases. Searches of websites maintained by organizations known to research and publish on the topic of two-year college mathematics were conducted, including the National Center for Education Statistics, the National Science Foundation, the Community College Research Center at Teachers College, and Charles A. Dana Center at the University of Texas at Austin, the AMATYC website, and others. Key words used in these searches included the following words used singularly and in combination with one another: math, mathematics, mathematics education, developmental, remedial, pre-college, algebra, calculus, advanced mathematics, statistics, etc.

Key words used to understand how the scholarly literature situates two-year mathematics curriculum in the broader liberal arts and sciences context included the following: liberal arts and sciences, liberal arts, science, STEM, STEM education, technology, technology education, engineering, engineering education, technician education, etc. Also, to ensure that the full spectrum of literature on two-year colleges was included in this literature review, I used an extensive set of keywords to capture the institutional context, including the following: two-year college, two-year college, community college, technical college, and junior college, and I also entered keywords related to four-year college and university, transfer, and articulation to determine whether literature was available to compare the two-year context to the 4-year context, including transfer.

In addition to the above methods, I reached out to several two-year college mathematics experts, including David Lutzer, Ellen Kirkman, and Rikki Blair, all authors of the Fall 2005 and/or Fall 2010
CBMS surveys. Rikki Blair also served as editor of the 2006 *Beyond Crossroads* report of AMATYC and was an especially thoughtful and gracious contributor. I also sought guidance from several two-year college mathematics practitioners and colleagues at the University of Illinois, including George Reese, Director of the Office of Mathematics, Science and Technology Education, and Catherine Kirby, Assistant Director of the Office of Community College Research and Leadership, who collaborated recently on a literature review on this same topic and brought numerous sources on two-year college mathematics to my attention.