IMPACT

IMPROVING MATHEMATICAL PROWESS AND COLLEGE TEACHING

American Mathematical Association of Two-Year Colleges

AMATYC

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The IMPACT graphic illustrates the ripple effect that a single action can create. All individuals have the power to generate ripples to influence positive change in the mathematics learning environment.

The *IMPACT* document was prepared by a team of dedicated AMATYC members.

AMATYC

OPENING DOORS THROUGH MATHEMATICS

About the Project

Teaching mathematics in the 21st century brings new opportunities and challenges to the mathematics community, especially in the first two years of college. The American Mathematical Association of Two-Year Colleges (AMATYC) has led the way in developing standards for intellectual development, content, and pedagogy. *IMPACT: Improving Mathematical Prowess And College Teaching* builds upon the content of *Crossroads in Mathematics* and *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College*. It is research-based and uses the experiences of individuals invested in mathematics in the first two years of college. Information has been gathered for this document from AMATYC members and others through focus groups, personal interviews, and research by the writing team.

Goal

The goal of *IMPACT* is to improve mathematics education in the first two years of college by presenting clear guidance on how to impact the mathematical prowess of students. This guidance is meant to inspire faculty, departments, institutions, and policymakers to examine, assess, and take action to improve every component of mathematics education in the first two years of college.

Vision

When the ideas of *IMPACT* are implemented, students are empowered to be mathematically proficient and take ownership as they engage in the learning process. Faculty will focus on facilitating student success through building conceptual understanding and developing procedural fluency in each students' chosen mathematical pathway with the support of their institutions.

IMPACT Live!

IMPACT Live! is the interactive online social multimedia portal of AMATYC. Feedback responses from presentations at the 2017 AMATYC National Conference helped shape the ideas regarding the online presence. It will include practical help in implementing the standards and be searchable in a variety of ways, particularly using keywords. It will contain electronic resources in various formats such as blogs, communities, news, lesson plans, worksheets, projects, and videos and will link these sources back to *IMPACT*. It is a portal that will provide opportunities for both synchronous and asynchronous interaction between members as well as a go-to resource.

Previous Standards Documents

Previous AMATYC standards documents can be found at www.amatyc.org by clicking on Publications.

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Final Words

AMATYC's standards merit continuous attention and review. The rollout of *IMPACT* and IMPACT Live! begins the ripple effect for the work on AMATYC's mathematical standards. The standards will remain the same unless changed by the delegate assembly but the presentation and implementation of them will continue to evolve through the work of the Mathematics Standards in the First Two Years of College Committee whose focus is on promoting the AMATYC standards as well as maintaining the digital products to support those standards. This document is written by AMATYC members for faculty, departments, institutions, and policymakers to examine, assess, and take action to improve every component of mathematics education in the first two years of college.

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Contents

Preface

Vision without action is a daydream.
Action without vision is a nightmare.
~Japanese Proverb

What is the Current Vision?

We live in a period where we are inundated with vast amounts of information critical for decision-making. Yet, many adults are often ill-equipped to make sound judgments. Mathematics, thus, is essential for developing informed citizens in the global society. In the United States and Canada, the teaching and learning of mathematics in the first two years of college plays a vital role in preparing individuals to solve problems in their personal lives, on the job, in society, as well as for specialized study in the fields of their choosing. Historically, the role of two-year colleges has included (a) providing general liberal arts education to students for associate degrees for the job market or transfer to four-year colleges, (b) vocational certification, (c) community education for lifelong learning and enrichment (Cohen & Brawer, 2008; Labaree, 1997), and (d) more recently, retraining workers to keep abreast with a changing economy (Mesa, Wladis, & Watkins, 2014).

In recognition of the importance of mathematical sciences for the common good and of the two-year college's role in mathematics education, the American Mathematical Association of Two-Year Colleges (AMATYC) published the forward-looking *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus* (AMATYC, 1995) and redoubled its implementation via *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College* (AMATYC, 2006). The 1995 standards were developed in the context of the calculus reform movement (Douglas, 1986; Steen, 1988) and the *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989). The *Beyond Crossroads* document was driven by a need for broad implementation of the 1995 standards, by an increased awareness of the need for adult quantitative literacy (Steen, 2001), and by educational research that indicated increased learning through student engagement and appropriate use of technology (Faust & Paulson, 1998; Hassi, Kogan, & Laursen, 2011; Hassi & Laursen, 2009, 2015; Khoshaim, 2012; Meyers & Jones, 1993).

Why the Need for a New Standards Document?

AMATYC provides leadership in the mathematics community for improving mathematics teaching and learning in the first two years of college throughout the United States and Canada. In particular, through *Crossroads in Mathematics* (AMATYC, 1995) and *Beyond Crossroads* (AMATYC, 2006), the organization has led the way to improve mathematical experiences for both students and faculty in the first two years of college. AMATYC views the development of standards as part of its ongoing process to strengthen mathematics education. In order to maintain their viability and currency, such documents must be reviewed and refined periodically. *IMPACT: Improving Mathematical Prowess And College Teaching* builds on the thinking behind the standards of the previous documents while encouraging the exploration of new frontiers in mathematics education. The addition of IMPACT Live!, the online extension of *IMPACT*, provides a platform for continuous sharing of initiatives and best practices.

Over the past two decades, research in the mathematical sciences has increased and broadened, revealing a world increasingly dependent on mathematics. The "demand for people with strong mathematical science skills is already growing and will probably grow even more" (National Research Council [NRC], 2013, p. 16). Increasingly, professionals in a variety of fields are "presented with the challenges and opportunities of large-scale data analysis and mathematical modeling" (NRC, 2013, p. 116). In ever-growing ways, the tools of mathematics continue to be used in a multitude of fields such as building trades, medicine, military science, communication and information science, and by physical and occupational therapists, social workers, artists, architects, and graphic designers.

In response to these developments in the mathematical sciences, and in the world at large, school and collegiate mathematics have changed significantly since AMATYC published *Beyond Crossroads* in 2006. As K-12 mathematics standards have evolved to integrate the Common Core initiative (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA Center & CCSSO], 2010), a need has emerged to reevaluate the teaching and learning of mathematics in the first two years of college. The changing roles of topics such as developmental mathematics, statistics, modeling, and pathways have been reexamined through collaboration among faculty at local, state, and national levels.

At the K-12 level, in 2010 the NGA Center & CCSSO released the Common Core State Standards for Mathematics (CCSSM). This set of recommendations has influenced mathematics education in the United States. Its recommendations for K–12 mathematics education include a focus on reasoning and problem solving, increased emphasis on modeling and statistics, and a balance among concepts, procedures, and applications. Its large-scale implementation and associated assessments are influencing *what* mathematics is taught and *how* mathematics is taught. As these standards and related assessments evolve, Common Core continues to have widespread impact.

As the students progress through education structured according to the Common Core standards, it was apparent that higher education needed to change as well. Subsequently, at the collegiate level, three recent reports represent significant landmarks in the evolution of undergraduate mathematics in the United States:

- *Common Vision for Undergraduate Mathematical Sciences Programs in 2025*, edited by Saxe and Braddy (2015) and published by the Mathematical Association of America (MAA) in collaboration with AMATYC, the American Mathematical Society (AMS), the American Statistical Association (ASA), and the Society for Industrial and Applied Mathematics (SIAM)
- *GAIMME: Guidelines for Assessment and Instruction in Mathematical Modeling Education*, published jointly in 2016 by the Consortium for Mathematics and Its Applications (COMAP) and SIAM
- The *Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report 2016*, published in 2016 by the ASA. This report updates the original *GAISE College Report* (Garfield et al., 2005)

These three documents demonstrate a general recognition that "the status quo is unacceptable" (Saxe & Braddy, 2015, p. 4), that statistics and modeling deserve increased emphasis, and that new curriculum choices are needed to meet the mathematical needs of many college students. AMATYC, AMS, ASA, MAA, and SIAM agree that this innovative mathematical curriculum needs to deemphasize lecture, to increase the use of active student-centered learning (Conference Board of the Mathematical Sciences, 2016), to make connections to other disciplines, and to engage students in written and oral communication and the meaningful use of technology. As a result, initiatives have begun in the areas of statistics and modeling, developmental mathematics, pathways, and collaboration has started between AMATYC and other organizations.

The increased need for the emphasis on statistics and modeling is actually demonstrated by the data itself. Of the 156 Common Core high school mathematics standards, 61 (nearly 40%) are standards in modeling or statistics. From 2010 to 2015, the number of students taking the AP Statistics exam rose by more than 150% to nearly 200,000 students. At U.S. colleges and universities, from fall 1990 to fall 2015, undergraduate enrollment in statistics courses more than tripled from 223,000 to 711,000 students. The increase from fall 2010 to fall 2015 alone was 41%, and of the 711,000 students enrolled in statistics, 35% were at two-year colleges (Blair et al., 2018). Moody's Mega Math (M^3) Challenge is an example of an initiative in modeling. It is an annual competition for high school students. It began with 572 students competing in 2006. In 2015, it had grown to nearly 7,000 competitors. Seeing the need to offer a similar opportunity for students in the first two years of college, AMATYC created the Student Research League in 2017. The competition entails finding a solution to an open-ended problem using mathematical modeling as well as researching careers related to the focus of the problem.

An example of an initiative in developmental education involves a collaboration between AMATYC, the National Association of Developmental Education (NADE) and the MAA. Together these groups sponsored national summits on developmental mathematics in 2013, 2016 and 2018. These summits brought together a wide range of professionals to share the latest findings in mathematics education research and development concerning students who enter college underprepared to pursue college-level mathematics.

Over the past decade, many two-year colleges have also used institutional and national data to determine that developmental students' persistence to an associate degree within eight years is consistently around 25% (Bailey, 2009). This startling statistic inspired two-year college leaders, researchers, and policymakers to explore possible solutions to improve students' outcomes to and through the first college level course (Bailey, Jaggars, & Jenkins, 2015; Hodara & Jaggars, 2014). Rethinking mathematics education in first two years of college is the current focus (Saxe & Braddy, 2015). What is it now? What should it be?

Research (Charles A. Dana Center, n.d.) related to curriculum and program development in mathematics education at the two-year college level has initiated the reexamination of courses in mathematics that align with a student's program of study. Institutions of higher education across the country are redesigning their mathematics programs to offer multiple pathways to help students achieve their intended goals.

There are currently three curriculum redesigns, referred to as pathways, which are being implemented nationally:

1. The statistics pathway is designed for students pursuing nursing, social work, and criminal justice.
2. The quantitative reasoning pathway focuses on fields such as communications, graphic design, and paralegal studies.
3. The traditional STEM pathway intended for students entering fields such as physics, chemistry, mathematics, computer science, and engineering.

Another promising development is the growing collaboration between high schools and colleges. This collaboration has included standards alignment, precollege interventions, improved placement practices, and dual enrollment, whereby students can earn college credits while still in high school. Dual enrollment has expanded from about 80,000 students in 2010 to 94,000 students in 2015, a 17.5% increase (Blair, Kirkman, & Maxwell, 2018). While school-college collaboration is not without challenges, such partnership inspires movements such as seen in *Seizing the Moment: Community Colleges Collaborating With K–12 to Improve Student Success* (American Association of Community Colleges, Association of Community College Trustees, & Higher Ed for Higher Standards, 2016), which aims to ease the transition from secondary to post-secondary education on all fronts, not just mathematics.

Transforming Post-Secondary Education in Mathematics (TPSE Math) is an expanding collaborative effort by leaders in mathematics education across the United States. Collaboration between AMATYC and TPSE Math smooths the transition from two-year to four-year colleges and research institutions. This initiative fosters work among a wide range of stakeholders that now includes community colleges "to effect constructive change in mathematics education at community colleges, four-year colleges, and research universities" (TPSE Math, 2017, para. 1).

Taken together, these developments call for a rethinking of the first two years of college mathematics: what it is now, and what it can be and should be in the future. New mathematical pathways are needed, ones that incorporate statistics, modeling, and meaningful use of technology, that deemphasize lecture, and actively engage students. This view is supported by the vision statement for TPSE Math, which W. E. "Brit" Kirwan quotes in his foreword to the Common Vision: Postsecondary mathematics should "enable any student, regardless of his or her chosen program of study, to develop the mathematical knowledge and skills necessary for productive engagement in society and in the workplace" (Saxe & Braddy, 2015, p. v; TPSE Math, 2017). The transitions between both secondary and post-secondary institutions with two-year colleges must remain smooth so that students receive a seamless, quality mathematics education.

What is the Renewed Vision?

The standards set forth in *Crossroads in Mathematics* and reinforced in *Beyond Crossroads* were visionary and remain current today. Nonetheless, there are serious challenges facing mathematics education; fortunately, they are tempered by an unprecedented spirit of collaboration across educational institutions and professional organizations. Various stakeholders are working with AMATYC to implement student-centered mathematics instruction that is both effective and efficient. Moreover, there is ample research evidence that engaging students in problem solving, reasoning, and sense making will yield improved mathematical proficiency, statistical proficiency, and quantitative literacy. By continuing to work with other stakeholders, faculty who teach mathematics in the first two years of college can develop bridges for students from their current state of mathematical understanding to a deeper level.

The vision presented in *IMPACT* is to improve mathematics education in the first two years of college by presenting clear guidance on how to impact the mathematical prowess of students. This guidance is intended to inspire faculty, departments, institutions, and policymakers to examine, assess, and take action to improve every component of mathematics education in the first two years of college. AMATYC and its membership will engage in this renewed vision to positively impact undergraduate mathematics education.

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Chapter 1

Making an IMPACT

Generating the Ripple Effect

You think you're just a drop in the ocean…
but look at the ripple effect one drop can make!
~Anonymous

When asked why they have chosen teaching as a career, faculty will often say it is because they want to have an IMPACT on students and their future. Have you, however, pondered over how you IMPACT your students? Consider the following

- A one-semester course with 30 students that meets three times a week for fifteen weeks is equivalent to 1,350 opportunities to IMPACT students.
- With these opportunities, in each semester, when teaching three classes, you will have 4,050 chances to IMPACT students.
- In a two-semester academic year, you will have 8,100 opportunities to IMPACT student success.

Now, that's IMPACT!

YOU have a tremendous IMPACT on shaping mathematics education in first two years of college!

YOU have a tremendous IMPACT on the mathematical literacy of a large number of students!

YOU have a tremendous IMPACT on the quantitative capacity of workers in workplace!

The intent of this document is to support your efforts to make a positive, meaningful, and long-lasting IMPACT! It is through the stories of students like Ana that we can see the positive effect a teacher makes in the lives of students.

Ana started her higher education path at a community college, with the intent to transfer to a university. After her first semester, she applied for a work-study position as a student aide for a math faculty member. He had a kind disposition and he ran his classes and interactions with his students in such a fashion that Ana could tell that his first priority was student success. This often meant addressing the anxiety that comes from struggling in mathematics. While Ana and other students attended his office hours, the instructor watched how well Ana tutored the other students and how much she enjoyed it. Before long, he walked her to the tutoring center and told the manager that *he had to hire her. She spent hours helping students with their math at every level, from basic mathematics through calculus. The most common comment she heard was that she explained the topics so well that the students wished Ana was their teacher. After a year of peer tutoring, with encouragement from the math instructors at her school, Ana decided to become a teacher. She switched her major from psychology to mathematics, transferred to the University, and after a few years, a couple of kids and a marriage, she earned her Bachelor of Science in Mathematics and began teaching as an adjunct faculty member at the community college she had attended as a student. Again, with encouragement from her colleagues to get a master's degree, she completed an intensive one-year master's program in Teaching and Teacher Education. She applied for a full-time position the year she graduated with her master's degree and she has been teaching full-time at the community college where it all started.*

Now Ana has the opportunity to similarly impact her students. If she had not been encouraged by the faculty at her community college, she might never have found her passion to teach mathematics.

Addressing Societal Changes

Teaching mathematics in the twenty-first century brings new opportunities and challenges to the mathematics community, especially in the first two years of college. Compared with previous generations, today's college students are "... more pragmatic. They say their primary reason for going to college is to get training and skills that will lead to a job, and let them make money" (Levine, 2012, para. 6). These students are immersed in an age of rapidly changing technology. The internet has been their social platform for commerce, inquiry, media engagements, and digital play. Yet, are today's students critical inquirers? Do they know how to research the internet while checking the credibility, reliability, and validity of information? Information on the internet, whether truth or fiction, provides the opportunity for students to be exposed to more diversity and global issues than any generation before them. This changing technology also increases the number of high-tech jobs for which training in these positions requires mathematical competency. It is critical that colleges create a mathematics learning environment that will captivate students' interest. The environment must empower them mathematically to succeed in a vast array of life opportunities.

As our society continues to change and evolve, so must our approach to teaching mathematics in the first two years of college. By building upon AMATYC's historic standards documents *Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus* (AMATYC, 1995) and *Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College* (AMATYC, 2006), the organization continues its legacy and leadership within the professional mathematics community with the release of this document. Both *Crossroads in Mathematics* and *Beyond Crossroads* form a solid foundation for the introduction of the four pillars of PROWESS in *IMPACT*: *Improving Mathematical Prowess And College Teaching.* These two sets of foundational standards undergird and permeate these pillars as well as the various chapters in this document.

PROWESS in Mathematics

The word "prowess" references extraordinary ability as well as distinguished bravery. AMATYC has created four pillars of PROWESS as an innovative way to enhance our students' mathematical ability and bravery through recommendations for continuous improvement of college teaching in the first two years of college. These pillars are

PR	proficiency
OW	ownership
E	engagement
SS	student success

As a result of focusing on these four pillars, AMATYC intends to foster mathematical PROWESS in all students by:

- Presenting multiple instructional approaches that will build mathematical proficiency as well as student ownership of learning (Chapters 3 and 4).
- Providing guidance to faculty to design and implement instructional programs that foster mathematical prowess in students (Chapters 3, 4, 5, and 6).
- Sharing successful models of redesigned mathematics curricula that will revitalize faculty and departments to engage in meaningful conversations as well as implement evidence-based strategies, courses, and programs (Chapters 7 and 8).
- Informing policy makers and legislators of the needs and challenges ahead for students and institutions and subsequently helping to implement policies that will lead to student success (Chapters 7 and 8).

AMATYC seeks to provide guidelines to inspire and challenge you and other stakeholders to take action to develop PROWESS in students. Every component in mathematics education (such as instruction, curricula, and assessment) as well as those who make decisions that affect the teaching and learning of the discipline (such as faculty, departments, institutions, policy makers), should focus on PROWESS. The impact will be *a ripple effect of change in mathematics learning environments* (as depicted in the cover graphic). Whether you are a faculty member, an administrator, or a policymaker, you can have an impact on student success in the first two years of college mathematics for thousands of students. Would you join AMATYC in broadening your impact by implementing this renewed vision for **Improving Mathematical Prowess And College Teaching**?

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Chapter 2

Who Are We?

Finding Our Voice

Perhaps because of their unique design as American institutions, community colleges have often been bellwether institutions for change, leading the way into new and unexplored territory.
~K. Patricia Cross (O'Banion, 1997, p. ix)

For the ripple effect of change to occur, utilizing the four pillars of PROWESS, there needs to be an understanding of the role of two-year colleges and collective diverse voices it represents in the complex national education system. For educational systems to function, the levels—primary, middle, secondary, and post-secondary—need to work together. At the same time, each level must embrace its unique role. Within these levels, there is also the need for collaboration among the specific academic disciplines in order to develop a cohesive path for students on their journey to becoming educated citizens. Many studies on teaching and learning in general, including higher education, have been conducted. However, one area that has received insufficient attention regarding its role is two-year colleges (Mesa, Wladis, & Watkins, 2014). For two-year colleges, the way mathematics is taught presents a unique set of challenges. By examining mathematics curricula, student and faculty characteristics, and student academic goals, we can continue to make progress in fostering mathematical prowess and improving teaching in the first two years of college mathematics. Who are we? Collectively we are a united body of mathematics educators—AMATYC—whose intent and devotion is to provide a national forum for the improvement of mathematics in the first two years of college (AMATYC, n.d.).

A Look at Our Students

Did you know that in the fall of 2015 in the United States, 40% of the 17 million undergraduates were enrolled in two-year institutions (National Center for Educational Statistics [NCES], 2015a)? Between 2015 and 2026, undergraduate enrollment at two-year colleges is projected to increase by 21%, while enrollment at four-year institutions is likely to increase by 9% (McFarland et al., 2017). This projected increase follows a recent decrease in enrollment numbers. Data from the Integrated Postsecondary Education Data Systems (IPEDS) indicated that, from 2010 to 2014, there was a 4% decrease in enrollment of full-time undergraduate students and a 2% decrease of all undergraduates at public two-year colleges. This paralleled a 5% increase in enrollment of full-time undergraduate students and a 3% increase of all undergraduates at public four-year universities (Ma & Baum, 2016). When limited to enrollment in mathematics and statistics courses in mathematics program, the trend from 2010 to 2015 was similar (i.e., a 4% decrease). This decrease followed a 10-year increase in enrollment numbers in mathematics courses at two-year colleges (Blair, Kirkman, & Maxwell, 2018). In addition, according to the National Student Clearinghouse Research Center (NSCRC, 2017), in the 2013-14 school year 46% of four-year college graduates had attended a community college at some point. In fall 2015, approximately 42% of all higher ed mathematics students were enrolled in United States public two-year colleges (Blair et al., 2018). As faculty members at two-year colleges, we are involved in the education of a large diverse student population; thus we teach students who have a variety of mathematical skills, a wide array of personal backgrounds, and a variety of academic goals.

In fall 2015, about 2.5 million two-year college students were full-time students; four million were part-time (Ginder, Kelly-Reid, & Mann, 2017; NCES, 2015a). It is important to note that one challenge unique to community colleges is getting a better understanding of the experiences of part-time students. In general, research on both part-time and full-time students' educational experience is premised on the notion of fixed classification: that is, both student groups enroll in a fixed number of credits in a semester (American Association of Community Colleges [AACC], 2016). However, the Community College Survey of Student Engagement has cautioned that part-time and full-time should not be viewed as fixed classifications because of their fluidity (Center for Community College Student Engagement [CCCSE], 2014). In reality, two-year college students may begin college as either part-time or full-time students and then switch while others move between the two classifications multiple times throughout their college experience. Understanding the changing nature of enrollment practices of students is important in better understanding the experiences of part-time students.

Almost all two-year college mathematics programs (94%) offer diagnostic or placement tests; however, in fall 2015, only 75% required placement tests of students who are first-time enrollees. This percentage was a 25% decrease from the 100% of mathematics programs that required placement tests in fall 2010 (Blair et al., 2018). Nearly 60% of U.S. students who take mathematics in college begin in pre-college non-credit-bearing courses, with more than 80% of them having initial enrollments in such courses at two-year colleges (Mills, 2016). Not all students take placement exams, but among those placed into developmental mathematics, research with data from Achieving the Dream Community Colleges suggests that "more students exit their developmental sequences because they did not enroll in the first or a subsequent course than because they failed or withdrew from a course in which they were enrolled" (Bailey, Jeong, & Cho, 2010, para. 1). Bailey et al. (2010) also found that of the students who were advised to enroll in a remedial course, less than 50% completed the entire remedial sequence and about 30% did not enroll in a remedial course.

Course enrollment trends appear to be changing in mathematics at two-year colleges, possibly as an impact from accelerated pathway programs that were designed to provide alternative course and sequences such as from or to a college-level mathematics or statistics course. Data from CBMS indicated a decrease in the percentage of two-year college students enrolling in pre-college-level courses (−32%; 368,000 fewer students) from 2010 to 2015 with an increase in the percentage of students enrolling in precalculus-level courses (21%; 77,000 more students) and Elementary Statistics or Probability Courses (104%; 143.000). Regardless of those changing numbers, enrollment in pre-college level courses remains high. From 2010 to 2015, the majority of the 1,918,000 two-year college students accounted for in the CBMS fall 2015 survey were enrolled in Intermediate Algebra (high school level; 299,000), College Algebra (above Intermediate Algebra; 292,000), Elementary Algebra (high school level; 277,000), and Elementary Statistics (with or without Probability; 251,000). There also was an increase in enrollment numbers in Calculus courses (11% increase; 15,000 more students). In fall 2015, a total of 193,000 students from 58% of colleges that participated in the CBMS study had enrolled in a Pathway course. Distance learning courses account for 12% of all mathematics enrollment with the largest enrollment in distance learning in College Algebra, Elementary Algebra, Intermediate Algebra, and Statistics (Blair et al., 2018).

Two-year colleges attract many students who historically have been underrepresented in science, technology, engineering, and mathematics (Mills, 2016; Smith, 2016; NSCRC, 2017). These students are more likely to face severe obstacles to success. From AACC (2017), we find that in the United States in 2015, 56% of two-year college students were women; in 2011-2012, 36% of two-year college students were in the first generation in the family to attend college; 17% were single parents; and 12% were persons with disabilities. Most two-year college students were employed. In addition to their studies in 2011-2012 22% of full-time students and 41% of part-time students have full-time jobs, and 40% of full-time students and 32% of part-time students have part-time jobs. Because of the lower tuition rates, many students with little to no income attend two-year colleges to further themselves toward a better socioeconomic life.

The two-year college student population is ethnically diverse. In 2015, in the United States about 60% of both Native-American and Hispanic undergraduates were enrolled in two-year colleges, as were more than half of black undergraduates (NCES, 2016). The general ethnicity of the students at two-year colleges nationwide is depicted in Figure 1.

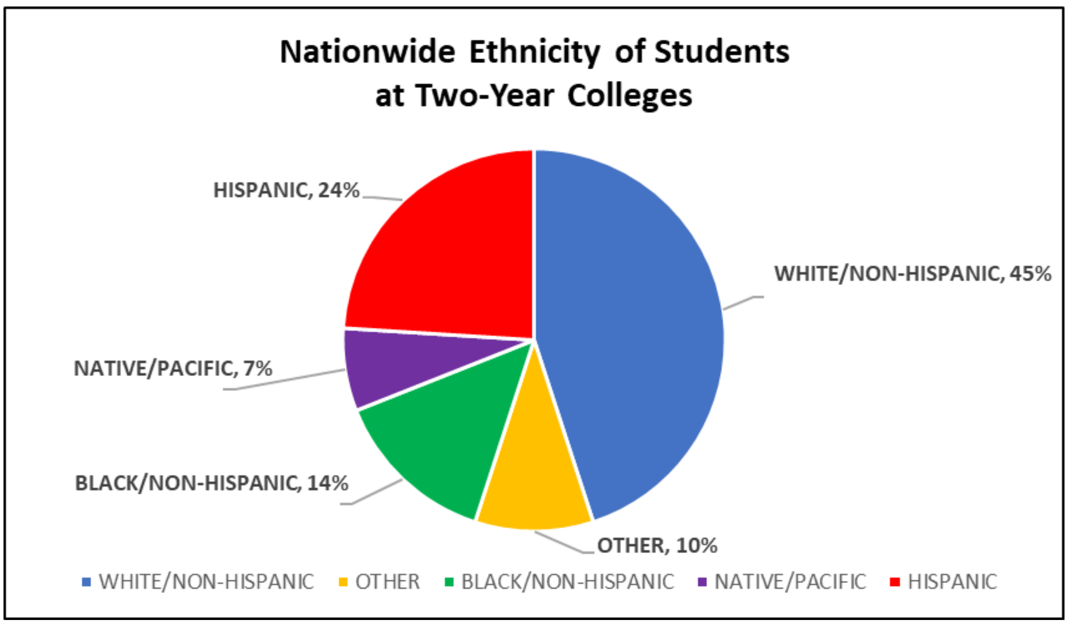

Figure 1. Nationwide student ethnicity of two-year college students (AACC, 2017).

The demographics at each college may be different, since the students served by your college usually represent the demographics of your local community. Three examples of the demographics of students at different colleges around the country are shown below. The pie charts show that there is no such thing as a typical student at a two-year college.

Miami Dade College, Florida is the largest institution of higher education in the country. Its eight campuses offer more than 300 educational pathways to a career. Since its founding more than half a century ago, the college has admitted more than two million students. During the 2014-2015 school year, the institution served one of the most diverse student bodies in the nation: 165,000 students from 191 countries, speaking 90 languages.

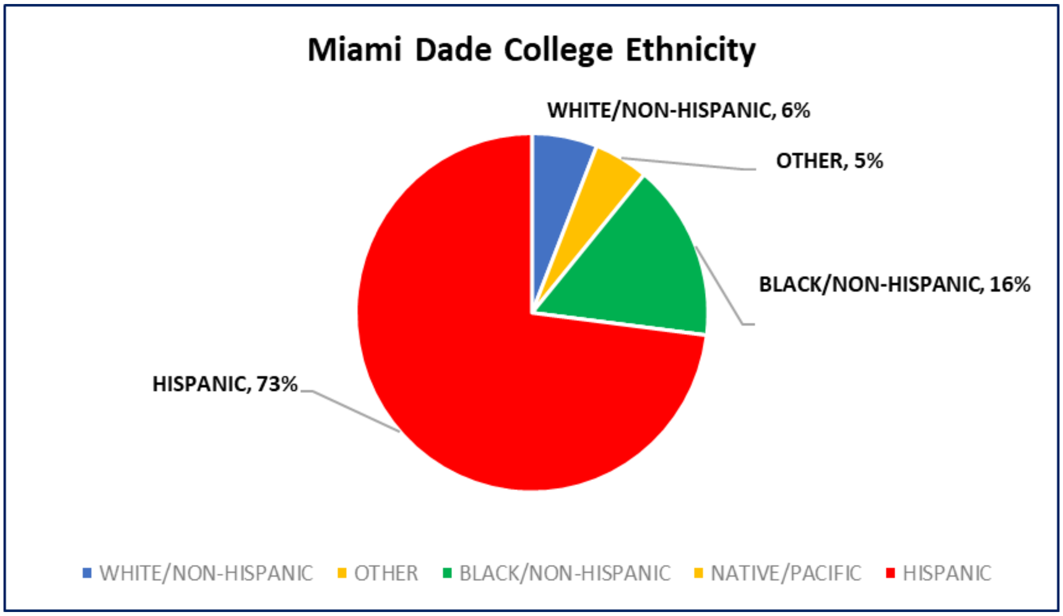

Figure 2. Miami Dade College (2015) student ethnicity.

The Maricopa County Community College District is one of the largest community college systems in the nation, comprised of ten regionally accredited colleges that serve a diverse student body in the greater Phoenix, Arizona area, including Chandler-Gilbert, Estrella Mountain, Gateway, Glendale, Mesa, Paradise Valley, Phoenix, Rio Salado, Scottsdale, and South Mountain. Approximately 200,000 students enrolled in credit and noncredit courses at a Maricopa Community College in 2015-2016.

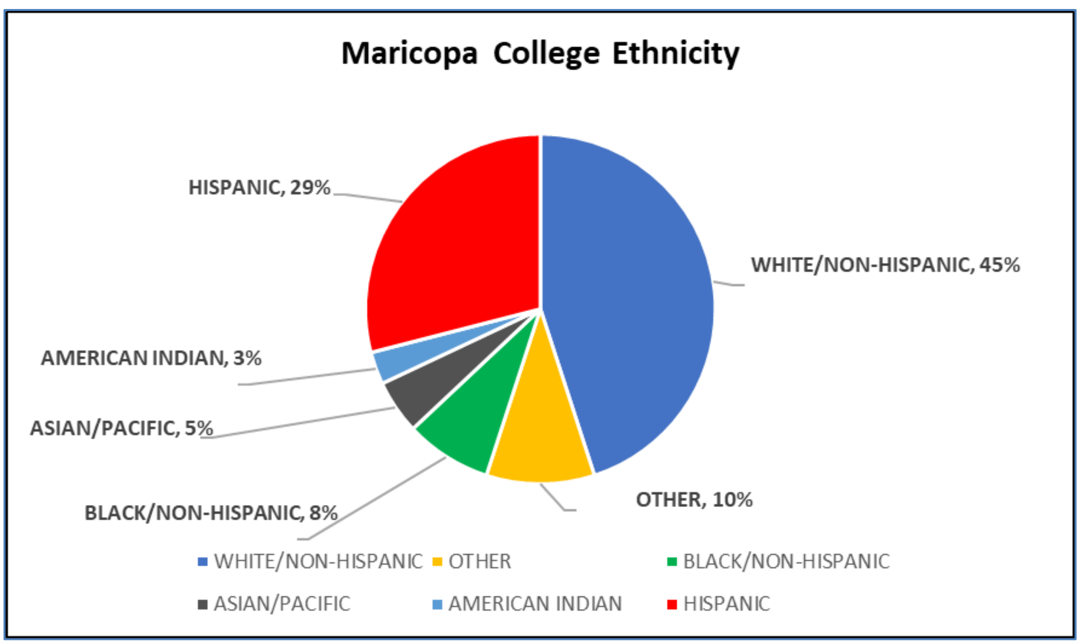

Figure 3. Maricopa Community Colleges (2017) student ethnicity.

Coconino Community College, Flagstaff, AZ, has served residents across the 18,000 square miles of Coconino County since 1991 and helped create the region's skilled workforce, which is improving the overall health, safety, and the economy in the region. The unduplicated headcount in 2015-2016 was 5,480.

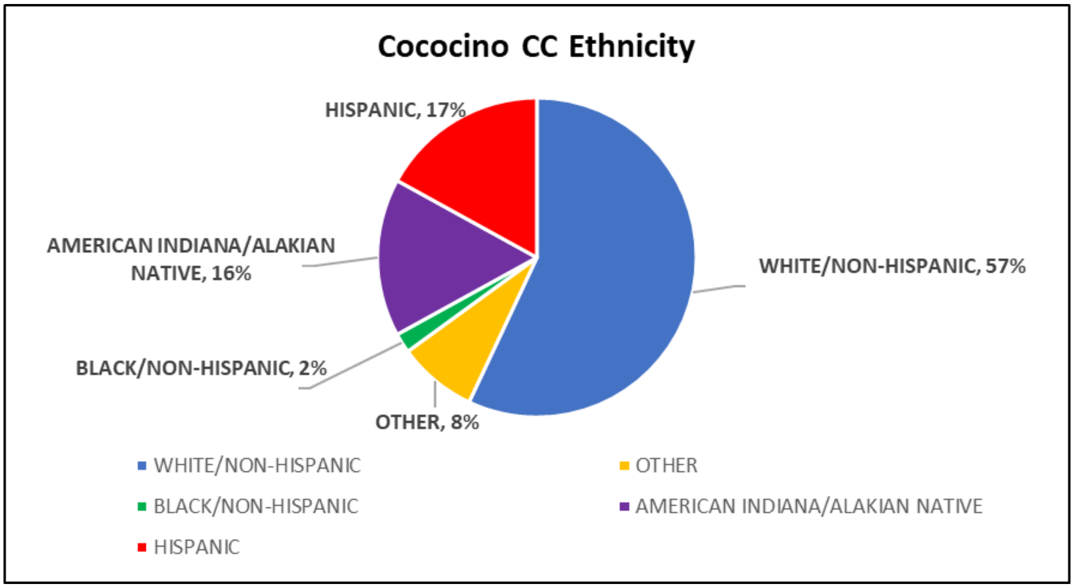

Figure 4. Coconino Community College (2016) student ethnicity.

These demographic characteristics highlight real students, each with their own story. One of them is Eddie, whose story is similar to that of many community college students.

Eddie and his parents arrived in San Fernando Valley, CA from Sofia, Bulgaria. He learned English quickly since his parents spoke none. He once remarked, "I had to be their translator for just about everything—setting up cable TV, calling the gas company, filling out DMV paperwork." Eddie was accepted to the University of California, Los Angeles (UCLA) through the Guaranteed Transfer Option program, where students attend a community college of their choice for two years, and then automatically transfer to UCLA without applying, as long as they kept a GPA above 3.5. Eddie chose Los Angeles Pierce College. While at Pierce, he obtained his first job, a mathematics tutor at the tutoring lab. While working as a tutor, he helped a student with hearing impairment to understand a problem and the big picture of concepts. "My mind was made up that day. I was going to be a math teacher," Eddie said. Eddie is currently the mathematics department vice-chair and the Math Specialist at Pierce's Center for Academic success. The opportunities available at two-year institutions for Eddie and others from diverse backgrounds are invaluable.

A Look at Our Faculty at Two-Year Colleges

The faculty at community colleges account for a large part of the faculty in higher education. In 2013, 24% of all higher education faculty taught at two-year colleges; one fifth of this number worked full-time at a public two-year college. Although the part-time faculty represented 37% of all higher education faculty, they represented 70% of two-year faculty, according to the National Center for Educational Services (2015b). CBMS fall 2015 survey data indicated that 67% of two-year college faculty were part-time and, when third party payees were omitted, 65% were part-time. In 2015, 64% of part-time faculty members were teaching six or more hours but fewer sections (36%) were taught by part-timers. Full-time permanent faculty members' weekly contact hours increased with an average of 18 contact hours per week in fall 2015 compared to 15 hours in fall 2010. Some faculty members were teaching more than 19 contact hours per week (Blair et al., 2018).

In regards to gender and ethnicity, two-year colleges have a slightly different mix of faculty. Women comprise 54.8% of two-year college mathematics faculty, compared with 45.9% in four-year colleges and universities (NCES, 2014a). Those findings were in alignment with results from CBMS 2015 (52%) (Blair et al., 2018). Even though the ethnic minority faculty population is increasing, the majority of full-time permanent mathematics faculty are white (non-Hispanic; 75%) and 40 or older (75%). Ethnic backgrounds of two-year college faculty were as follows: 8.6% Black (compared with 5.2% for four-year colleges and universities), 5.5% Hispanic (vs 3.9%), 3.5% Asian (vs 8.0%), 0.4% Pacific Islander (vs 0.2%), 0.6% American Indian/Alaska Native (vs 0.4%), 0.7% two or more races (vs 0.7%), 4.5% race or ethnicity unknown (vs 4.5%) (NCES, 2014b).

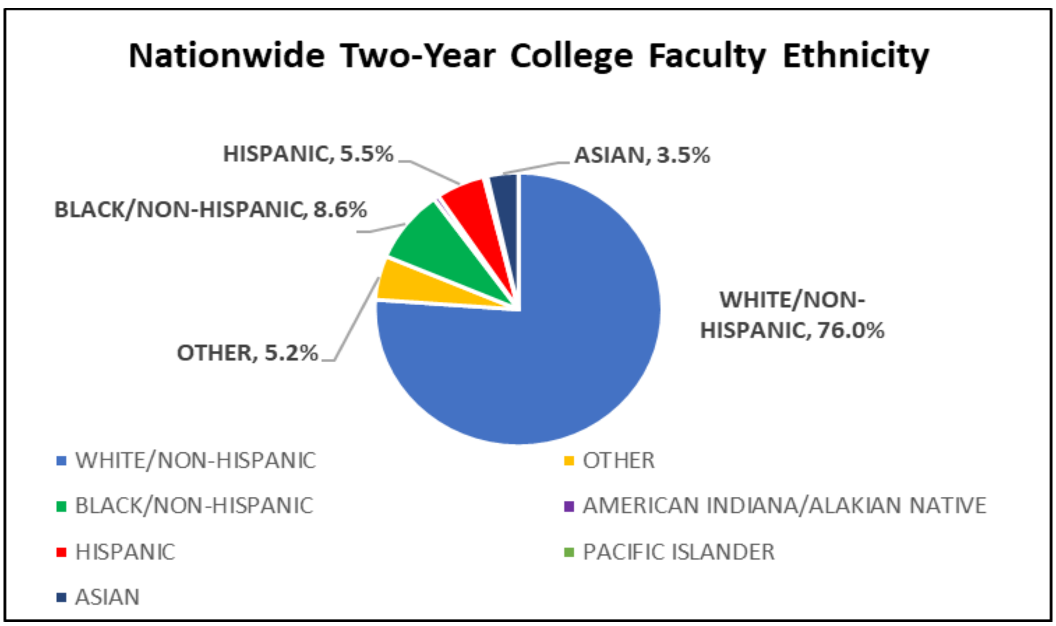

Figure 5. Nationwide two-year college faculty ethnicity (NCES, 2014b).

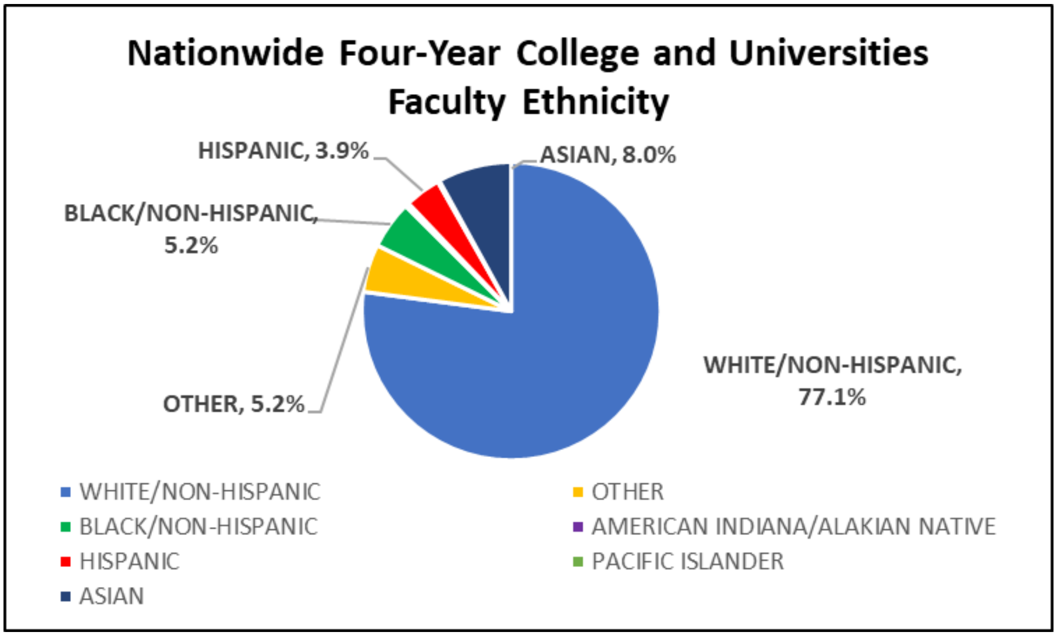

Figure 6. Nationwide four-year college and universities faculty ethnicity (NCES, 2014b).

Faculty educational background and work history are also different from counterparts from four-year colleges and universities. The majority of mathematics faculty have a master's degree as their terminal degree (80% of full-time permanent faculty; 76% of part-time faculty) and 15% hold a doctoral degree. Seventy-three percent (73%) of full-time permanent faculty and 58% of part-time faculty have a degree in an academic major in mathematics (Blair et al., 2018). The primary source of new hires of two-year college faculty is graduate school (37%) followed by part-time or full-time temporary employment at the same college (26%) and teaching at other two-year colleges (19%); secondary sources include four-year colleges and universities (4%), unemployed (4%), secondary schools (1%), and nonacademic employment (1%) with 9% unknown (Blair et al., 2018). This may suggest that becoming a two-year college faculty member is a primary career goal and not just a fallback option.

As with students, examining overall demographic data masks the stories of individual faculty members. Julie is another example of a community college student who became a successful two-year college faculty member.

Julie's start with mathematics was not a positive one when she failed algebra in her first year of high school. When she later attended Indian River Community College (now Indian River State College) in Florida, somehow her College Algebra teacher convinced her she was one of his very best mathematics students. Due to his intervention, Julie became confident enough to become a mathematics tutor and a high achieving student in addition to being a college athlete and a musician,. She has an earned doctorate, and is now a mathematics professor at Valencia College, and has been honored with a long list of local teaching awards and national accolades as well as being invited to be involved with a plethora of national initiatives. Julie's journey demonstrates the impact that community colleges and a caring faculty have on students. Her understanding of the community college student and of the importance of individual faculty actions helps keep the ripple effect of IMPACT moving through her students.

AMATYC's Voice for Change

Two-year colleges make up almost 1,700 of the 4,700 degree-granting postsecondary institutions (counting branch campuses as separate institutions) (NCES, 2014c). While we have many commonalities with four-year institutions, we also have a specific niche, and thus voice, in higher education. The basic mission of a two-year college is to provide education to residents in their locality. The culture of a two-year college usually reflects the culture of the local community. The goals a two-year college typically include academic and vocational instruction at the lower division level, remedial instruction, and lifelong learning. In addition, many of these colleges allow for open admission access, provide education at an affordable cost, and have small class sizes (Pannoni, 2015).

The diverse demographics of two-year colleges and consequently the challenges that faculty may encounter in teaching, provide opportunities for them to be more innovative in their vocation. AMATYC continues to support educators by providing leadership in improving mathematics teaching and learning in the first two years of college throughout the United States and Canada. The global society, technological advances, social media, diverse workplace skills, changes in K-12 education, and innovations in brain and learning science are influencing teaching and learning of mathematics. Thus, we have the opportunity to IMPACT mathematics education in the first two years of college, and beyond.

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Chapter 3

Proficiency
Developing Students' Mathematical Knowledge

Time spent leads to experience, experience leads to proficiency, and the more proficient you are the more valuable you will be.
~Malcolm Gladwell (2008)

Students in the first two years of college are taking mathematics courses that range from basic arithmetic to differential equations. It is important that no matter the course, the primary learning outcome ought to be mathematical proficiency, the first pillar of PROWESS. Irrespective of a student's academic pursuits, mathematical proficiency is a critical component of being a productive member of society. Achieving such an outcome has a positive ripple effect. Consider Risa, a student who attained proficiency in mathematics through the help of her teacher.

Risa began her college career at a community college by taking Intermediate Algebra and, like many students, learning mathematics did not come easily for her. As a result, she was convinced that she did not have a mathematical mind since she had struggled with mathematics for as long as she could remember. During this college class the professor would lecture on the concepts and emphasize the memorization of formulas and steps to solving problems such as linear equations. Risa often asked, "When will I ever use this?", to which the instructor would respond saying that "you'll need to use this in your next math course." For Risa, this was simply insufficient for motivating her to learn mathematics. After not succeeding in Intermediate Algebra, she retook the course from another instructor, Dr. Boote, who had a very different approach to teaching students. In contrast to Risa's previous teacher, Dr. Boote focused her instruction more on making the mathematics come alive through embedding mathematical concepts within real-world contexts. For example, when learning about linear functions, Dr. Boote used the comparison of cell phone plans. "For Plan A, the initial set up charge for a cell phone plan was $25 with an additional monthly charge of $69 for unlimited data usage. For Plan B, the initial set up charge was $55 with an additional monthly charge of $59 for unlimited data usage. Which plan will be cheaper after one year? Which plan will be chapter after five years? When will the plans cost the same amount?" Dr. Boote not only embedded the mathematics within a context that was meaningful for students, but she

also probed students to justify their thinking and model the mathematics to help build a conceptual understanding. In the past, Risa had only experienced linear functions through algebraic representations, devoid of context, which added to her struggles in trying to understand the behavior of linear growth. Risa learned the "how, why, and where" a concept would be used which helped her to build a deeper understanding of the mathematics, even if it was not an area that she was going to study in the future. She used this idea of connecting classroom topics to applications in future courses. She has since earned a master's degree in sociology and teaches at a two-year college. With Dr. Boote's guidance, Risa was able to become mathematically proficient and succeeded in reaching her goals.

Characterizing Mathematical Proficiency

Dr. Boote realized that for Risa to be mathematically proficient she needed to do more than just learn mathematical procedures and that proficiency in mathematics is multifaceted. However, what does it mean to be mathematically proficient? In AMATYC's Crossroads in Mathematics, the Standards for Intellectual Development addresses desired modes of student thinking and presents goals for student learning outcomes. They identified seven specific areas of focus:

- problem solving
- modeling
- reasoning
- connecting with other disciplines
- communicating
- using technology
- and developing mathematical power (AMATYC, 1995).

Through the lens of the Standards, proficiency is characterized more broadly by not only adherence to these areas, but additionally by correctly navigating a mathematical procedure and perceiving mathematics as an enriching and empowering discipline.

In its 2001 book, *Adding It Up: Helping Children Learn Mathematics*, the National Research Council (NRC) defines mathematical proficiency as a multifaceted model with five interdependent strands essential to the learning of mathematics

- Conceptual understanding: comprehension of mathematical concepts, operations, and relations.
- Procedural fluency: skill in carrying out procedures flexibly, accurately, efficiently, and appropriately.
- Strategic competence: the ability to formulate, represent, and solve mathematical problems.
- Adaptive reasoning: the capacity for logical thought, reflection, explanation, and justification.
- Productive disposition: the habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy (p. 11).

These five areas were key components to the development of the Common Core State Standards for Mathematics (CCSSM) and the Standards for Mathematical Practice (SMPs), a variant of mathematical proficiency (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA Center & CCSSO], 2010). The SMPs are endorsed by the National Council of Teachers of Mathematics (NCTM) and state that students should be able to

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Construct viable arguments and critique the understanding of others.
- Model with mathematics.
- Use appropriate tools strategically.
- Attend to precision.
- Look for and make use of structure.
- Look for and express regularity in repeated reasoning (NGA Center & CCSSO, 2010, p. 6-8).

Though not all states have adopted CCSSM, a number have similar standards and outcomes. Together, the AMATYC Standards for Intellectual Development, NRC's strands for mathematical proficiency, and the mathematical practices from CCSSM, paint a picture of mathematical proficiency that goes beyond developing procedural fluency. In *IMPACT* we develop a new definition unique to the teaching and learning of mathematics during the first two years of college. CCSSM highlights *focus, coherence, and rigor* as essential principles for effective mathematics teaching and learning. *Focus* intends that faculty teach fewer topics than they have traditionally taught, *coherence* emphasizes building knowledge and understanding of mathematics within and across grades, and *rigor* aims to balance procedural fluency, conceptual understanding, and applications of mathematics (NGA Center & CCSSO, 2010). To expand on the notion of rigor, NCTM (2014) provides a definition of procedural fluency in their position statement

> Procedural fluency is a critical component of mathematical proficiency. Procedural fluency is the ability to apply procedures accurately, efficiently, and flexibly; to transfer procedures to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or procedure is more appropriate to apply than another. To develop procedural fluency, students need experience in integrating concepts and procedures and building on familiar procedures as they create their own informal strategies and procedures. Students need opportunities to justify both informal strategies and commonly used procedures mathematically, to support and justify their choices of appropriate procedures, and to strengthen their understanding and skill through distributed practice (para. 1).

Proficiency in Mathematics: An Example of Number Sense and Fraction Operations

One of the missions of the two-year college is to provide pre-college level content courses, such as developmental mathematics, for students as they remediate on critical topics necessary for college-level mathematics. Students often enter the community college with deficiencies in their understanding of fraction operations, as well as number sense. Thus, it is an important goal of two-year colleges to help students build their mathematical proficiency with fractions. Consider the following example that illustrates the mathematical ideas that can be leveraged to facilitate students' development of proficiency with fractions.

When thinking about understanding fractions, students are encouraged to make sense of fractions and fraction operations from a multiplicative perspective. That is, in addition to a part-whole model, a ratio model, and a division model, the idea of fraction is developed using partitioning and iterating. For example, 11/3 is 11 copies of one-third, where 1/3 is the amount we get by taking a whole, cutting it up into 3 equal parts and taking 1 of those parts. An outline of the learning trajectory follows.

- develop a multiplicative view of fraction
- compare fractions
- create equivalent fractions
- focus on what represents one whole unit
- addition of fractions
- subtraction of fractions
- multiplication of fractions
- division of fractions including the common denominator algorithm and the invert and multiply algorithm.

Throughout all activities focused on fractions, students are encouraged to use the meaning of fraction to solve problems in ways that make sense to them. That is, the focus is not on teaching different algorithms directly but to allow students to make sense of problems, use the meaning of fraction, and to have the mathematically sound algorithms and procedural operations to emerge from their sense of meaning of fractions.

Relative to multiplication of fractions, it is common for students to learn to multiply fractions simply by "just multiplying the numerators and the denominators." For example, $\frac{7}{8} \cdot \frac{3}{4} = \frac{7 \cdot 3}{8 \cdot 4} = \frac{21}{32}$. This style of teaching leads to misconceptions:

- Students learn to view a fraction as consisting of two whole numbers rather than learning to develop a multiplicative notion of a fraction where a fraction is perceived as a single entity.
- Students fail to develop number sense. Often, students are unable to answer the following: Why does seven-eighths times three-fourths produce a result that is greater than one-half but less than one?
- Students often try to use the same multiplication procedure when adding fractions. That is, they incorrectly add the numerators, then add the denominators when adding two fractions.

When devoid of meaning and understanding, in the mind of a student, the multiplication of two fractions algorithm becomes just another of a long list of procedures to follow–procedures that may or may not make sense to the student.

Modeling with mathematics provides a means by which students can make sense of multiplication of fractions, and contribute to their development of mathematical proficiency. That is, as students engage in the modeling process, they develop meanings and understandings from which the desired procedure may emerge in a way that makes sense to them. Consider the following task: *Terry noticed that there was $\frac{3}{4}$ of a rectangular cake left after the party and that $\frac{1}{8}$ of the remaining cake had all of the frosting taken from it. What part of the original cake remaining still has frosting?* Students may be encouraged to model this situation by representing the fact that $\frac{3}{4}$ of a rectangular cake is left after the party (see Figure 1). Note that the rectangle has been cut up into 4 equal parts. Each part represents $\frac{1}{4}$ of the whole rectangle. Three of these parts are shaded. That is, 3 copies of $\frac{1}{4}$ are shaded. We say 3 copies of $\frac{1}{4}$, or 3 one-fourths, or just $\frac{3}{4}$.

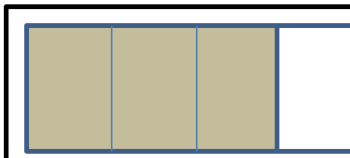


Figure 1: Representation of ¾ of a cake.

Now, $\frac{1}{8}$ of *this* amount had all the frosting removed from it. To represent this idea, we can cut the remaining cake into 8 equal parts as shown in Figure 2. One-eighth of the remaining three-fourths of the cake is represented by the top row shaded darker. Using this model, students can see the portion of the remaining cake (shaded lighter in this model) that still has frosting. They can determine that there are $7 \cdot 3 = 21$ such pieces. When compared to the entire cake (remember that we originally started with $\frac{3}{4}$ of a whole cake), the portion that still has frosting is $\frac{21}{32}$ of the entire cake. Using this method of modeling situations, students may come to understand multiplication of fractions. That is, $\frac{7}{8} \cdot \frac{3}{4}$. With repeated reasoning (SMP #8), students may come to realize that the product of the numerators $(7 \cdot 3 = 21)$ represents the number of pieces of cake under consideration in the problem (in this case, the amount of cake that still has frosting). The product of the denominator $(8 \cdot 4 = 32)$ represents the total number of pieces of cake. This leads to the traditional algorithm for multiplying fractions: $\frac{a}{b} \cdot \frac{c}{d} = \frac{ac}{bd}$. With careful instruction, students can make sense of the product of two fractions by thinking about taking, for example, seven-eighths of a copy of three-fourths. When students are able to do this, they have developed a powerful way of thinking about fractions multiplicatively and increased their mathematical proficiency. Students then have the opportunity to develop a mental model for multiplication of fractions. That is, they may learn to imagine what seven-eighths of a copy of three-fourths might look like. When students are afforded the opportunity to model with mathematics, the traditional algorithms can emerge from student thinking. The algorithms then are part of a well-connected network of understanding of ideas and mental images. When this is the case, students are able to develop procedural fluency.

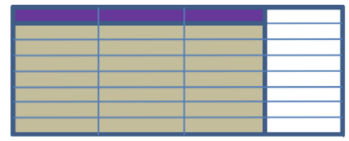


Figure 2: Representation of the cake cut into 8 equal parts.

According to AMATYC's (2006) *Beyond Crossroads*, literacy focuses on the ability to collect, organize, interpret, model, represent, and use data to help solve real-world problems. In order to develop a conceptual understanding, students must reach a level of mathematical literacy, which is defined as the capacity to identify, understand, and engage in mathematics to make well informed judgments about the role that mathematics plays (Niss, 2003). Research in mathematics education identifies that solving real-world problems is a complex process that often cannot be done quickly (Carlson & Bloom, 2005), but when students have the ability to apply mathematics to real-world problems they have moved beyond observing and executing a series of isolated skills to the realm of critical thinking.

Many collegiate programs have critical thinking as a learning outcome, and mathematics courses are key in developing such skills. AMATYC's Standards for Intellectual Development is important to building this outcome. A learning environment that promotes and cultivates critical thinking integrates learning activities and instructional strategies that reflect knowledge of students' skills, interests, cultural backgrounds, language proficiency, and individual needs. Thus, students should be encouraged to participate in learning mathematics processes that are facilitated through team-building skills, collaborative projects, portfolios, research, or field investigations. It is through solving meaningful projects and investigations that students develop the ability to think critically and apply mathematics to real-world problems.

According to Devlin (1997) and Boaler (2016), students' views on the meaning of mathematics is generally different from those of experts in the field. Mathematicians generally define mathematics as a discipline of patterns that can be considered creative and artistic, yet students often describe mathematics as a set of procedures and calculations. These two differing viewpoints underscore the need for faculty to assist students in discovering the patterns, beauty, and mathematical structure for students to move beyond the view that mathematics is simply procedures to be followed. According to the CCSSM and AMATYC's Standards for Intellectual Development, to be mathematically proficient it is necessary for students to

- know mathematics procedures and execute core computations fluently
- view mathematics as relevant to their daily lives
- demonstrate evidence of mathematical understanding
- utilize the structure in the mathematics
- make sense of and solve problems
- apply mathematics to everyday situations
- communicate mathematically and do so with precision
- defend their work and critique the work of others.

These attributes are interrelated and contribute to the development of mathematical proficiency. In the following section, we discuss how faculty can foster and assess these practices and offer suggestions for mathematics departments to assist faculty in building mathematical proficiency in students.

Fostering Mathematical Proficiency in Students

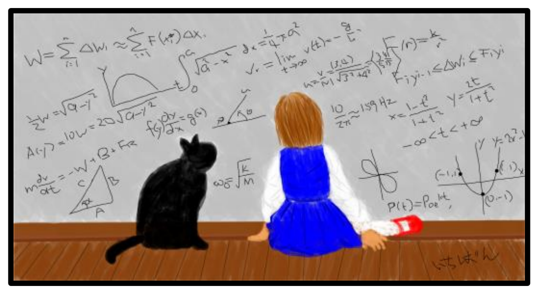
Faculty, departments, and institutions can contribute to the development of mathematical proficiency in students by creating high-quality curricula and learning environments that challenge students to think creatively and critically in and outside the classroom. Developing mathematics curricula that engender proficiency is a long-term process that leverages evidence-based research. Faculty who develop such curricula should also engage with professional organizations and collaborate with local and regional stakeholders. Suggestions are provided for creating an effective mathematics curriculum

- As a first step in curriculum design, instructors should determine the learning outcomes students need to meet at the end of a course (Wiggins & McTighe, 2005), and also consider the skills that are necessary for subsequent courses.
- The curricula and teaching processes must create and sustain equitable access to quality teaching and learning.
- Curricula sequences should be designed to support the needs of students in a wide variety of college programs and have multiple paths for different majors or student interests.
- Create curricula and activities that will foster the use of multiple approaches or representations to examine mathematical concepts.
- Curricula should promote quantitative thinking through activities that emphasize the recognition of patterns, relations, and functions.
- Students should be provided opportunities to represent and communicate mathematical ideas using multiple representations such as numerical, graphical, symbolic, and verbal.
- Curricula should provide opportunities for students to develop or improve these skills through substantive and real-life applications.

Curricula cannot be effective without fostering a productive learning environment which promotes mathematical proficiency. The development of an effective learning environment, in and outside the classroom, should be a collaborative initiative between mathematics faculty, support staff, and students. When constructing such learning environments, consider

- The learning environment must be welcoming and promote principles of inclusion, access, and equity (Chao, Murray, & Gutiérrez, 2014).
- Faculty should be mindful of how their biases and prejudices may affect student learning.
- Faculty should find a way to spur an appreciation of how mathematics can be used outside of the classroom environment (NRC, 2001).
- Faculty should be involved in training tutors specifically on how to assist students effectively in the first two years of college mathematics.
- Learning resources such as the library, disability services, student support networks, and tutoring centers should be available to students who may be in need.

It is undeniable that a supportive and caring department and faculty can be instrumental to helping a student attain mathematical proficiency. A case in point:



Anne was a single mom attending school to become an elementary school teacher. She was taking classes at the local university and needed to pass a standardized exam to become a certified teacher. Even with the help of university tutors, she was unsuccessful in passing the mathematics portion of the exam. So, she approached Kate, a soon-to-be mathematics teacher at a nearby community college, for help. Kate suggested to Anne that she focus on understanding the mathematical concepts and suggested she speak with Kate's students enrolled in the mathematics teachers' prep course. Anne found the conversation with future mathematics teachers extremely insightful and valuable and wished she had been taught such things during her educational path. Kate, with the consent of the mathematics department, invited Anne to periodically visit teacher prep courses throughout the semester to help her gain such insights and patch up the holes in her mathematics. It was here where Anne learned the building blocks of mathematics, how to be persistent in mastering the basic skills of mathematics, and how these fundamental concepts build upon one another. Kate continued to check in with Anne and invite her to class when discussing mathematical concepts that Kate knew were areas in which Anne struggled. Through these opportunities and hard work Anne eventually became mathematically proficient and passed the mathematics portion of the standardized exam. She is now a first grade teacher, and has earned her Masters in Education. It is evident that Kate's caring, a supportive department, and hard work was instrumental in Anne's acquisition of mathematical proficiency.

Creating robust curricula, interactive learning environments with an emphasis on applying mathematics, and strong student support networks will foster mathematical proficiency in students.

Examining Mathematical Proficiency

After examining how to foster mathematical proficiency in students, it is important to identify how these attributes can be assessed. *Assessment procedures* that are ongoing and provide data on the nature and quality of learning lead to improvements in student learning. This process provides the necessary data for making informed decisions about curriculum, learning environments, teaching, and program development (AMATYC, 2006). Assessment instruments and practices must be aligned with the appropriate curriculum and instruction. They should measure (1) whether students have a coherent understanding of mathematical concepts, (2) students' fluency with computational and procedural skills, (3) students' ability to utilize various problem-solving strategies, and (4) students' ability to communicate mathematical constructs numerically, analytically, graphically, and verbally.

Research points to the importance of utilizing *authentic* assessments (Silva, 2009). Authentic assessments strive to evaluate students' abilities in real-world contexts and involve multiple indicators that are relevant, meaningful, and realistic (Romberg, 1995). Their focus is on measuring analytical, collaborative, and communicative skills, as well as students' ability to utilize what they have learned in real-world situations. Classroom assessment techniques should not only be formative in nature, but diagnostic and summative as well (Boaler, 2016). Faculty and departments should use results to revise curricula and improve teaching.

Assessment results can be used to motivate faculty to review and revise the curriculum to ensure that students are mathematical proficient. The Mathematical Association of America (MAA) Common Vision document (Saxe & Braddy, 2015) provides a framework for improving the mathematical curriculum in the first two years. This framework states that instructors should intentionally plan curricula to

- Enhance students' perceptions of the beauty, vitality, and power of the mathematical sciences.
- Enhance students' understanding of mathematics as a creative endeavor.
- Increase students' quantitative and logical reasoning abilities needed for informed citizenship and for the workplace;
- Increase students' confidence and joy in doing mathematics and statistics.
- Improve students' ability to communicate quantitative ideas orally and in writing (and since a precursor to communication is understanding, improve students' ability to interpret information, organize material, and reflect on results).
- Encourage students to continue taking courses in the mathematical sciences (Saxe & Braddy, 2015, pp. 12-13).

Assessing mathematical proficiency should reveal if students are able to apply procedures appropriately, are able to demonstrate understanding of mathematics, can make sense of problems, can apply and communicate mathematics, and can justify their thinking. Meeting these criteria demonstrate that students are reaching mathematical proficiency.

Working towards Mathematical Proficiency

The unique characteristics of teaching mathematics in the first two years of college allows us the opportunity to foster mathematical proficiency by creating curricula and learning environments that meet the needs of all students while making it relevant to their everyday lives. Through the broad range of courses that we teach, from developmental mathematics to general mathematical skills to specific technical skills to advanced mathematics, we have the opportunity to make a wider impact on producing mathematically proficient citizens. Making the mathematics relevant and applying it to everyday situations is a key component in helping the students make sense of the concepts and lead to greater mathematically understanding and mathematical proficiency.

Mathematical proficiency is achieved when students know mathematical procedures and are able to execute core computations fluently and precisely, can utilize the structure of mathematics to make sense of and solve problems, are able to apply mathematics to everyday situations and defend their process, and can view concepts as relevant to their lives and communicate mathematically. This must be a collaborative effort that involves various stakeholders—faculty, departments, and support services—all focused on addressing the need of all students.

Is your interest piqued about fostering mathematical proficiency in your students? Do you already have great information or activities involving mathematical proficiency? Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

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Chapter 4

Ownership

Taking Responsibility and Showing Initiative

You cannot teach a man anything; you can only help him to find it within himself.
~Galileo Galilei

Why did you become a mathematics teacher? Odds are that you found joy in the subject and wanted to share it with others. Perhaps it was because of the beauty found in a formula that explains why a phenomenon occurs in nature. Maybe you are curious and love to solve problems or puzzles. Or, you like the elegance in the language of mathematics and the certainty it brings. As educators, we would like to see a similar passion grow within our students for learning mathematics. Through the second pillar of PROWESS, students' ownership in their own education, will learning take place.

To spark this interest within our students, both faculty and students first need to have a common understanding of what learning is. One perspective is that learning is both a process and a product. It is an individual, internal, and personal activity. We cannot learn for another person. The learner must take responsibility for learning as it can only reside within the individual (Milton, 1973). By the time students reach our classrooms they often have an improper view of what learning is. They believe in a dualistic ideal that learning is about determining right or wrong instead of realizing that learning can be contextual and relative (Perry, as cited in Thoma, 1993). Too often, they also are waiting for extrinsic motivation instead of relying on their own intrinsic motivation to learn. Several studies have shown students who develop extrinsic motivation do not achieve at as high of levels as those who develop intrinsic motivation (Lemos & Verissimo, 2014; Pulfrey, Buchs, & Butera, 2011). It has also been shown that students with intrinsic motivation pursue subjects to higher levels and are more likely to persist through completion (Stipek, 1993).

Consider the contrasting stories of two students in a Beginning Algebra class. Both John and Lola enrolled in the class because it was required for their degree programs. John was promised a new car by his father if he completed the course with a grade of B or better. Lola, on the other hand, was a returning student with no such promise made to her. John dropped out of class before midterm whereas Lola completed the class with a grade of A. In this case, extrinsic motivation was not enough to encourage John to even do his homework. Lola understood the value of learning and completed her associate's degree.

As faculty, it is our responsibility to guide students to find this motivation. Instead of luring them with extrinsic motivational processes, which shift their focus to valuing the consequences of task completion, we should assist them to focus on valuing the task itself (Kohn, 1993). However, first, we need to look at what the expectations should be of our students as learners before we investigate how to help them meet these outcomes.

Student Ownership

The best faculty who "achieve[ed] remarkable success in helping their students learn in ways that make a sustained, substantial, and positive influence on how those students think, act, and feel" (Bain, 2004, p. 5) do so by cultivating three components of student ownership of learning

1. **Discovery**. An ideal classroom is where students are active participants in formulating conjectures, developing strategies for solving a problem, engaging in investigative tasks, or analyzing data. It is through these guided investigations that learning begins to take place.

2. **Responsibilities**. As students begin the journey of taking ownership of their own learning, they have responsibilities that they may assume on their own and others to which they may need to be directed. It is imperative that students clearly understand the objectives and goals of a course and are aware of the rubrics used to assess the quality of their work. It is a matter of fostering trust between the student and the teacher. This trust is that student can expect that the teacher will provide the assistance needed to accomplish the goals of the course and vice versa, that the teacher can expect that the students take responsibility and will meet the requirements set forth to achieve those goals.

   Arguably, the most important responsibility for the student is meaningful self-assessment. Students must recognize assessment as an integral component of the teaching-learning process and not just a means by which instructors assign a grade to their performance. Feedback garnered from a variety of assessments can help students better understand what constitutes an appropriate-and-complete response to a task, and assist them to develop their confidence in performing self-assessments. The ability to assess one's own work effectively is an important life skill, and of great value in the workplace.

   Self-assessment is a process in which students reflect on the quality of their work, compare it to explicitly stated criteria, judge how well their work reflects the criteria, and make appropriate revisions. Also, it is a formative process that informs students about what part of their thinking and subsequent work require revisions and improvement. Some strategies (whether prompted by the instructor or initiated by the student) that students may use to develop effective self-assessment practices include

   - reflecting on the knowledge they already have that might assist them in new situations
   - drawing from previous work that may relate to new circumstances
   - using graphic organizers, which organize facts, concepts, ideas, or terms in a visual or diagrammatic way so that the relationship between the individual items is made clear
   - evaluating their own progress to recognize what they do and do not understand
   - using rubrics (when provided) to evaluate their progress during an assessment or activity.

3. **Continued Learning**. The goal of each student should be deep learning: that is, "develop initiative multiple perspectives, think about their own thinking that they tried to understand ideas for themselves; that they attempt to reason with concepts and information they encountered, to use material widely, and to relate it to previous experience and learning" (Bain, 2004, p. 10). A student's journey to meet this goal will encounter accomplishments as well as setbacks. Students need to be able to accept failure or mistakes as an important part of learning. As the entrepreneur Malcolm Forbes (1978) once said, "failure is success if we learn from it." Recent studies have shown that when mistakes are made, the brain grows (Moser, Schroder, Heeter, Moran, & Lee, 2011). One type of response or spark observed in the brain is simply due to the conflict between a correct response and an error; it is not necessary that a person is aware that they have made a mistake. The second response is the reflection of the conscious attention to the mistake. According to Dweck (2006), people with growth mindsets have greater brain activity to follow mistakes. Although such people do not exactly enjoy failure, they are less miserable because they are not defined by their mistakes. They understand that the path to success will have failures along the way and they are comfortable facing them, so long as there are opportunities to learn along the way. It is through persistence that brain growth occurs and learning takes place.

When students take initiative of their own learning, the results can sometimes have a positive ripple effect for other students as is demonstrated by Kyela's story.

Kyela, a beautician pursuing her associate's degree, enrolled in a numeric skills class as a result of her performance on the college's placement test. She was understandably anxious about her math abilities, but she took ownership for her learning. As the semester progressed Kyela gradually took responsibility not only for her own learning but for that of the members of her group. Eventually she organized Sunday morning study sessions at the local coffee shop for anyone in the class to attend. As a result of her actions she achieved a grade of A in the course and the average grade in the class exceeded the average grade of the other sections of the same course that semester.

Faculty Fostering Student Ownership

In general, faculty should be working towards empowering students to take ownership of their learning by promoting self-regulated learning. Students should take control of and evaluate their own learning through the phases of task perception, goal setting and planning, implementation, and adaptation (Winne & Hadwin, 2008). Faculty should be guiding and engaging students in activities that foster discovery, responsibilities, and continued learning. According to Mortimer and Scott (2003), there are three tasks for the instructor in the student learning process:

1. introduction of concepts
2. support for the development of meaning
3. provision of opportunity for transfer of ownership, practice, and application to student

For the first task the instructor must be prepared to use a variety of ways to introduce a concept. The primary focus should be on fostering curiosity within the student. By providing students with open-ended questions or utilizing inquiry-based learning techniques, instructors are supporting the students' intellectual need to understand a concept so that they are better motivated to learn it (Harel, 2013). If done correctly, students will be working on the discovery component of ownership.

For the second task, the key word is "support". Faculty must be patient, supportive, and available to help when students are frustrated or confused, but still allow them to struggle and make mistakes. It is vital that the instructor does not "do all of the heavy lifting" for the student. When students ask for help, a possible response is "let's think about this for a minute… Do you want my brain to grow or do you want to grow your brain today" (Frazier, 2015, para. 13)? Faculty need to know when and how to intervene when work is headed in the wrong direction and be able to use good questioning techniques to redirect students rather than giving them immediate answers. Class activities should guide and direct them to begin to assume responsibility for their own learning. Students must have a variety of opportunities to develop confidence in their abilities.

When utilizing group work, faculty must make sure that it is not just a way to have work done faster, but that individual ownership is taking place. Consider Beth, an instructor who utilizes the flipped model of teaching so she has opportunities every class period to take on a guiding role while students are engaged in group work. Her role has evolved over time as she has reevaluated what level of ownership the students have in the activities. Initially, her first semester of teaching was just spent answering questions, but in time she began to also do "interventions". As she walked around the room, she pointed out possible errors in logic and asked groups to reexamine their thinking, thus encouraging **group** ownership. However, she realized that was not enough. Now, each semester she works at incorporating ideas that lead to **individual** ownership.

For the final task, the transfer of ownership to students happens in a variety of ways. Faculty can assist students to take ownership at the beginning of a course by allowing them to have a voice in how the course is structured. For example, Judy, a mathematics instructor, often involves students in the development of her course syllabi (Barkley, 2010). They determine aspects of the syllabus such as expectations and the consequences of not meeting those expectations when doing group work. She also provides them the opportunity to choose from a variety of learning activities that satisfy the course objectives.

Throughout a course, it is important that an instructor ensures that students understand the objectives of the course and are able to meet them. One example of how to achieve this is the method that Kevin uses in his classroom.

He has created a checklist of objectives for his students to use as a way to prepare for exams. After finding out (through surveys) that the students were not using them, he looked for other ways to enforce this idea. He made two changes to the checklist. In upper-level classes he added the words "I can" at the beginning of each objective. He required students to look at the checklist at the end of each activity or class period to see where they stand. In his developmental courses, he has students reflect some more; they must check one of three statements for each objective as suggested by Boaler (2016):

- *I can do this independently and explain my solution path(s) to my classmates or teacher.*
- *I can do this independently.*
- *I need more time. I need to see an example to help me (p. 152.)*

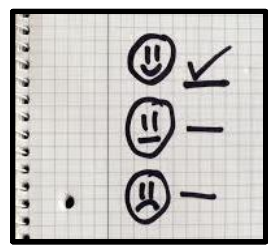
Students hand in the checklist when they take the exam and are then required to reflect on their perception of their knowledge once the exams are handed back.

It is a faculty's responsibility to design activities and assignments that will guide students to master course objectives. Students need to first try out and practice new ideas in familiar situations and then move to applying the knowledge to new and unfamiliar contexts (Mortimer & Scott, 2003). These contexts should include applications that go beyond the typical story problems. Students need to be presented with problems in a way that requires them to determine what technology, techniques, or methods to utilize and how to use them effectively. In an effort to improve success by engaging students in meaningful applications, a community college system in Florida contextualized their Intermediate Algebra and College Algebra courses. Business faculty were involved in the creation of real-world problems upon which the content was built. Mathematics faculty needed the support from business faculty to find realistic and meaningful applications. The success rate of students was 10% above those of students in courses not incorporating these problems.

Last, providing a variety of assessments will help students recognize areas in their learning they need to improve. Feedback garnered from different assessment tasks is vital. Instead of assigning endless homework problems, it may be more beneficial to ask students to answer some reflection questions, as suggested by Boaler (2016):

- What was the big idea we worked on today?
- What did I learn today?
- What good ideas did I have today?
- In what situations could I use the knowledge I learned today?
- What questions do I have about today's work?
- What new ideas do I have that this lesson made me think about (p. 158)?

We illustrate these suggestions with an example from Barbra. She utilizes emoticons to have students gauge their understanding of a topic. Her quizzes begin with students choosing a smiley face, plain face, or sad face to indicate how they think they will perform. Next, they take the quiz and then indicate (with the same emoticons) their views of their performances. The entire class then goes over the quiz and students correct their work and make comments about what went wrong (or right). Afterwards, they use emoticons once more to indicate their actual performance. Students then write a few statements regarding what they need to do based on their results from the quiz. Most of the responsibility of the assessment is on the student, but Barbra does go over the quizzes and indicates mistakes students may have overlooked. She also praises them for their work and self-assessment as appropriate.



Faculty Ownership

We have taken a brief look at student ownership and ways in which faculty can guide students in the process. Now we focus on faculty and how we can take ownership of our roles. When examining the faculty role in education, a large part involves the other pillars of PROWESS: mathematical proficiency, engagement, and student success. For this part of the discourse, we will examine three key areas in which faculty can take ownership: creating a learning environment, taking an active role in course design, and becoming a reflective practitioner.

Learning Environment

The Learning Environment involves instruction and assessment practices intentionally developed to help all students achieve course (as well as individual) goals. It is a place where they experience mathematics with the guidance of faculty. While the word "classroom" is often used to refer to the learning environment, we prefer the broader term "learning environment" to include all settings in which faculty and students interact, including the online environment. First, looking more broadly at the idea of Powerful Learning Environments, Merrill (2002) summarizes four characteristics of learning environments that seem to be common in current instructional theories: prior knowledge and experiences of the student must be activated in order to build new knowledge on pre-existing knowledge, new skills or knowledge must be demonstrated to the student through modelling, the student should have the opportunity to apply their new knowledge and skills, and the newly acquired skills and knowledge must be integrated into real-world activities. In general, the learning environment

- Incorporates the necessary physical space, materials, technological resources, and support staff who facilitate effective learning of mathematical concepts and skills.
- Encourages student-faculty contact.
- Incorporates innovative teaching and learning strategies that use technology and activities designed to promote active student engagement, meaningful discourse, and cooperative learning.
- Fosters active student engagement in mathematical thinking and encourages student creativity and risk-taking.
- Promotes a culture that values the diverse interests and backgrounds of students.
- Addresses diverse talents and ways of learning and teaching.
- Is designed to be effective in developing PROWESS, which includes increasing students' persistence, grit, and communication skills.

Narrowing the focus, we suggest four areas of concentration for providing an effective learning environment: method of instruction, teamwork, diversity, and learning outside of the classroom.

The *method of instruction* is a personal decision for faculty. Instructors should be aware of innovations in the area of instruction and be willing to adjust their methods as appropriate. Any strategy used should

- Support student engagement with the material, especially considering the diverse learnings needs of the students.
- Be thought-provoking.
- Include clear communication and explanation of topics and goals (Cai, Kaiser, Perry & Wong, 2009.)
- Be focused on building mastery of the learning outcomes.
- Use questioning to promote active learning and to measure student understanding.
- Incorporate technology that is appropriate for the task at hand.
- Use multiple assessment measures (Huba & Freed, 2000.)
- Provide both formative and summative feedback that are low-stakes.
- Take into consideration changes that might need to be made for distance learning courses.

The second area of concentration, *teamwork*, is complex but vital. The ability to work in a team structure is among the most valued skills employers need when hiring new employees (Adams, 2014). Facilitating successful teamwork requires training on the techniques and justification for the specific type of group work. Based on work done by Johnson & Johnson (1999), when incorporating group work we suggest five aspects to focus on

- Structure for positive interdependence: Group interaction is necessary for successful resolution of the question or task, and for linking individual success to the success of the group.
- Structure for interaction: Group interactions include discussing solution paths, important concepts, and connections to prior knowledge, as well as facilitating help and words of encouragement when needed.
- Structure individual accountability: Students are held accountable for their share of the work in the group.
- Structure social skills: Group interaction requires interpersonal, social, and collaborative skills. Students must be provided guidance on how to effectively interact in a small group.
- Structure group processing: Group members discuss effectiveness in reaching their goals and in working together.

The third area of concentration when designing a learning environment is *diversity*. Faculty must recognize that diversity manifests itself in a variety of ways: age, gender, ethnicity, socio-economic background, and academic preparation. To address issues related to diversity, faculty should

- Have high expectations for all students and clearly communicate those expectations (NCTM, 2000; Jamar & Pitts, 2005; Center for Community College Student Engagement [CCCSE], 2008).
- Use best practices to increase student success rates, which include using diagnostic assessment to counteract poor performance and vary the instructional styles in the classroom (Holloway, 2004).
- Strive to encourage underrepresented groups.
- Consider diverse languages and cultures as assets to mathematical knowledge and highlight contributions made from such groups (Holloway, 2004).
- Advise students about the availability and appropriate use of academic support resources.
- Collaborate with appropriate support service personnel to respond to the needs of students with disabilities.
- Be sensitive to situational factors in which many students are balancing family, job, and academic responsibilities; provide constructive suggestions and support for overcoming those challenges.
- Be sensitive to the impact of mathematics anxiety and teach students to employ remedies related to mathematics self-efficacy (Pajares, 1996):

    - Make explicit the importance of mathematics self-efficacy to student success including the four sources of self-efficacy: mastery experiences, vicarious experiences, physiological states, and social persuasions. Understand that there is a cyclical relationship between the four sources (Usher & Pajares, 2006, 2009).
    - Facilitate confidence in students by cultivating new mastery experiences. Since mastery experiences is the best predictor of self-efficacy, faculty need to rebuild mathematical competencies to scaffold learning (Usher & Pajares, 2006, 2009; Zientek, Fong, & Phelps, 2017).

The fourth area of concentration highlights the idea that the learning environment is not just what takes place inside the classroom, but also *outside of the classroom*. This encompasses a wide variety of considerations

- Regularly require students to work on mathematics outside the classroom. This will include expecting students to prepare for class as well as to practice what is done in class. Instructors will encourage these behaviors with timely feedback (Huba & Freed, 2000).
- Encourage appropriate interaction with students and between students inside and outside of the classroom.
- Encourage explanations of concepts to peers and various audiences such as professionals and laypeople (Angelo, 1993; Huba & Freed, 2000).
- Provide service-learning opportunities for students in your courses.
- Foster undergraduate research.
- Be available outside of the classroom to assist individual students.
- Be involved in the design of and the decision-making about physical spaces that support mathematics instruction (such as tutoring centers).
- Identify and recommend necessary technology that assists students in exploring and mastering mathematical concepts. Technology should be available and accessible to all students.

Course Design

Most often, course design refers to the length, content, and structure of courses, but in this document, we will examine it in a broader sense to include components of instructional design. The goal of a good course design should be to foster learning. Decisions about course design should articulate how the curriculum is going to be delivered to students in ways that promote PROWESS. These decisions are best viewed as a joint responsibility by all faculty involved with a course, including a joint decision on ranges of acceptable variation between sections and delivery methods. We provide suggestions (in no particular order) for course design

- Assure that learning outcomes in mathematics distance learning sections are consistent with those of similar mathematics courses taught in classrooms.
- Include a variety of assessment techniques such as performance tasks, interviews, open-ended questions, observations, projects, and portfolios in addition to the traditional paper-and-pencil tests.
- Utilize various sources for course materials. These might be traditional textbooks, e-books, or Open Educational Resources; the selection of these materials should be based on criteria related to quality, effectiveness, and affordability.
- Offer alternatives for course duration. Traditional semester or quarter length courses should be combined with alternatives to provide the best student experience. This might include co-requisite structures, fast-track courses, and individualized learning.
- Faculty should be open to different styles of teaching; effective course design incorporates diverse styles within and across courses.
- Provide support for students to develop a more diverse set of learning skills.
- Ensure that assignments and assessments address the needs of a wide variety of students, both culturally and physically. (For this purpose, we include learning disabilities in the physical category of diversity.)
- Address and correct issues connected to students' misconceptions.

- Use learning technology in all mathematics courses to support curricular goals and course outcomes.
- Use appropriate technology as a tool to aid students to discover patterns, test conjectures, and validate conclusions.
- Use technology that is accessible to all students.
- Make available technology applications and software that students may use in other courses as well as their daily lives.

Continuous improvement of course design can be achieved by using effective assessments in which faculty identify assessment tools linked to desired student learning outcomes and proceed through a four-step implementation cycle of planning, gathering relevant data and evidence, interpreting them, and using results to make informed instructional decisions. Instructors should participate in the development and assessment of not only individual courses but also how the courses contribute to general education outcomes in mathematics.

Becoming a Reflective Practitioner

Instrumental to faculty ownership is to be a reflective practitioner who examines curriculum and teaching practices to identify areas that need improvement. We offer suggestions for becoming a reflective practitioner

- Consider whether students are taking ownership of learning in the classroom. To do so requires a clear understanding of what ownership means and how to assess it.
- Continually review courses and curricula and determine processes for continuous improvement.
- Keep abreast with current research on learning and teaching, and incorporate findings in courses.
- Faculty should be encouraged to craft and try an action research project.
- Foster a growth mindset in students.
- Faculty should examine teaching practices through four complementary lenses—autobiographical experiences as learners, students' views, colleagues' perceptions, and educational literature (Brookfield, 2002).
- Faculty should be encouraged to share ideas with each other. This can be done at the department level through monthly faculty meetings where participants can take turns to share information about specific courses, or general strategies on teaching and learning. New ideas can also be acquired through professional conferences, or on IMPACT Live!

Department and Institution Ownership

As faculty take ownership of individual responsibilities for the learning environment, course design, curriculum, and assessment, it is the role of mathematics departments and institutions to support faculty in their teaching. By faculty uniting as a department, they are more likely to influence their institutions into listening to and acting upon the needs of the faculty. The institution needs to work with the faculty to determine the best course of action given the resources that can be made available.

One area that departments and institutions have the most influence over is in providing a supportive learning environment consisting of contemporary classrooms, mathematics tutoring labs, learning centers, counselors, and service for students with disabilities, to name a few. Learning environments should be adaptable to the needs and characteristics of students. Classroom layouts, which include furniture in the case of traditional settings, the design of virtual courses, and technology resources for both, all contribute to the learning of mathematics. As such, departments and institutions should

- Supply the necessary equipment and training to create classroom environments that maximize the learning of mathematics.
- Ensure that students have access to any needed technology, such as computer software and hardware, digital recorders, calculators, and videos.
- Design classrooms (real and virtual) that follow guidelines, such as those addressed in Universal Design for Learning (CAST, 2011).
- Support best practices in face-to-face, online, and hybrid/blended classrooms.

Departments and institutions must create environments that support both learning and social interaction. Learning centers should be welcoming, accessible, and staffed with well-trained tutors. Departments and institutions should

- Provide adequate space and resources for peer and professional tutoring as well as mathematics resource centers.
- Have strict requirements for tutors (for example, they are only to tutor courses for which they are qualified).
- Establish sufficient training opportunities for mathematics tutors, supplemental instructors, and student support staff.
- Offer workshops for students that include (but are not limited to) mathematics study skills, anxiety reduction, and technology usage.
- Make learning resources available at times suitable for students (including nights and weekends).

Another area that departments and institutions have the most influence over is the instructional materials that faculty use in their classes. The purpose of mathematics courses and programs in college is to develop students' mathematical proficiency with the intention of preparing them for other courses and the workplace. Departments and institutions must oversee curriculum development and assessment in mathematics courses and programs. They must ensure that decisions are based on the needs of the local student population but that results also align and agree with national trends and visions as well as curricula at transfer institutions.

A curriculum must be designed for today's students and tomorrow's society. It must effectively meet the needs of as many academic paths and disciplines as possible. In particular, attention should be paid to the influence of technology, research on student learning, mathematics content, and skills needed for successful careers and responsible citizenship. Thus, departments and institutions should

- Work with the faculty to determine outcomes for each course, while conversing with outside sources such universities, businesses, legislatures, and national organizations.
- Ensure that outcomes in the developmental mathematics program include quantitative literacy, which is necessary for student success in future college-level courses.
- Encourage collaboration among departments regarding instruction and assessment of mathematics outcomes embedded in non-mathematics courses.

- Implement periodic reviews and redesign of student learning outcomes.
- Evaluate placement and prerequisite requirements to align with course outcomes.

The next area in which departments and institutions must recognize their responsibility and role is in fostering and providing professional development opportunities by the establishment of an effective professional development program. Participation in professional development activities has a measurable impact on teaching. Keys to providing an effective professional development program include (Morley, Jamie & Zutes, Spring, n.d.)

- obtaining faculty engagement and ownership
- making the process easy to administer
- tying it to the Annual Performance Evaluation
- being consistent and flexible
- rewarding active participation
- encouraging faculty with similar goals to attend activities together
- making all forms electronic, easy for faculty to modify and easy for managers to track
- creating a faculty portfolio location on employee portal or LMS.

The final area that departments and institutions need to take ownership in is that of assessment. Curriculum assessment provides mathematics departments with data to make informed decisions about course content and student learning. It is an ongoing process by which a college or department assesses what mathematics students know at the end of their course or program. Results should be analyzed extensively and discussed, as well utilized to revise and improve curriculum and courses. Departments and institutions should

- involve full-time and part-time faculty in designing and implementing course and program assessments
- link department-wide assessment instruments to course outcomes
- assess courses frequently
- plan for and conduct periodic assessment of all mathematics course outcomes
- analyze assessment data and use the results to improve student learning
- retain records relating to various course-wide interventions to review and reflect upon.

Working Together

Students entering two-year colleges bring with them a variety of ideas of what learning is and what their role is in order to be as a successful student. They, as well as faculty, departments, and institutions, should assume ownership in their respective roles, yet work collaboratively toward the same goal of academic success. Opening effective continuing lines of communication is key to each group's ability to take ownership of their role.

Are you looking for ways to heighten your ownership of your role as a member of the mathematical community? Would you like to learn about more ways to foster ownership in your students? Do you already have great information or activities involving faculty or student ownership? Head to AMATYC.org/IMPACTLive and find innovations your colleagues using or contribute innovations and ideas of your own.

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Chapter 5

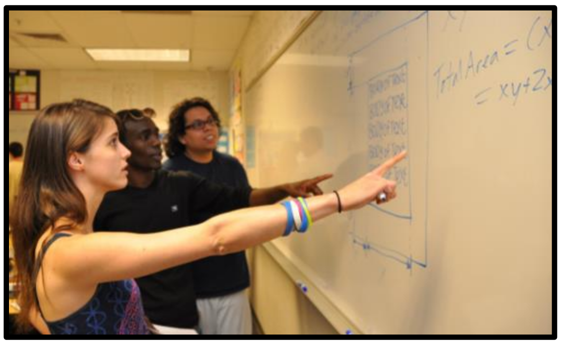
Engagement

Developing Intellectual Curiosity and Motivation in Learning Mathematics

The students who are most engaged are the ones who
think they matter to the teacher.
~Dr. Russell Quaglia (2016, p. 6)

At some point, we have all had disinterested students in our classrooms, whether in face-to-face, online, or hybrid settings. How do we engage them to increase their interest in learning mathematics? Engaging students intellectually in the process of learning mathematics is fundamental for improving student achievement in the first two years of collegiate mathematics and thus it is the third pillar of PROWESS. Contemporary research has demonstrated the central role of learning environments in promoting effective teaching and learning of mathematics where students are meaningfully engaged (Bishop, Caston, & King, 2014; Kim, Grabowski, & Sharma, 2004; Kuh, 2007). Kuh (2007) found that "students who talk about substantive matters with faculty and peers, are challenged to perform at high levels, and receive frequent feedback on their performance, typically get better grades, are more satisfied with college, and are more likely to persist" (p. 1). Designing a learning environment that fosters active student engagement in mathematical thinking, encourages student creativity and risk-taking, and promotes a culture that values the diverse interests and backgrounds of students is a shared responsibility of students, faculty, institutions, and other stakeholders (Burn & Mesa, 2017). This kind of environment allows students to develop their voice where they have ownership of their learning. Quaglia (2016) found that "when students feel like they have a voice at school, they are 7 times more academically motivated" (p. 6). This is a substantial increase! Such learning environments furnish students with the appropriate physical space, materials, technological resources, and support staff necessary to facilitate effective learning of mathematical concepts and skills. An example of active student engagement in the classroom is highlighted in the following vignette.

Rachel is a mathematics instructor at a community college in the Southwest who cultivates student engagement in her classes. Her philosophy of teaching and learning mathematics centers around the idea that students learn best when they are socially, actively, and cognitively engaged in their own learning process. This school of thought resides within constructivism, where students construct meanings of mathematics through problem solving and sense making while working with their peers. With this notion of learning in mind, Rachel employs various teaching strategies that allow students to make conjectures and think through mathematical ideas during class. One such strategy is called paired board work where students tackle mathematical tasks at the whiteboards in the classroom. Rachel's *classrooms have whiteboards along all four walls that can accommodate a class of 30 students and she strives to create a 360° classroom. During paired board work, students are given roles—one as the writer who is responsible for demonstrating his or her solution on the board, while the other student serves as the reviewer to monitor the quality of the solution path. Often, Rachel asks all students to tackle the same problem on the board, but at other times, different problems are given to each paired team. The primary goals of this strategy are to provide opportunities for students to engage in thinking mathematically and for the instructor to assess student thinking in real time. The level of engagement and mathematical conversations are remarkably improved when students complete tasks at the whiteboard, followed by informal reporting of various solution strategies employed by different paired teams. This allows for students to critique each other's mathematical reasoning and solution paths, correct mistakes and misconceptions, and create an atmosphere where students view the learning of mathematics as a process. In reflecting about the use of this teaching strategy, Rachel commented: "At first, students are shy and a bit reluctant to talk to each other at the whiteboards for fear that their thinking is incorrect. After reassuring them that mistakes are expected, respected, and inspected in my class, students begin to open up and take risks when problem solving. Learning is messy and often uncomfortable, but I believe students need to think about class as their 'think tank' where ideas are born, some ideas die off, and others flourish. This is part of the learning process!" Rachel believes that when mathematics classes utilize student engagement strategies, the learning is transformed!*



Engaging Students In and Out of the Classroom

We need to stimulate meaningful dialogue among students, faculty, and support staff and to build students' views of mathematics as an investigative and exploratory activity. A robust learning environment is at the heart of accomplishing this. Publications by the National Governors Association and Council of Chief State School Officers (NGA Center & CCSSO, 2010), National Council for Teachers of Mathematics (NCTM, 2014), and the Mathematical Association of America (Ludwig, 2018) call for characterizing an exemplary learning environment as one that is community-centered where students can freely articulate their own ideas, challenge the thinking of their peers, and embrace new ideas and ways of thinking, such as demonstrated in Rachel's vignette on paired board work.

The three components of a robust learning environment are *learner-centered, knowledge-centered, and reflective learning*. The notion of a *learner-centered* environment allows students to construct new knowledge and understanding based upon previous knowledge. A *knowledge-centered* environment is one in which students can identify the "big ideas" and learn how to apply them in novel situations. Finally, a *reflective learning* environment is one in which students monitor their own learning and recognize what they understand and what requires revisions in their thinking. Weaving these three components into classroom instruction provides opportunities for students to engage in meaningful mathematical practices that "can create an atmosphere of comfort, invite open expression, invite meaningful class discussions, allow for the development of peer learning, and nurture student-teacher and student-student connections" (Bishop, Caston, & King, 2014, p. 60).

In the AMATYC (1995) *Crossroads in Mathematics*, the Standards for Intellectual Development focused on problem solving, modeling, reasoning, connecting with other disciplines, communicating, using technology, and developing mathematical power. These standards held true to the notion that learning mathematics requires students to be engaged in developing mathematical meanings and convincing arguments through modeling and solving contextual problems. More recently, the Common Core (NGA Center & CCSSO, 2010) movement highlighted the need for improving and incorporating meaningful mathematical practices in the learning of mathematics at the K-12 level. These practices, referred to as the Standards for Mathematical Practices (SMPs), should also be leveraged in the first two years of mathematics at the collegiate level. For example, "*SMP3: Construct Viable Arguments and Critique the Reasoning of Others*" (NGA Center & CCSSO, 2010, p. 6), is a practice that engages students in conjecturing, sense making, and reasoning while also evaluating the mathematical thinking of their peers. The ideas promoted by *Crossroads in Mathematics*, as well as the Common Core SMP, are captured in Rachel's vignette about paired board work where students make their thinking public to others by illustrating their solution paths on the whiteboard for review and critique. This activity increases students' level of engagement in their own learning and in thinking about mathematics.

It is also important that our mathematics courses in the first two years incorporate strategies and activities that effectively engage students from culturally and linguistically diverse backgrounds. Faculty and stakeholders must recognize that, particularly at two-year colleges, diversity manifests itself in a variety of ways such as age, gender, ethnicity, socio-economic background, academic preparation, and career interests. Mathematics can serve as a gateway discipline for providing access to educational and economic opportunities and can be a powerful tool for increasing student self-confidence. We, as faculty, should provide students with opportunities to highlight and celebrate the mathematical contributions of women, various ethnic and minority groups, and individuals with disabilities (e.g., emphasize the story of women who were human computers in the book *Hidden Figures* (Shetterly, 2010). A multitude of practices both within the college mathematics classroom and outside can effectively address the diverse needs of two-year college students by increasing access to meaningful learning.

Over the past several decades, research in mathematics education has shown that effective teaching and learning of mathematics flourishes in a student-centered environment (Larsen, Hassi, Kogan, & Weston, 2014; Zakaria, Chin, & Daud, 2010). Larsen et al. contend that student learning outcomes and student retention, specifically, are improved when collegiate mathematics courses leverage student-centered teaching. They also found that inquiry-based instruction (an active learning teaching strategy) benefited all students and leveled the playing field for women given that the data showed "women's cognitive and affective gains were statistically identical to those of men, and their collaborative gains were higher" (p. 412).

Improving the teaching-learning process is predicated on discovering robust approaches to connecting thinking and mathematics. Progressive mathematics faculty recognize that learning is not a process of receiving and remembering information, but rather an opportunity for students to think critically and develop mathematical meanings. The research abounds with compelling evidence that students at all educational levels learn mathematics effectively when they construct their own mathematical understanding (Simon, 1995; Steffe & Thompson, 2000). This constructivist view is not a novel idea but is a very useful one as mathematics educators and cognitive psychologists come to understand better the nature of learning mathematical concepts. Constructing mathematics is more than the acquisition of new concepts. It also involves reconstructing prior knowledge and integrating with new ideas. Furthermore, mathematical knowledge is now viewed as being socially constructed, that is, mathematics is learned through a process of communication within a community of learners, as illustrated with Rachel's vignette on active engagement teaching strategies. Another example of active learning is showcased in the following vignette.

Diego is teaching a beginning math course to first semester college students. To help students review course material before each test, Diego put together an activity that gets students actively involved in their own learning and provides *them the opportunity to discuss course content with their peers, eventually helping them to become confident learners. The activity is called "Take a Fresh Look—Math Is Easy." Two weeks before each test, Diego posts a blank "Take a Fresh Look—Math Is Easy" list in class and asks students to visit the list and identify those topics in which they need help and put their names beside those topics. Then, everyone is asked to write their names in front of the area in which they are willing to help. To ensure that all students have the opportunity and the incentive to participate, students are asked to volunteer only once. If there are two volunteers for an area, they are asked to pair up and address the area together. Successful completion of this exercise entitles each presenter to four bonus points on their upcoming test. After the list is completed if there is any area for which there is no volunteer to help, the professor's name will go there. Beginning with the next class session, topics are covered in class by students who volunteered to help in 5-10 minute short presentations. This exercise proved to be very successful, actively involving students in their own learning and helping each other, creating a true learning community. Results of the first test confirmed the success of this exercise as test grades were slightly higher. The real improvement was noticed on the second test and onward. Students' creativity and eagerness to help each other led some to prepare handouts for everyone, or to present a concept map on the board, or to lead a question and answer session during their presentation.*

The exercise in Diego's vignette allowed the quiet students to find and use their voices to teach others, while encouraging and empowering everyone to be engaged in meaningful, worthwhile discussion of mathematics. This engagement extended beyond the classroom by encouraging students to work on mathematics outside of the classroom, both individually and collaboratively. A prized outcome of mathematics education is that students cultivate the power to use mathematics productively once they leave school and enter the workplace. This, however, requires that students are presented with opportunities to use mathematics productively during the years that they spend in school. In short, students need to focus more on the thinking behind the mathematics they are learning, rather than focus on simply doing mathematics. This can be achieved through engaging discussions so groups reflect on their thinking and the thinking of other members, such as illustrated with the "*SMP3: Construct Viable Arguments and Critique the Reasoning of Others"* (NGA Center & CCSSO, 2010, p. 6).

In summary, when creating an engaging environment both in and out of the classroom for students to learn mathematics, there are a set of key principles to guide implementation

- Students should interact with each other often through meaningful discourse and collaborative activities for the purpose of sharing and refining ideas.
- Students should develop as mathematical thinkers by engaging in inquiry-based learning through exploration, conjecturing, questioning, sense making, and seeking alternate solution paths.
- Students should be provided opportunities to make mistakes and collectively learn from them.
- Students should work in a physical setting that promotes teamwork, builds respect for one another's ideas, and critique the thinking of others.
- Students should work with appropriate tools to expedite computations and symbolic manipulations, but also to formulate hypotheses, test conclusions, and validate their thinking.

Engaging Students in the Online Environment

Higher education institutions have experienced a recent surge in online course enrollment. Allen and Seaman (2014) reported a 16.1% annual increase in students enrolling in online courses from 2002 through 2012 and predicted that online course enrollment will continue to increase in the future. Student engagement can be key to reducing attrition (Angelino & Natvig, 2009; Angelino, Williams, & Natvig, 2007). Therefore, faculty members must increase student engagement to boost retention and provide more productive and successful online learning environments.

Encouraging student engagement is a central concern for online instructors in higher education (Poll, Widen, & Weller, 2014). Poll et al. proposed six strategies for effectively engaging students in online learning

- Build a sense of community.
- Clearly state online course expectations and objectives.
- Use online tools and technology that promote interaction.
- Encourage the interchange of ideas and knowledge.
- Ensure feedback is timely and relevant.
- Create an online learning environment that is student-centered.

By implementing these six strategies, Poll et al.'s data illustrated increases in student engagement, learning outcomes, and course completion.

Asynchronous activities, such as discussion board assignments, provide additional opportunities to actively engage students online. They allow valuable faculty-student and student-student interactions, encouraging the exchange of ideas and knowledge. Discussion assignments can help students build a sense of community. Effective discussion topics will be thought-provoking and clearly related to course outcomes (Poll et al., 2014). In online mathematics courses, discussion topics may include selecting the best method for a particular problem, test-prep strategies, or memorization techniques for lengthy formulas. Such topics provide students the opportunity to engage with the course material in a way that promotes a student-centered online learning environment.

Tallent-Runnels et al. (2006) found that allowing students a degree of control over the pace of online lessons can improve student engagement. According to Wilson and Whitelock (1998), regularly incorporating dramatic tension in online instruction increases student engagement. Students must feel challenged for learning to take place (Vygotsky, 1978). In general, online instruction should provide multiple opportunities for them to engage with the content, with each other, and with the instructor.

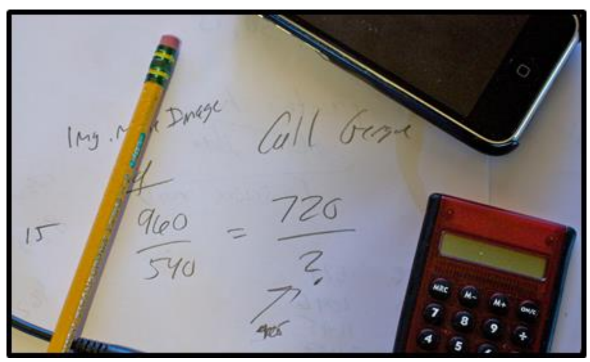
Engaging Faculty in the Pursuit of Excellence

To foster an environment of professionalism, institutions and departments should find innovative ways to engage faculty in collegial dialogue about best practices for improving the learning experience for students. Effective teaching is a result of faculty preparation, experience, reflection, and continued professional development. When faculty engage in these activities, the result is an invigorated commitment to teaching and innovation, which benefits students, the department, the college, and society as a whole. Departments and institutions can promote student prowess by creating a climate of collegiality for faculty, providing growth opportunities, and supporting faculty evaluation, reflection, and improvement.

Cultivating Collegiality

To create a climate of collegiality among both full-time and part-time faculty, an effective department environment encourages all faculty to develop and share their expertise with each other. Departments who have built collegiality among faculty find innovative ways to work collectively to enhance course materials, such as their assessments, and debrief about their teaching as a way of improving the quality of collegiate mathematics instruction.

Furthermore, departments whose members collaborate and share a common vision for the teaching and learning of mathematics move closer to the goal of increasing student success in the first two years of collegiate mathematics. This collaboration should center around building a community of faculty who work together by discussing ideas related to teaching mathematics, developing student assessments, and analyzing samples of student work. In the K-12 environment, professional learning communities (PLC) have been successfully implemented to promote communication among teachers and enhance teachers' mathematical knowledge for teaching (DuFour & Eaker, 1998; DuFour, Eaker, Many, & Mattos, 2016). However, learning communities are far less common among postsecondary mathematics faculty but if implemented could have a significant impact on cultivating collegiality. One benefit of faculty collaborating in a learning community is that they can discuss the details of course assessments, materials, student work, and other issues that arise when teaching. The process of developing a faculty learning community could facilitate the writing and reviewing of assessment items, for example, to ensure clarity and purpose of the items. The following vignette highlights the experiences of three faculty, who are new to teaching Calculus, while working in an informal learning community.



Three calculus instructors—Janell, Ashley, and Miriam—decided to work together one semester to create better assessment tools. Since none of the instructors were veteran Calculus 1 teachers, they felt compelled to form a learning community focused on creating tests, accompanying review activities, and classroom activities that engaged students. In reflecting about their experience, Janell commented, "we gained valuable knowledge on how to write effective test problems that targeted specific skills by looking at tests that were written by experienced instructors. We were able to eliminate 'ineffective' and 'defective' problems more quickly by pooling our experiences with those questions." Ashley felt that working together helped her write tests that were neither too hard nor too easy. With the collaboration, they all were holding their students to the same standards. In addition to the benefits that these three faculty gained, students also benefited from sharing their lesson plans, reviews, and assessments. The collaboration allowed the faculty to catch each other's mistakes and enhance their instructional materials. Since the review sheets they created were similar, students from all three classes were able to study together for upcoming tests. Janell comments that, "it was really encouraging to see so many groups of students working together in The Math Solution (our math study center) many with a sense of excitement and engagement." Ashley reflects, "I know that I became a better teacher because I was able to use Miriam and Janell's years of teaching experience to help guide my own teaching in my classroom. I also believe that our students were more successful. I wish we had learning groups like this for every class."

Forming learning communities among faculty in smaller mathematics departments is a challenge due to not having multiple instructors who are teaching the same courses. For these faculty, there are opportunities to collaborate with educators from other institutions across the nation. The Networked

Improvement Communities (NIC) is a unique example of a national group of faculty who collaborate on issues related to teaching and learning. According to LeMahieu (2015), four characteristics of successful NICs that promote effective collaboration are

- A focus on a well-specified aim.
- A deep understanding of the problem, the system that produces it, and a relevant theory of improvement.
- A guide for incorporating improvement science when determining the effectiveness of programs.
- A plan to coordinate and accelerate the development, testing, and refinement of interventions and their effective integration into practice across varied educational contexts.

NIC can serve as an excellent resource for all instructors, especially those who have limited opportunities to collaborate with local faculty in their institution.

Departments that actively engage faculty, support and mentor new members, encourage existing instructors to innovate in the classroom, and invite experienced teachers into leadership roles can create an environment of collegiality. Some key principles to guide departments are

- Promote an environment where instructors are encouraged and supported to share, improve, and reflect upon course materials, resources, and assessments through learning communities.
- Coordinate a faculty-mentoring program to help new faculty integrate into the culture of the department and institution.
- Encourage faculty to embrace teaching as a continuous improvement endeavor by attending conferences and participating in professional learning communities within the department and beyond.
- Provide opportunities for faculty to develop as leaders in their department, institution, and profession.

Providing Faculty Development and Supporting Faculty Improvement

Supporting and offering professional growth opportunities for faculty should be an ongoing initiative of institutions of higher education. Similar to the medical field, teaching is a discipline that evolves, and faculty need opportunities for continuous enhancement of research-based teaching practices that support students' active and cognitive engagement *with* mathematics. Traditional forms of support, such as offering faculty travel for conferences, providing sabbatical leaves, and coordinating department colloquiums and symposiums, provide experiences for faculty to grow and expand their knowledge about teaching mathematics. To push the boundaries of these traditional supports, faculty should also be encouraged to pursue other efforts, such as completing additional graduate coursework, participating in discussion groups focused on reviewing scholarly publications, and leading action research projects designed to produce informative results for improving practice. These examples can build community among faculty and further develop instructors as effective practitioners. Mathematics departments and institutions should provide regular and comprehensive faculty development opportunities for both full-time and part-time faculty, as well as support to participate in programs offered outside of their college or district.

In order to support faculty improvement, departments should establish and communicate a shared departmental vision for the teaching and learning of mathematics. This vision can drive the department toward a culture where growth in the art of teaching and enhancement of mathematical knowledge becomes an established characteristic. The department chair should promote an environment where faculty are nurtured to innovate and experiment with new ways of teaching. This can be achieved by creating a list of initiatives that the faculty within the department wish to engage in, then allowing them to determine which of them pique their interest the most. The initiatives of the department may change from semester to semester or year to year, but they should all be motivated by the department's shared vision. This vision should form the foundation for faculty evaluation that leads to improvement. Teacher evaluation is the process of self-review, as well as the review of faculty work by supervisors, peers, and students. Different types of evaluation, such as peer evaluation, student evaluation, self-evaluation, and administrative evaluation may contribute to a faculty evaluation process that improves student learning. Each type of evaluation is a valid tool for self-improvement in teaching and learning. Objective and subjective criteria should be included in the evaluation process. Informal discussion among and between peers should be encouraged to promote excellence in teaching. Departments and institutions can ensure that the periodic evaluation process for part-time faculty be as rigorous as that for full-time faculty. Departments and institutions can

- Provide a description of the faculty evaluation process to instructors.
- Specify the rubric criteria to be used for rating particular aspects of the faculty's performance.
- Gather input from multiple sources in the faculty evaluation process, (i.e., peer evaluation, student evaluation, self-evaluation, and administrative evaluation).
- Include opportunities for self-reflection on the part of the faculty member.
- Require input from the faculty member and evaluator in the establishment of a future action plan.
- Encourage and support innovation and classroom research as methods toward faculty improvement.

Working Together for Engagement

The primary message of this chapter is that we need to find innovative ways to engage students in and out of the classroom, as well as engage faculty in the pursuit of improving the teaching and learning of mathematics. Engaging faculty to pursue excellence requires that departments and institutions build an environment that supports collegiality, provides professional growth, and fosters self-evaluation and reflection. Finally, instructors should think critically about how students can be engaged actively and cognitively with the mathematics, during and after class. Active learning strategies, such as in Rachel's vignette, can provide a community of students invested in their learning. Our community also needs further research in this area to identify model departments and their effectiveness in supporting student success. Finally, the ability to share our ideas with faculty across the nation through IMPACT Live! (the online extension of *IMPACT*) will play a crucial role in the ongoing pursuit to engage our students and other faculty as we strive for student success.

Would you like your students to be more engaged in class? Are you wondering what you can do to rejuvenate yourself so that you are more engaged as a member of the mathematical community? Do you already have great information or activities involving faculty or student engagement? Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

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Chapter 6

Student Success

Stimulating Student Achievement in Mathematics

Action is the fundamental key to success.
~Pablo Picasso

Student Success is integrated with proficiency, ownership, and engagement as the final pillar of mathematical PROWESS. Two-year colleges are now at the center of the *learning college* movement (Flynn, n.d.; AACC, n.d.), where the goal of education is to put student learning first—a critical focus of the Student Success Agenda (Achieving the Dream, n.d.). Three questions are critical to this agenda:

1. What is student success?
2. How can student success be enhanced by design?
3. What can be measured or assessed that constitutes as evidence of student success?

By examining the answers to these questions, we can focus on engaging all key stakeholders in the process of promoting success for students.

What is Student Success?

With the ongoing dialogue about higher education focusing on college completion, accountability, and assessment, it is important to have a common definition for student success (Fulton, 2017). Success can be defined as meeting a goal or outcome. We therefore define *student success* as the fulfillment of a student's academic or professional goals or outcomes. During the past decade, various key performance indicators have been standard practices used in higher education literature as well as all six regional higher education accreditation agencies to measure student success (Community College Research Center [CCRC] & American Association of Community Colleges [AACC], 2015a), Cuseo, 2012). These include

- Academic Achievement or Successful Course Completion (Grade of A, B, or C) and Success in Subsequent Courses. This indicator focuses on high levels of academic achievement including academic recognition of any kind (for example, dean's list, scholarships, honors credit, Phi Theta Kappa, AMATYC Student Mathematics League, AMATYC Student Research League).
- Student Persistence or Term-to-term Persistence. Do entering college students enroll, stay enrolled and maintain their enrollment in the college? Institutional data collected on persistence should track students' continuous enrollment in consecutive terms fall-to-spring and fall-to-fall (National Student Clearinghouse Research Center [NSCRC], 2015; Berkeley, 2017).
- Educational Attainment. This focuses on entering students' persistence to completion of their degree, program, or educational goal. National data reports track students' advancement from developmental education to college credit courses, successful "gateway" course completion, and completion of degree and certificates.
- Student Advancement. The focus of this indicator is on a student's successful progress and completion of college degree or program. For example, two-year college students have diverse goals, which include transferring to a four-year university, earning an associate's degree, completing courses for professional growth, and completing courses for personal growth or to earn a job related to their degree.
- Holistic Development. This places emphasis on whether students develop not only intellectually, but also emotionally, socially, artistically, and creatively as they progress through and complete their college experience.

These indicators underscore the importance of ensuring that students are enrolled in appropriate courses aligned to meet their academic needs. Such alignment should be indicative of a high quality curriculum which seeks to answer the questions (Bailey, Jaggars, & Jenkins, 2015; O'Banion, 1997)

- What are the core skills, competencies, and content knowledge that we want our students to learn?
- How can we ensure that our students are learning (CCRC & AACC, 2015b)?
- What evidence do we have—in the form of product deliverables—that authentic learning is taking place?
- How can we, as members of a learning-centered institution, contribute individually and collectively to teaching for optimal student learning?

Enhancing Student Success by Design

Students enter our classrooms with varied academic preparation and expectations, which requires the entire college community to work together to advise and place them into appropriate pathways while creating a positive learning environment to maximize their success (Center for Community College Student Engagement [CCCSE], 2018). Producing and sustaining a learning environment that promotes student success should be a goal that unites administrators, support services, faculty, and staff. Schools should understand their student population, including barriers to student success. Support services should be available and accessible to minimize those barriers. According to AMATYC (2005, 2006), a two-year college that promotes and cultivates student success is one in which

- students experience an atmosphere where diversity is valued, individual differences are appreciated, and students have a sense of physical, social, and emotional safety
- faculty are engaged in continuous student success improvement efforts
- the institution provides academic support for faculty and students
- physical space is equipped with a variety of learning resources (such as computers, print materials, models, and workspaces) that reflect the different modalities and styles of learning.

Initial Assessment and Placement

In order to provide institutional supports for students, mathematics faculty, support staff, and administrators need to understand their student population. Because two-year colleges teach a high number of students who do not place into college-level mathematics courses, institutional leaders must recognize the challenges of programs, such as developmental mathematics, and explore initiatives to transform the ways in which they are facilitated.

Departments and institutions must provide multiple measures to support the decision-making process related to initial placement of students into mathematics courses (Bailey, Jaggars, & Jenkins, 2015). Mathematics faculty should be involved in the placement process, which may call for the use of a variety of assessment measures. Institutions must provide knowledgeable advisement to support students with these measures, while determining the most advanced courses for which they have the sufficient mastery of prerequisite skills and acceptable probability of success. Departments and institutions with demonstrated expertise in the area of placement do the following to achieve student success

- Ensure that mathematics faculty are involved in the design of mathematics placement measures and processes.
- Work to train advisors to place students into the most appropriate course for which they have prerequisite skills.
- Advise students into appropriate mathematics courses using a system that combines meaningful measures of readiness and attention to students' life goals.
- Provide structure for students to work closely with their advisors and faculty to ensure that their plan for mathematics learning is appropriate.
- Create opportunities for students to understand desired outcomes in mathematics courses.
- Evaluate the effectiveness of the placement processes as measures for student success.

Many students come to college with seemingly insurmountable obstacles to overcome. The flexibility of choice of courses and mathematical pathways provided by two-year colleges allow them to overcome these obstacles. A case in point is Emma's story.

Emma endures instability in her family and has had previous failures in mathematics. She has demonstrated her proficiency at circumventing obstacles. For example, one obstacle that she encountered was being denied admittance to the local high school due to the school's internal policies after her family moved. From the start of her college experience, Emma has taken ownership of her learning. She relates the following experience with her choice of her first college mathematics class upon enrollment at the two-year college. "I had the choice of going straight into College Algebra or taking the Intermediate Algebra class because ... of where I scored on the placement test and so I actually decided to take the Intermediate Algebra class just for a refresher course. I had been out of school for so long."

This is a course selection strategy employed by some students, especially non-traditional students. The students' first mathematics class is one or more levels lower than that in which their placement test scores indicate they are eligible to enroll. They describe a need to rebuild their mathematics foundation.

Advising Students

Once students are properly placed, higher education communities need to be a guiding force to them as they traverse their academic path. One method is via the use of the Survey of Entering Student Engagement (SENSE) design principle, which focuses on students having a *clear academic plan and pathway* (CCCSE, 2018). Students must appropriately be advised to follow an academic plan and a pathway that will help them to reach their goals. They are more likely to persist if they are not only advised on what courses to take but also assisted to set academic goals and to create a plan for achieving them. In order for there to be a clear academic plan and pathway for students, mathematics departments should develop, implement, evaluate, assess, and revise courses, course sequences, and programs to help students achieve their academic and career goals.

When considering alternative mathematical pathways, it is important to note that most students in the first two years of college do not take a sequence of mathematics courses that lead to achieving their goals. Either they take no mathematics at all, or they attempt one and not others. Such students are likely to not obtain a degree or certificate or transfer to a four-year institution (Mills, 2016). In the case of developmental mathematics, a small fraction of students is successful. To achieve the vision of *IMPACT*, we must employ proven mathematical pathways and instructional practices that increase student success.

Various new pathways curricula are being discussed not just by higher education institutions but also among policy makers at the provincial, state, and local levels. The multiple pathway conversation continues to grow and there are several projects currently being implemented to shorten and strengthen mathematical course-taking sequences so as to improve student success.

Learning Environment

Students and faculty must be knowledgeable about research on how students learn mathematics and the effects of variables such as age, race, gender, career goals, socio-economic background, and language skills. Instructors must recognize the need to create a nurturing environment that raises students' self-esteem and encourages them to continue their study of mathematics. In this environment, faculty, support service personnel, and students must be a team. Factors that are instrumental to student learning include

- Mathematics departments and faculty mindfulness of how their biases and prejudices may affect student learning. The classroom must be welcoming and promote principles of inclusion, access, and equity (Chao, Murray, & Gutiérrez, 2014; AMATYC, 2005).
- Faculty incorporation of innovative teaching and learning strategies that use technology and activities designed to promote active student engagement, meaningful discourse, cooperative learning, fostering active student engagement in mathematical thinking and encouraging student creativity and risk-taking.
- Faculty exploration of ways to spur appreciation of how mathematics can be used outside of the classroom environment (National Research Council [NRC], 2001).
- Faculty involvement in mathematics professional organizations (AMATYC, 2014a).
- Faculty collaboration with instructors in both mathematics and non-mathematics disciplines to develop learning communities that pair a mathematics class with a class in another

department and actively seeking out guest speakers from scientific fields.
- Faculty involvement in training tutors specifically on how to assist students effectively in the first two years of college mathematics.
- Learning resources such as the library, disability services, student support networks, and tutoring centers focusing on the availability to students who may be in need.
- Learning resources incorporating the necessary physical space, materials, technological resources, and support staff facilitating effective learning of mathematical concepts and skills.
- Learning resources encouraging student-faculty contact.
- Student participation in student mathematics clubs and competitions.
- Students help in recruitment of fellow students, including those from underrepresented groups, into mathematics-intensive programs and careers.
- Student exploration of career opportunities in STEM-related fields.

This list updates AMATYC's (2006) recommendations addressing the diverse talents and ways of learning and teaching and is designed to be effective in developing PROWESS.

Technology undoubtedly has had an impact on the mathematics classroom. During the past decade, two-year colleges have experienced an unprecedented growth of 344% in the number of courses offered in the online and hybrid (blended) modality (Allen & Seaman, 2014). Faculty who are actively involved in the design and delivery of these courses must take action to ensure that the goals, learning outcomes, and learning experiences are not compromised in the absence of face-to-face interactions between instructor and students and between students and students. Faculty teaching courses via distance learning must receive sufficient training in this mode of delivery.

Institutional Responsibilities for Enhancing Student Success

Institutional leadership—department chairs, department leaders, and administrators—has an obligation to develop a professional mathematics department comprised of dedicated and qualified faculty and an environment that fosters their growth in their vocation. Such a department is key to student success.

Institutions Hire Qualified, Knowledgeable, and Diverse Faculty and Staff

Selecting highly qualified mathematics faculty is essential to student achievement. Departments and institutions must employ candidates who are credentialed and highly knowledgeable about teaching and learning theories for mathematics, and committed to the mission of two-year colleges. Faculty, both full-time and part-time, should be supported with appropriate office space, technology resources, and access to student information. Departments and institutions should

- develop and apply suitable criteria for hiring new faculty that reflect AMATYC's (2014b) position statement on faculty academic preparation
- advertise personnel vacancy notices widely; contact professional organizations, graduate schools, and other entities to broaden the applicant pool in order to hire diverse, qualified highly knowledgeable faculty about teaching and learning theories for mathematics
- include faculty members on all search and hiring committees, for full-time and adjunct faculty.

AMATYC's (2014a) viewpoint is not intended to replace any regional, state, or local requirements or recommendations that may apply to hiring faculty, assigning them to classes, or evaluating their performance or qualifications but rather "to provide guidelines that reflect the collective wisdom and expertise of mathematics educators throughout the United States and Canada regarding appropriate preparation for two-year college faculty involved in the teaching of mathematics, whether on a full-time or part-time basis" (para. 1).

Promote Professionalism

Professionalism with its core values of expertise, autonomy, commitment, and responsibility is at the heart of improving student success in mathematics. All mathematics faculty who teach in the first two years of college need to possess a strong academic preparation, participate in supportive professional development, be open to change and improvement, demonstrate an ability to work in teams with other faculty, and be willing to assume responsibility for carrying out multifaceted professional activities. These are not attainable without deliberate faculty action.

Effective mathematics instruction requires the integration of a variety of instructional strategies, resources and materials, technology, and delivery formats. Knowledge of instructional methods that are aligned with up-to-date research into the ways students learn mathematics must be used to improve instructional practice. Institutions should

- offer faculty professional development opportunities on multiple approaches to effective instruction
- provide instructors with appropriate resources necessary to design and implement instructional strategies that actively engage students
- establish and maintain the infrastructure and resources essential to the support, development, and teaching of distance learning courses in mathematics (these should be aligned with current best practices)
- offer training to faculty about career planning and advising for students.

AMATYC (2014a) suggests faculty be life-long learners in both content and pedagogy in order to stay current in the field of mathematics. Area of professional development might include

- graduate coursework in mathematics and mathematics education beyond the level of the individual's previous study
- courses in some other disciplines served by the two-year college mathematics curriculum may also be appropriate
- doctorate in mathematics or mathematics education
- reading journals
- instruction on the use of current technology to enhance the teaching and learning of mathematics
- attending professional conferences, webinars, mini-courses, and/or summer institutes
- publishing books and journal articles.

Institution Responsibility for Creating Learning Support Environments

When two-year college students describe their early college experiences, they typically reflect on occasions when they felt discouraged or considered dropping out. Their reasons for persisting usually included one common element: a strong, early connection to someone at the college (CCCSE, 2009, 2018). Students generally benefit from having a personal network for academic and social support. One of the main challenges that institutions face is a better understanding of students' experiences.

While this is a challenge, it is also an opportunity for colleges to be purposeful in creating learning support environments that address students' socio-academic needs. We suggest some ways to create a supportive learning environment.

- **First Week of School**. The first week of school is often a period when students experience high levels of back-to-school anxiety and stress. These are sometimes caused by the busyness of that week, and the necessity to quickly meet academic "housekeeping" requirements such as registration, textbook purchase, familiarization of where classes are held, as well as course syllabi. An effective and supportive educational environment reduces challenges at the beginning of the term. We suggest colleges provide a supportive environment during that week to help alleviate stress levels. This can involve having more counselors or advisors to assist with registration. Precision-scheduling dramatically reduces late add-ons to classes and enforces an application deadline for new students allowing faculty to reclaim the first week for learning.
- **Mathematics Support Services**. Departments and institutions should provide services that support both student success and social interaction among mathematics students, for example, tutoring services, mathematics clubs, peer or faculty mentoring.
- **Supplemental Instruction**. This is a learning support program that utilizes student peers to provide student-led instruction. A Supplemental Instruction (SI) session, which is student-led, creates a non-threatening environment where students, regardless of their sociocultural or academic background, can interact with each other (Arendale, 2002). Arendale's research indicates that SI can have a positive impact on student learning.

Institutions have the responsibility to actively foster and support the professional development of their mathematics faculty to improve their instruction which will lead to student success. To facilitate this, colleges should provide mathematics faculty with

- reassigned/release time for professional enrichment projects and/or activities
- financial support for such things as those associated with participation in workshops, conferences, college coursework, and professional collaboration activities
- compensation or reassigned/release time for the development of curriculum, innovative pedagogical approaches to instruction, and new educational media
- sabbatical or professional leave (AMATYC, 2014b).

Corequisite Pathways Model

The "corequisite" model allows for students to go directly into college-level mathematics classes while receiving learning support at the same time (California Accelerated Project [CAP], n.d.; Complete College America [CCA], n.d.). The CAP details methods of implementing corequisite remediation, including "pairing a transfer-level course with a support course, extending instructional time through additional lecture or lab hours, or requiring students to participate in academic support services or supplemental instruction" (para. 3). At the time of this publication, several states have enacted or are in the process of the legislative actions related to guided pathways, which includes the corequisite model (Educational Commission of the States [ESC], n.d; Johnstone, 2017).

Linking Developmental Math with Student Success

A course on student success is typically taught as corequisite to (in conjunction with) the "redesigned" first college mathematics course. The content includes concepts from the learning sciences (i.e., mathematics study skills, anxiety reduction, technology usage, awareness of college academic support resources) to help students develop the skills and "tenacity" needed to be successful in mathematics, other college level coursework, and in their future careers and lives as citizens. Students often build stronger bonds with their peers, including classmates, faculty, and staff because they spend more time together (CCCSE, 2017; Kuh, 2007).

During high school, Hannah was never very good at mathematics. When she came to college, she realized that she had not applied herself during high school and it was time to get serious about school. She enrolled in an elementary algebra course, which she succeeded in quite well. Hannah then simultaneously enrolled in an Algebra Success Course and College Algebra. She was accustomed to a lecture format course, and was successful in that format. The new course was group-oriented coursework where students needed to support each other in the learning. Hannah found this new style of coursework challenging and soon realized that "the pressure was put on me to learn instead of pressure put on the teacher to lecture." Hannah realized that, despite a student's past experiences, success in a course means that students need to be prepared to take the skills and knowledge imparted by the teacher and apply those skills to mathematics concepts. According to Hannah, the faculty created a mathematics program that "uses several different learning techniques to try and help accommodate as many students as possible. I think that is great because it will benefit not only me, the traditional learner, but other nontraditional types of students." Hannah feels that after that first college math class, she "found that the classes after that [got] easier once you [understood] the strategies for learning and understanding mathematics."

Assessing Student Success

We have defined student success and established the core skills and competencies we want our students to learn. Now, we focus on how best to assess student success. From the onset, any form of assessment should be evidence-based and data driven. Institutions and departments should embody a culture of evidence; that is, "collective mindset, one in which critical decisions affecting students are informed by data and evaluated in light of whether student achievement increases" (Manning, 2009, p. 5).

Assessment and Maintenance

Assessment refers to processes that provide information on the nature and quality of learning. As identified in Chapter 4, this feedback is critical for the three areas where faculty can assume ownership: Curriculum, Course Design, and Learning Environment. A single assessment activity may produce information on just one component or it may address multiple areas. In all, the purpose of assessment is to improve learning and build PROWESS. To do so we suggest

- Assessment should be an ongoing process of collecting pertinent evidence that informs instructors about students' level of mathematics proficiency.
- Assessments should be authentic: that is they should accurately evaluate students' abilities in real-world contexts.
- Assessments should focus on evaluating students' higher order thinking skills collaborative work, and communicative skills.

Assessments are used at different levels: each classroom, each course, and each program. Each level seeks to provide acceptable improvement over time. The validity and reliability of assessments should be measured and developed as part of the process. Presumptions about either validity or reliability of particular assessments need to be supported by evidence. Recent shifts in the primary mission of two-year colleges from access to completion have resulted in greater emphasis on outcomes-based assessments for greater accountability across the various stakeholders. The lists below describe what and how assessment is done at each level: Classroom, Course, and Program.

Classroom Assessment

- use Learning Assessment Techniques (LAT), such as exit tickets, quick writes, and concept maps, which have emerged as effective instruments for unifying teaching, learning, and assessment (Barkley & Major, 2015)
- use Classroom Assessment Techniques (CAT) which identify a set of learning outcomes together with an active learning instructional activity and guidelines to analyze the student's work (Angelo & Cross, 1993)
- incorporate assessment activities into the classroom on a regular basis
- provide continuous feedback, and in ways that are most helpful to student learning
- adjust classroom activities in response to assessment information
- discuss assessment results with students and explain how the information is being used to make instructional decisions
- use a variety of assessment techniques including formative, summative, and authentic assessments
- use assessment data as a learning tool to address misconceptions and misunderstandings
- assessments should support learning and be useful for both instructors and students.

Course Assessment

- develop core student learning outcomes for each mathematics course in collaboration with other local or regional faculty in the K-20 system
- communicate course outcomes to students at the beginning of the course
- use course assessments to measure achievement of those outcomes and determine needed improvements
- use results of assessment to improve the learning environment during the course and in subsequent semesters.

Program Assessment (AMATYC, 2012)

- identify assessment tools linked to desired institutional student learning outcomes and proceed through the assessment implementation cycle to implement improvements
- develop assessments to monitor placement and progression in sequences and pathways
- train faculty to participate in the development and assessment of general education outcomes in mathematics and determine which of the general education outcomes are met when students complete a given mathematics course
- continually use assessment results to evaluate program effectiveness, and provide feedback to faculty, administrators, and students.

Institutional Research

Institutions generally collect a vast amount of data for various reasons. For the purposes of student success in mathematics, we suggest a culture of evidence that focuses on

- using results to determine "what works" and what requires improvement
- collecting and sharing systematic, timely, useful, and user-friendly information about student learning and educational experience
- establishing a culture that encourages all stakeholders to rigorously examine and openly discuss institutional performance
- tracking cohorts (e.g., first time in college, first generation, degree-seeking vs. non-degree seeking, major) of entering students to measure outcomes and identify areas for improvement
- disaggregating data by student characteristics, such as age, gender, race or ethnicity, and income level
- using the results of student and institutional assessments to make routinely informed decisions about strategic priorities, resource allocation, faculty and staff development, and improvements in programs and services.

Working Together for Student Success

Increasing the number of students who achieve student success is not easy. There are no quick fixes for the problems that face today's two-year colleges, particularly as they relate to the mathematics curriculum in the first two years. We need a long-term sustained focus from professional organizations, college leadership, faculty, staff, and policy makers. As noted previously, a collaborative spirit is imperative to improving mathematics prowess and college teaching.

Would you like to design a new approach in your classes that would promote student success? Are you wondering what can be done to inspire your institution to have a concrete plan for improving student success? Do you already have great information or activities involving student success? Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

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Chapter 7

Continuing the Ripple:
Bringing the Community Together to Accomplish Change

> People are always looking for the single magic bullet that will totally change everything. There is no single magic bullet.
> ~ Temple Grandin (Autism Research Institute, 1996, para. 26).

The *IMPACT* document provides suggestions for improving the teaching and learning of mathematics for the primary purpose of increasing students' mathematical PROWESS in the first two years of college. One component of *IMPACT* is to help faculty seek continuous improvement for better ways to meet the needs of their students. Change can happen at many different levels: classroom, department, college, state, and national. For example, an instructor may seek to employ active learning in a classroom. A department may create major-specific mathematics pathways, revise its curricular philosophy, or adopt a process to establish quality instructional materials. A college may choose to rethink its placement policies and at the same time consider alternative models for delivering mathematics content and pedagogy. A multi-campus institution or system may define and solve problems collaboratively and rethink articulations between K-12, two-year colleges, and four-year institutions. A state may choose to help meet the needs of more students with greater efficiency and more appropriate enabling policies. Lastly, national initiatives that promote STEM learning and enhance state standards, such as the Common Core movement, can elevate the teaching and learning of mathematics. In all of these instances, the work involves multiple stakeholders working together to make meaningful change.

For effective implementation of change, faculty can benefit from the support of college administration and their department. In parallel, the department benefits from faculty ownership and support of the administration to enact such changes. Changes at the college level also require faculty and administration working together to review and update local policies and procedures that foster campus support for reform. Such changes are not easy, but there are now many examples of institutions and groups working to influence the types of changes that this document advocates.

Change, especially educational change, often requires periods of disruption, discomfort, and inconvenience on the part of faculty, administrators, and students. It is important, though, that such temporary issues not stand in the way of actions that will help students succeed and better meet their academic goals. One model for success in accomplishing educational change is to consider and involve stakeholders as change is envisioned and implemented. Those who seek to initiate change in the first two years of mathematics at the college level should never lose sight of the following five key elements for effective change: (1) student-centered, (2) policy-enabled, (3) administratively-supported, and (4) culturally-reinforced, (5) educator-driven. These elements are based on the work of the Charles A. Dana Center at the University of Texas at Austin. The Dana Center has been working for many years to improve student success in mathematics and has a track record for successfully impacting change. The organization is working with statewide systems and individual institutions to build mathematics pathways. It believes that *all* students in higher education should enroll in pathways that will

- prepare them to use mathematical and quantitative reasoning skills in their careers and personal lives
- enable them to make timely progress towards completion of a certificate or degree
- empower them as mathematical learners (The Charles A. Dana Center, n.d.-a).

A key outcome of their work is the development of alternatives to the traditional algebra-for-all pathway, based on the needs and goals of students in a changing world. They encourage local educational leaders to develop their own structures and strategies so that mathematics pathways are built as follows:

1. **Institutions implement structural and policy changes quickly and at scale**. Mathematics pathways are structured so that all students, regardless of college readiness, enter directly into mathematics pathways aligned to their program of study. In addition, students complete their first college-level mathematics requirement in their first year of college.
2. **Institutions and departments engage in a deliberate and thoughtful process of continuous improvement to ensure high-quality and effective instruction.** Students engage in high-quality learning experiences in mathematics pathways designed so that strategies to support students as learners are integrated into courses and are aligned across the institution and that instruction incorporates evidence-based curriculum and pedagogy (The Charles A. Dana Center, n.d.-b).

The Dana Center has developed resources to help stakeholders engage in thoughtful planning, knowing that the logistics of working on the transfer and applicability of pathways to programs can be daunting. This work takes time and commitment and needs someone to manage the process to make sure that important details that might negatively impact students are anticipated and avoided. Amy Getz (personal communication, May 9, 2017) from the Dana Center suggested a number of takeaways from their work:

- Local work at the institutional and classroom levels is critical, but simultaneous work across all levels of the system is necessary for change to be taken to scale.
- Standardization evolves to "coherence without conformity." That is, there is both structure and flexibility.
- Development of a model for engagement across a system requires a strategy for working with all of the institutions. Some institutions are more ready for change than others.
- Policy is complex and important. The Dana Center stresses the importance of being proactive on policy issues and prioritizing advocating for change as part of the process.

- Transfer and applicability to program requirements and pathways are issues for both two-year and four-year colleges. Two- and four-year transfer partners need to establish memoranda of understanding for mathematics requirements.
- Statewide-level change is possible but requires a strategy.

As faculty, when our frame of reference is just one institution it is easy to lose sight of what shifts are happening in college-level mathematics around the country. To provide a national perspective, every five years the Conference Board of the Mathematical Sciences (CBMS) surveys a sample of two-year and four-year college mathematics departments and publishes a statistical abstract of undergraduate programs in the mathematical sciences in the United States. For the first time, the 2015 CBMS survey addressed the implementation of mathematics pathways. The survey reported that in the fall 2015, fifty-eight percent (58%) of two-year colleges indicated having implemented a pathways course sequence, enrolling a total of 192,000 students (Blair, Kirkman, & Maxwell, 2018). Some colleges reported implementing not one, but multiple pathway courses such as Foundations (often non-algebraically intensive courses designed to prepare students for college-level gateway courses), Quantitative Reasoning/Literacy, and Statistics. In addition, significant changes occurred between 2010 and 2015 with respect to course content, delivery methods, and instructional strategies.

Another organization, The Carnegie Foundation for the Advancement of Teaching, has a national presence in working on solutions to low transfer-level mathematics completion rates through their Carnegie Math Pathways program utilizing Networked Improvement Communities (NIC). The work of the NICs is leveraged to promote change in institutions and systems through their "Change Package", which pushes beyond the traditional curriculum adoption reform to include the needed supports for both students and faculty. The "Change Package" includes

- accelerated pathways coursework
- ambitious, relevant, problem-centered curriculum
- student-focused, collaborative pedagogy
- productive persistence (socio-emotional) interventions/practices
- language and literacy supports embedded in materials and training
- comprehensive and sustained professional learning opportunities
- network engagement to support adoption and ongoing improvement.

Although this work initially focused on non-STEM pathways, additional units were developed to allow students to move into algebra intensive pathways (C. Thorn, personal communication, July 13, 2017).

In the rest of this chapter, we provide examples of change, the challenges encountered, the solutions employed, and results experienced. We share how faculty, administration, policy, and culture interacted to improve outcomes for students. The intent of this chapter is not to say that such changes are appropriate for all, but to illustrate the types of large-scale changes that have been made in mathematics in the first two years of college and how such changes occurred.

Changing a State

Building a Community of Two-Year and Four-Year Faculty: The Ohio Mathematics Initiative

In May 2013 the Ohio Department of Higher Education (ODHE) (at the time called the Ohio Board of Regents) convened the Ohio Mathematics Summit, a meeting of mathematics faculty from all 36 two- and four-year public institutions of higher education in Ohio. The Summit was organized to explore

- policies that were impacting mathematics education in the state's two-and four-year postsecondary institutions
- student retention issues confronting institutions across the state
- concerns about the Ohio Transfer Module guidelines for mathematics, statistics, and logic
- effectiveness of quantitative pathways for STEM and non-STEM postsecondary majors.

This meeting resulted in the creation of the Ohio Mathematics Steering Committee with the goal to develop expectations and processes that result in each campus offering pathways in mathematics. These pathways will yield (1) increased success for students in the study of mathematics, (2) a higher percentage of students completing degree programs, and (3) effective transferability of credits for students moving from one institution to another (ODHE, 2014, p. 2).

The Steering Committee was chaired by Joan Leitzel, Professor Emeritus of Mathematics at The Ohio State University. Uri Treisman and the Dana Center provided assistance to the Committee. The final report released in March 2014 included an action plan, *Rethinking Post-Secondary Mathematics* (ODHE, 2014). The recommendations of this report resulted in the creation of the state-wide Chairs and Leads Network, consisting of mathematics chairs and leads from each of Ohio's public institutions of higher education. This network has enabled timely, meaningful, and cross-institutional communication. Some of the accomplishments of the Network include

- the development of a framework for mathematics pathways
- the development of a quantitative reasoning course that is transferable statewide
- a revision of the Ohio Transfer Module Mathematics, Statistics, and Logic Guidelines
- the development of Fast Fact sheets about the work to maintain communication (Ohio Mathematics Initiative)
- bringing together college and high school mathematics faculty, advisors, and counselors

Mathematics faculty play a central role in this project which has helped to develop an influential statewide "mathematics community." The Chairs and Leads Network collaborate with administrators on their own campuses and the ODHE to implement ideas. Communication is an important component of this project where subgroups work to revise, revamp, or replace state-level policies that hinder or prevent innovative course offerings and non-traditional approaches to remediation and mathematics education. In addition, individual institutions engage mathematics faculty in revisions to course offerings, remediation, student support services, and mathematics pathways aligned with programs of study. Another facet of the project is state-level work with K-12 partners that explores 12th grade transition courses along with other pathways from secondary to postsecondary institutions. Finally, professional development activities and regional workshops provide training to faculty. Paula Compton, Associate Vice Chancellor, Articulation and Transfer for the ODHE (personal communication, April 22, 2017) sums up what they have learned: "When there are overarching goals that will help students with their mathematics education, faculty will come together to pursue those goals with the support of the state and teams of faculty meetings and professional development opportunities."

The work in Ohio centered on concerns about what is best for students in a world of changing demands. Key players worked to enable the necessary policies to allow change to happen. Administrators understood and supported the endeavors, communication was robust to support a culture that reinforced the work, and faculty played a central role throughout.

Changing Policy to Multiple Pathways

The Maryland Mathematics Reform Initiative (MMRI)

Shortly before Brit Kirwan retired as Chancellor of the University System of Maryland in 2015, he made a commitment to facilitate multiple mathematics pathways for students in public two-year and four-year institutions in Maryland to better meet the needs of students. The University System of Maryland received a First in the World grant from the U. S. Department of Education to "develop, implement, and evaluate a statistics pathway in order to accelerate developmental students' progress into credit-bearing postsecondary courses and help more of those students reach certificate or degree completion effectively and efficiently" (The University System of Maryland, 2016).

Twelve schools, seven community colleges, and five University System of Maryland institutions chose to participate in the grant although all public and private institutions in Maryland may participate in the meetings and professional development activities. The grant supports faculty to experiment with and collect data on student success when innovative pedagogy and placement strategies are used to create the goal of having better mathematics pathways for students. According to Nancy Shapiro, Principal Investigator and Associate Vice Chancellor for Education and Outreach of University System of Maryland, a high priority of the project was to revise the Code of Maryland Regulations regarding the general education mathematics requirement that applies to all public institutions of higher education in Maryland, since the existing regulatory language was interpreted to be discouraging to the implementation of mathematics pathways. A new Code of Maryland Regulations general education mathematics requirement was approved in July 2016 with new courses that can be applied to a student's program of study to be in place by July 2018.

Each institution participating in the grant is developing a new pathway to the first college-level statistics or quantitative literacy course. According to John Hamman, Dean of Mathematics and Statistics (personal communication, April 17, 2017), Montgomery College chose to use the Dana Center Mathematics Pathways Foundations of Mathematical Reasoning course to prepare students for a college-level statistics course. Initially, the biggest challenge for Montgomery College was the short time to select and develop a new foundation course and have it through the college's curriculum approval process so that a limited pilot could be conducted the following fall. The Foundations of Mathematical Reasoning course has some study skills built in, but faculty will embed study skills videos in the course as well. There are issues that will be studied carefully, such as whether the course will be appropriate for students who enroll in Survey of College Mathematics rather than Statistics, and if the new course provides students with an adequate mathematics background for other subjects that have an intermediate algebra prerequisite.

The College of Southern Maryland also based their Foundations of Mathematical Reasoning course on the Dana Center. Rob Farinelli, Associate Vice President of Academic Affairs and Professor of Mathematics at College of Southern Maryland (personal communication, July 21, 2017), said that their college's students, following successful completion of this course, will be able to enroll in either a college level Statistics course or a new Quantitative Literacy and Reasoning course. Some colleges participating in the project have selected other curricular options to prepare students, reinforcing the Dana Center's (A. Getz, personal communication, May 9, 2017) concept of "coherence without uniformity." Many of the colleges in the project report challenges with helping advisors understand the rationale for the pathways and why they should advise students to take the new foundation course.

With the help of leaders, who took on the role to enable the policy changes required to shift practice, the work focused first on what was best for Maryland students. Supported by campus administrators, the new opportunity for change triggered a culture that reinforced innovation, bringing together two-year and four-year college faculty in the state to lead the work on new mathematics pathways for students.

Changing a System

Mathematics Pathways: Ivy Tech Math Pathways Project, Indiana

Ivy Tech Community College is Indiana's public, statewide, singly accredited community college with 14 regions and over 40 sites throughout the state. In just four semesters, a number of teams composed of faculty, staff, and administrators overhauled its assessment and placement process; established three pathways of gateway mathematics courses aligned with different programs, majors, degrees, or career programs at the college (Tech Math, Quantitative Reasoning (QR) with developmental mathematics corequisite, and STEM); and eliminated standalone developmental mathematics courses in the Quantitative Literacy pathway. Rob Jeffs, Professor of Mathematics at Ivy Tech Wabash Valley and Carrie McCammon, Math Pathways Project Director at Ivy Tech Wabash Valley Region, stated (personal communication, April 24, 2017) that college faculty and academic leaders worked in partnership with the Dana Center to achieve

- validating the mathematics competencies that students in each program needed to be successful in the curriculum, seek employment in the field, or transfer to a university
- grouping the necessary competencies into a minimum number of gateway courses and work with program faculty to assure that the courses students select for their program meet the respective program's quantitative requirements
- convening four teams (Tech Math, QR, STEM, and Skills Development) to work with mathematics and program faculty to implement coursework and materials for pilots; evaluate content and pedagogy; and provide professional development for faculty who teach the new courses
- reviewing and aligning all of the questions in the 14 strands of test questions for the ACCUPLACER to courses in order to have more meaningful cut scores
- implementing multiple measures for placement
- implementing professional development in support of the QR, corequisite, and Tech Math courses
- surveying and identifying faculty who needed additional coursework to teach the QR course
- collecting and reporting on data on student success in the new Math Pathways courses

Faculty were central to this project and took on leadership and supporting roles. Jeffs and McCammon reported (personal communication, April 24, 2017) that "... the focus was on student success. … The cooperative work of math faculty and program faculty in the development of the QR and Tech Math pathways facilitated meaningful progress."

Previously, small numbers of students in technology programs passed the developmental and gateway course sequence. Jeffs and McCammon reported that as of 2017, after two years, 64% earn a C or better and 73% earn a D or better, which is leading to increased graduation rates for technology programs. With the co-requisite model with the QR course, Ivy Tech has seen over 60% of students who enrolled in the QR course successfully pass in one semester. Previously, if students had to start in the first of four developmental courses, fewer than 10% completed the gateway course in multiple semesters.

Major initiatives, such as the Ivy Tech Math Project, always have challenges. In addition to the four semesters needed to develop the new courses, new assessments, and placement procedures, an implementation timeline was established for phasing in and phasing out courses since community college students typically attend part-time. Resources were essential for training, stipends, faculty offloads, and money for materials for the Tech Math course. With changing demands, more faculty were needed for the QR courses and fewer for the STEM mathematics courses. Some faculty were required to take a few courses and participate in professional development in order to teach the QR course. An ongoing challenge is transferability. Work is underway to look at degree outcomes rather than courses so that the outcomes of the QR course can be evaluated. Collaborations through the Indiana Transfer Single Articulation Pathway and the Indiana Math Innovations Council will help with transferability of the new courses.

The Ivy Tech Math Project transformed mathematics in the Ivy Tech system with its unwavering focus on student success through the creation of mathematics pathways and the improvement of assessment and placement. Faculty, staff, and administrators participated in the statewide teams and helped to develop a culture of high expectations.

Changing an Institution

Shortening the Pipeline through Collaboration: Harper College High School Course Alignment Project, Illinois

Often, student success is achieved when all stakeholders work together to find solutions to critical issues. One of the important aspects of the Harper College High School Course Alignment Project was that administrators brought key players together early for difficult conversations as the project needed to garner support of a larger group of faculty. Kimberley Polly, Professor of Mathematics at Harper College, (personal communication, May 1, 2017) noted "No one likes change and this project required high school and college faculty to think differently about a seamless transition from high school to college.

In 2009, administrators from Harper College's three feeder school districts met to look at data on where their graduates placed in mathematics courses when they arrived at Harper. After reviewing the data, it was clear that it was important to increase the percentage of high school students who placed into college level mathematics courses at Harper, and to shorten the time it took to get to college level courses for those students who placed into developmental courses. Polly described the outcome of years of meetings and discussion as a comprehensive plan to move students towards college readiness in mathematics. The first part of the plan was the alignment of high school and college curricula which then led to the development of a high school final exam written collaboratively by high school and Harper faculty. Next came discussion of alternative methods of placement into college level courses using the results on the high school final exam. When this final exam was given in May 2012, the scores were lower than expected. As a result, the high school faculty and Harper faculty got together to discuss new alternatives for senior year mathematics. They proposed a "catch up" course for a subgroup of students so that they might be college ready in math by the end of senior year. If the students had done poorly on a final exam written entirely by Harper faculty, the success of the partnership might have been in doubt. The dual credit Quantitative Literacy course became a senior-year option; high school seniors were also allowed to take Harper's highest level developmental math course, Intermediate Algebra.

Polly's response to what they learned that would benefit others is that "building trust takes time and a lot of commitment from both sides. Strong partnerships require compromise and compromise makes both systems better … . Having high school faculty teach dual credit courses helps to smooth the transition from high school to college … , strengthens the prerequisite high school courses which makes students more prepared for our courses as they move forward."

Administrators brought a small group of high school and college teachers together to address issues of student success and began to develop the culture for change. The data on placement and student success highlighted the need to better address the challenges facing incoming students. Faculty set goals to decrease the number of students placing into developmental mathematics, shorten the time required to get to college level mathematics, and align high school and college courses. Over time, a culture of collaboration has been built that serves students.

Meeting the Needs of Liberal Arts and Humanities Students: Tarrant County College and The University of Texas at Arlington Redesign Projects

Two colleges in Texas, Tarrant County College and The University of Texas at Arlington, each undertook similar reform projects to get students into appropriate mathematics pathways based on their majors. After reviewing data on student success and researching various mathematics pathways, Tarrant County College formed an exploratory team to propose some changes. The team consisted of mathematics faculty members, an advisor who was also a mathematics adjunct, the Student Success chair, and the Math and Science Division Dean. Working from the Dana Center's Guiding Principles and after careful research and communication with intentional transparency, the team recommended modifying the Developmental Math I course and eliminating Intermediate Algebra as a prerequisite for the two most common, non-STEM oriented college level mathematics courses taken by students, Statistics and Contemporary Math (Quantitative Reasoning). This reform started as a pilot on two of the campuses and has been implemented districtwide.

Tommy Awtry, Dean of Mathematics and Science on the Southeast campus of Tarrant County College, described replacing the Intermediate Algebra prerequisite for the Statistics and Contemporary Math courses as a significant change that required the engagement and ownership of mathematics faculty at the district level since Tarrant County College is a large, multi-campus, one-district college. Key challenges for this change first involved conducting research and then sharing this information with a broad number of key players throughout the six campuses in the district. Awtry felt it was important to focus on what is best for the students, rather than instituting an initiative because others are doing so or simply for the sake of implementing something new. Awtry (personal communication, May 2, 2017) also noted that "Reform works when the movement is faculty and data driven, and when the implementation team is given enough time to research, pilot, and gather data. Reform often fails when it is administratively driven or when not enough time is given for research and data gathering. Choosing well-respected and positive individuals for the implementation team is also a critical element for successful reform."

Shanna Banda, Learning Resource Director at the University of Texas at Arlington, along with faculty redesigned all of the entry-level mathematics courses, developed appropriate pathways for students based on their degree plan, and created two new developmental courses. She noted (personal communication, May 10, 2017) that the Fundamentals of Contemporary Mathematics course "serves students entering Contemporary Mathematics or Elementary Statistics along with a Fundamentals of

Algebra course that serves students entering College Algebra or Business Algebra." In addition, they updated all other courses, added lab components and technology, and worked with other disciplines to change the required mathematics course when appropriate. This work, driven by the need to place students in the appropriate course for their degree plan, yielded higher course success and retention rates.

Once both institutions had created new mathematics pathways along with new foundations courses, a memorandum of understanding was written to ensure transferability of the mathematics courses from Tarrant County College to University of Texas at Arlington. Banda reminds us that projects such as theirs take several years to implement completely. She says, "Change is never easy, but fortunately people were quick to realize the importance of the efforts."

These data-driven projects began with a focus on student success while administrators supported the changes. Faculty played a key role in determining how best to meet student needs and policy modifications eventually required bringing two schools together. While the culture reinforced the changes, those changes took significant time.

Improving Student Success through Equity Mentoring: The Equity Mentoring Project at the Community College of Aurora, Colorado

Improving student success is not always just a matter of changing mathematics pathways, revising courses or creating new ones. Sometimes, it is necessary to change what goes on in individual faculty classrooms. The Equity Mentoring Project at the Community College of Aurora, Aurora, CO, focuses on increasing student success by applying the University of Southern California's Center for Urban Education Equity Scorecard to identify and change practices and beliefs that lead to inequitable outcomes for students in terms of race or ethnicity. An important part of this was to develop an understanding of how higher performing faculty were obtaining student success results.

A team of mathematics faculty used the Equity Scorecard to collect information about faculty classroom practices in developmental mathematics courses and College Algebra at the Community College of Aurora. As the team gathered evidence and reviewed data, they found that some faculty had success rates that the department sought for all instructors. According to James Gray (personal communication, May 15, 2017), then the mathematics Department Chair at the Community College of Aurora, this provided the project team "an anchor to inquire how those faculty were able to get such good results." He reported that the team was "asked to reflect upon the findings from a race-conscious point of view and develop recommendations for changes designed to positively impact inequitable outcomes. They were assisted by Center for Urban Education Equity who helped them navigate through the process of looking at the evidence in new ways. As a result, the Mathematics Department developed and implemented the Equity Mentoring program at the college.

Faculty learned a number of lessons about themselves and their students. One important lesson had to do with the idea that communication is cultural. It was easier for the faculty to understand this concept in regards to international students. Faculty learned how different subcultures can communicate in very different ways, and how these ways impact the students' expectations. Another lesson was that although information was usually communicated verbally, there was nonverbal communication when faculty ignored things that they had previously verbalized such as students coming in late or texting in class. The nonverbal message to students was that the faculty were not really concerned with their rules. By listening to the experiences of students and faculty of color about what they experienced in their education histories, they learned that from a very early age, students of color are exposed to powerful and pervasive race-based messages about whether they will be successful in mathematics. These messages come from society as a whole but also from individual teachers and faculty who expect less of their students of color. These students often learn that it is important for faculty to understand the narratives that they have heard about themselves and their capabilities, and to intentionally and purposefully disrupt these narratives. Finally, the process confirmed the basic principle that every faculty member has taught a student who had legitimate skill preparation issues who overcame them through persistence. Likewise, every faculty member has taught a student who appeared to have all the talent and ability necessary to succeed in their mathematics class yet did not pass. Through action research into their own practices, they learned how their own actions and beliefs impact whether or not they create an environment in which students exhibit the persistence needed for success regardless of skill level.

The chair mentored the full-time faculty and each of them was asked to mentor two part-time faculty. Mentors reviewed individual faculty data that compared their success rates to the course average, class observations, syllabi, and they reviewed the tasks each faculty asked their students to do between the first day of class and the first exam. They found that the lowest level developmental mathematics class had the highest level of inequities. Since part-time faculty taught the majority of these sections there was a focus on including part-time faculty who taught this course.

Gray reported that there were challenges to overcome during this project since faculty did not know of any other examples of equity work being done in this way. A few of them were concerned that by addressing inequities they would also necessarily reduce rigor. Some faculty wanted to do this work but did not know where to begin. Other instructors were fearful that they would say the wrong thing and be labeled as culturally insensitive. As a result of this work, one of the criteria the department uses in hiring new faculty is to hire people who have an interest in, and talent for, doing equity work.

In addition to the Equity Mentoring Project, the Aurora Math Department also engaged in redesigning their developmental mathematics courses and implementing a co-requisite remediation model for College Algebra. They collected significant data about student success and compared success in their new, accelerated developmental course to that in the developmental mathematics courses it replaced. In addition, they compared student success in the new course with traditional instruction versus mastery learning. They also broke down student achievement by ethnicity and gender and generated the same data for their Intermediate Algebra course. They looked at ethnicity and gender data for individual instructors and examined their students' success rates when they went on to College Algebra. Over time, faculty who participated in the Equity Mentoring Project increased success rates for their students. The higher student success rates in Intermediate Algebra resulted in higher success rates in College Algebra. The combined reforms at the Community College of Aurora yielded high success rates across most ethnic groups. For example, Gray noted that in 2015-2016 and 2016-2017 78% to 82% of students passed both the traditional College Algebra and a College Algebra modeling course with no gaps for Black and Hispanic students. In fact, Black and Hispanic students sometimes slightly outperformed Caucasian students.

The impact of the project went beyond the Math Department. The lessons learned led to the creation of the college's Equity Leadership Academy. Each semester, five to six faculty go through a similar process in which they do action research about one another's practices. The work of the Equity Leadership Academy is done in a community of practitioners who help each other learn and grow. Faculty led this project with the support of administrators (and assistance from the Center for Urban Education Equity) to better understand and meet the needs of their students. They intentionally developed the culture of a community of practitioners to help one another through this work.

Increasing Student Access to College through Open Education Resources: The Maricopa Millions Project at the Maricopa County Community College District, Arizona

In 2012, the Maricopa County Community Colleges tasked a small group of faculty and staff to research open educational resources (OER) and develop a vision for how Maricopa should engage in this effort. Given the name Maricopa Millions Project, the primary goal from the beginning was to remove cost and access barriers associated with traditional textbooks and publisher subscription codes by supporting faculty adoption and development of OER. The commitment of district administration to fund the program was based on the goal that the project would save Maricopa students $5 million over five years in course materials, while providing students with immediate and permanent access to learning. This administrative support was vital for involving passionate faculty in the process, many of whom were already interested and invested in OER before the outset of the initiative. Cost saving was not the only focus, however. As the project unfolded, Maricopa Millions expanded its efforts to include event to bring broader awareness to faculty and students in order to maximize the impact of OER where it is most needed, in the classroom.

Lisa Young, Faculty Director, Center for Teaching & Learning at Scottsdale Community College, served as a leader on the Maricopa Millions project. Young reported that "Due to the desire to reduce the cost of education to students and ensure they have access to critical learning materials, faculty adoption of OER was an important focus" (personal communication, April 9, 2018). Maricopa Millions has used funds committed by the district's leadership to offer incentives to faculty through grant funding to develop, revise, remix, and adopt OER by calling for proposals to create content for courses with the highest enrollment. This developed content has been publicly shared via Canvas Commons (with the search tag MMOER) and promoted within Maricopa at faculty-focused dialogue days and other OER events, such as Open Education Week. Young also stated that "Students have benefited from increasing adoptions, and some have even been directly engaged by way of student-focused awareness events designed to teach them how to use the 'low-cost/no-cost' filter when searching for classes."

While Maricopa Millions set out to save students $5 million over five years, the project surpassed its goal and resulted in a savings of over $11 million. This is directly attributable to the nearly 30 courses funded and adopted through the nine phases of the grant process, and it also reflects the wider campaign for promoting open resources led by the steering committee and chairs. For example, to boost enrollment in OER courses (and to raise student awareness in general), Maricopa Millions also adopted the #textbookbroke campaign and faculty engaged directly with students at different campuses. Faculty participants set up event tables outside of the student center and interacted with passing students about textbook costs and how to search for courses with "low-cost/no-cost" materials. These events were not only informative for students but rewarding as unique student-faculty interactions outside of the classroom. The great success of Maricopa Millions was possible because of active engagement on all levels – from students and faculty in the classroom to administrative support.

Due to the immense success, the Maricopa County Community Colleges has decided to institutionalize Maricopa Millions by creating a Faculty-in-Residence OER Coordinator assignment, wherein a faculty OER champion would receive full reassigned time for 2-3 years to focus on growing OER initiatives throughout the colleges. The project continues to evolve by focusing now on student engagement and pedagogical innovation in that its grant funding model will encourage faculty to develop, revise, remix, and adopt OER according to one or more of the following focus areas: improving accessibility, incorporating culturally-sustaining pedagogies, developing renewable assignments, and enhancing courses with multimedia and interactives.

Working Together for Accomplishing Change

The projects that are profiled in this chapter are just a sample of projects that are underway to help students succeed by reaching college level mathematics as quickly as possible. Institutions are looking at creating mathematics pathways that are relevant to students' program of study. Administrators are eager to support projects that will increase student success. Although each of these projects have had challenges, it is much easier to navigate the challenges when you are part of a community of practitioners whose culture reinforces the work. There are now examples of positive outcomes when leaders are willing to question long held beliefs about what mathematics students need and how students are assessed and placed. The work continues and we hope that your institution's story of change will be shared within our mathematics community.

Are you frustrated with decisions being made about mathematics education at the institutional, state, or national level? Would you like to collaborate with others to effect change? Do you already have great information or ideas on how to work with stakeholders? Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

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Chapter 8

Implications for Research:
Moving the Research Agenda Forward in Mathematics in the First Two Years of College

Research is to see what everybody else has seen, and to think what nobody else has thought.
~ Albert Szent-Gyorgyi (1957, p. 56)

The purpose of this chapter is to provide mathematics education researchers, and those interested in learning more about research in the field, with thoughtful questions and ideas to further the research agenda at the two-year college level. While the traditional role of two-year college faculty is focused on teaching, there is a number of them who regularly engage in the scholarship of teaching and learning through investigating methods to improve Proficiency, Ownership, Engagement, and Student Success. The more faculty can engage in such activities, the more the field of mathematics education is advanced.

Research in mathematics education at the two-year college level is emerging as a vital field of inquiry for understanding the complexities of teaching and learning mathematics. In 2009, AMATYC created a research committee, called the Research in Mathematics Education for Two-Year Colleges (RMETYC) Committee. Committee meetings have included collaboration among higher education researchers from two-year colleges and universities to further our knowledge of teaching and learning of mathematics at the two-year college level (AMATYC, 2009). In 2012, as an extension of RMETYC's discussions, Sitomer et al. outlined a research agenda calling for a concerted effort to investigate and publish research specifically focused on two-year college mathematics in the areas of instruction, student experience, curriculum, and technology.

There are many ways to contribute to this agenda. Some faculty in two-year colleges have already begun. Consider the case of Lee.

Lee, a two-year college mathematics faculty member, returned to graduate school to pursue a doctoral degree in mathematics education. This middle school teacher had a transformative experience in piloting MathScape, a non-traditional NSF-recognized curriculum. It encouraged hands-on tasks, group work, student discussions, and assessment in the form of projects. Later, as Lee was curious about what a calculus course with these characteristics would look like in the two-year college setting, and how it would impact students' learning, he approached the college mathematics department chair. The chair was highly supportive and intrigued to learn how the recommendations from the study Lee planned could positively impact success rates in the department's calculus class. As a doctoral *student, Lee quickly realized that though research on the teaching of calculus existed, it was challenging to locate information related specifically to two-year colleges. In a review of the literature, he found AMATYC's Crossroads and Beyond Crossroads documents. These became foundational to guiding his research. In parallel, Lee developed a Calculus course at the two-year college that included research-based, hands-on tasks, group work, student discussions, and non-traditional assessments. His research in the context of two-year college calculus, and the supporting literature provided by AMATYC, paved the way for his continuing work on improving the teaching and learning of two-year college mathematics.*

Lee's story is just one of many where two-year college faculty have expanded their understanding of mathematics education by investigating various phenomena in the field and by leveraging foundational documents, such as the Crossroads in Mathematics, to further their research. In this chapter, we provide a brief background on three types of research methods in mathematics education, then we elaborate on potential research endeavors within each of the four pillars of *IMPACT*: Proficiency, Ownership, Engagement, and Student Success (PROWESS). The chapter concludes with research ideas on two-year college faculty development.

Research Methodology in Mathematics Education

A Brief Discussion

Stories like Lee's are encouraging, and subsequent related research works can provide important insights into how students learn mathematics at the two-year college level, which ways of teaching are effective, and what kinds of resources best support student success. What does it look like to do a planned, systematic, and peer-reviewed inquiry that is held accountable and deemed valid among educators and stakeholders? There are many answers. Each one depends on the question(s) to be investigated and the investigator who carries out the research.

According to Schoenfeld (2000), research in mathematics education serves two primary purposes: to understand the nature of mathematical thinking, teaching, and learning (Pure); and to use such understanding to improve mathematics instruction (Applied). AMATYC embraces the idea of leveraging research to improve two-year college mathematics education, as evidence by AMATYC (2011) Strategic Plan, Priority III: *Promote research on the teaching and learning of mathematics and statistics in the first two years of college*. Research comes in many forms. It can be a quantitative, qualitative, or mixed methods study. It can aim at one classroom, or it can be scaled to an institutional level. One form of research that focuses on the classroom is called *action research*. Mills (2003) describe action research in the following way:

> *[It] is any systematic inquiry conducted by teacher researchers to gather information about the ways that their particular school operates, how they teach, and how well their students learn. The information is gathered with the goals of gaining insight, developing reflective practice, effecting positive changes in the school environment and on educational practices in general, and improving student outcomes* (p. 4).

If an instructor organizes and carries out an evidence-based reflection on a personally relevant question about classroom practice and discusses results with colleagues, the instructor is participating in action research (Sagor, 2000). If the faculty is invited to engage in peer review or share results at a conference or in a publication that contributes knowledge about practice to a larger instructional community, then the faculty is involved in the scholarship of teaching and learning (Dewar & Bennett, 2015). For questions that are of interest to college administrators, such as aspects of curriculum or instruction, a common research approach is evaluative, where the focus is on results about merit or significance. Applied educational research addresses questions whose answers have immediate and broad pragmatic application. Basic educational research looks at questions regarding how and why teaching and learning unfold, interact, and produce (or not) desired results.

There are many research processes appropriate for each of the three types of educational research—quantitative, qualitative, and mixed methods. For *quantitative research*, the focus is on identifying *what* is happening (rather than exploring the *how* or *why* of a phenomenon). A study using this approach generally begins with a set of assumptions about phenomena to be studied, frames a hypothesis based on the assumptions, designs a study to create a quantifiable dataset, then uses statistical analyses to report on the results of the hypothesized relationships. A shortcoming of quantitative research is that while it sheds light on the phenomenon of interest, it does not provide details to explain the *how* or *why* of the phenomenon.

Qualitative research on the other hand digs into the natural progression of a phenomenon across time, people, and contexts. The research is not necessarily longitudinal but could involve a period of time between a pre-treatment and a post-treatment. More like a documentary film than snapshots, qualitative research provides insight into why and how things happen. It can be exploratory in nature and often begins without concrete hypotheses in place to drive the study. Qualitative approaches rely on documents, observations, and interactions with what and who is being studied. Statistical methods common to quantitative research are aimed at generalizability based on metrics for reliability and validity, while qualitative research targets credibility, authenticity, and transferability, along with dependability and confirmability (Creswell, 2003; Ellis, 2004; Lincoln & Guba, 2000; Mertens, 2005; Patton, 2015). Qualitative research provides stakeholders with evidence that has been member-checked for inter-rater reliability, where the potential bias of the researcher and the research process are taken into consideration, and multiple passes through data and through data collection leave the door open for falsifiability.

Mixed methods research uses both qualitative and quantitative approaches to create multi-dimensional answers to questions of what, how, why, and for whom. At its core is a meaningful integration of quantitative and qualitative results. In all three methods, the type of research one conducts is directly related to the research question(s) to be investigated. Our own development as instructors can benefit from doing and reading all kinds of research. Thus, as both producers and consumers of mathematics education research, in the ensuing sections we propose potential investigations that focus on each component of mathematical PROWESS—Proficiency, Ownership, Engagement, and Student Success. We also provide a discussion for research on faculty development.

Research on Mathematical Proficiency

Improving Student Achievement

While a number of different descriptions of mathematical proficiency exists (AMATYC, 1995, 2006; NRC, 2001; NCTM, 2000; NGA Center & CCSSO, 2010), little is known about the ways stakeholders—students, faculty, staff, and administrators—in two-year college mathematics education define proficiency, and how well these definitions align with related standards described by researchers and professional societies. The question, *What do we mean by proficiency?*, suggests several areas of research that would help us better understand mathematical proficiency in the first two years of college, as well as how curricula and teaching practices align with various strands of proficiency. For example, how do stakeholders in two-year colleges define mathematical proficiency, either explicitly (such as ways in which proficiency is described in learning outcomes or syllabi) or implicitly (such as which types of behaviors or measures are used as evidence of proficiency)? Furthermore, we might explore how these implicit and explicit definitions differ for various stakeholders. Do instructors define proficiency one way, but use measures and teaching approaches that suggest implicit values that differ from their stated explicit values?

Another important area of research in defining mathematical proficiency at the two-year college level is to explore in more detail how it might differ from proficiency in the K-12 context. While most of the mathematical topics covered in the first two years of college are similar to content taught in primary and secondary schools, the college context differs in a number of ways that may impact how college students learn (Mesa, Wladis, & Watkins, 2014). As a result, mathematical proficiency at the two-year college level may be different from that in the K-12 context. In fact, there is evidence that adult learners use mathematical reasoning skills differently from K-12 students (see Sitomer, 2014). However, little research has directly compared adults' and K-12 students' learning progressions to determine how adults may (or may not) learn the same content in different ways. Research that directly explores these similarities and differences may lead to clearly articulated standards of proficiency that are more appropriate for adult learners. *Design research* studies that investigate community college students' understanding of proportionality, such as Breit-Goodwin's (2015), have the potential to explore adult students' learning progressions with respect to learning trajectories of mathematical concepts that have been researched in the K-12 context.

In whatever way we define mathematical proficiency, if we do not have appropriate, reliable, and valid instruments for investigation, we may be unable to clearly assess and understand the extent to which students, instructional approaches, or programs successfully develop proficiency. At the K-12 level, there are several research instruments that have been widely and field-tested and validated; for example, the National Assessment of Educational Progress (NAEP), Trends in International Mathematics and Science Study (TIMSS), and the Programme for International Assessment (PISA), along with the more recent Common Core assessments from Smarter Balanced (SBAC) and the Partnership on Assessment of Readiness for College and Careers (PARCC). However, for two-year colleges, very few assessment instruments have been rigorously tested. While we may use those from K-12, they may not be reliable or valid for the two-year college population because the history of test development includes many examples of instruments that were developed with one group, but were problematic when implemented for different populations (D'Ambrosio, Kastberg, & Lambdin, 2007).

Some mathematics education researchers have begun work to create and validate assessments for the college context. For example, concept inventories have been developed for pre-calculus and calculus research (Carlson, Oehrtman, & Engelke, 2010; Epstein, 2013). Work from two projects is currently underway to create and validate an elementary algebra concept inventory (Wladis et al., 2017a; Wladis et al., 2017b) and a concept inventory for intermediate and college algebra for research purposes (Watkins, Strom, Mesa, Kohli, & Duranczyk, 2015). However, to date these are the only concept inventory projects that focus on mathematical topics below the pre-calculus level. According to Jaggars and Stacey (2014), there is an urgent need to focus on assessments for pre-college level courses, since more two-year college students enroll in developmental mathematics than in credit-bearing courses. Due to the lack of systematic research in this area in the two-year college context, there are opportunities for researchers to develop and test measures of various types for mathematical proficiency. For example, they can work to create test items that will identify specific domains and types of proficiency (such as conceptual understanding of fractions, or strategic competence in writing algebraic expressions in an equivalent form). Carlson et al. (2010) provide an example of how cognitive interviews with students can be used to develop items that accurately reflect common student misconceptions of particular concepts. This qualitative strategy could be adapted to the two-year college context and utilized in developing assessment instruments.

Finally, we can use existing definitions of mathematical proficiency as a resource for generating future research. AMATYC's *Crossroads in Mathematics* (2006) introduced seven Standards for Intellectual Development: problem solving, modeling, reasoning, connecting with other disciplines, communicating, using technology, and developing mathematical power. A student who meets these standards might be considered mathematically proficient. Each of these standards suggests areas of research on student proficiency as little is known about how these standards are implemented and practiced in two-year college mathematics education.

Other standard documents such as *Principles and Standards for School Mathematics* (NCTM, 2000), the Common Core State Standards (CCSS) (NGA Center & CCSSO, 2010), and seminal research on problem solving (see Schoenfeld, 1985), can help us operationalize the meaning of problem solving in the context of two-year college mathematics in order to pose questions about students' proficiency with problem solving. For example:

- What kinds of knowledge and prior experiences impact students' problem solving strategies?
- How do two-year college faculty members construe problem solving and in what way do these faculty integrate problem-solving in their courses?

Contextual mathematics and modeling have been a focal point in K-12 mathematics education. As with problem solving, we might also be interested in researching the following questions on modeling and mathematical proficiency:

- How do two-year college faculty understand mathematical modeling and how do they integrate modeling in their courses?
- How does engaging in mathematical modeling in two-year college classrooms impact students' mathematical proficiency and what tools are being used to assess this proficiency?
- What types of tasks are appropriate for modeling and supporting students' mathematical proficiency?

Finally, developing students' proficiency with mathematical argumentation in K-12 settings is an important area of research (Ellis, Bieda, & Knuth, 2012; Stylianides, 2007). Additional questions that could be investigated are

- To what extent do the tasks in two-year college mathematics curricula provide opportunities for students to engage in mathematical argumentation?
- To what extent do stakeholders (for example faculty in other disciplines and professional and technical programs) value students' proficiency in mathematical argumentation?

Taking a critical stance on how we and others define and measure mathematical proficiency sets a foundation for important research that will add to our understanding of students' mathematical understanding in the unique context of two-year colleges.

Research on Ownership

Promoting Student and Faculty Involvement

Before beginning any research endeavor regarding the concept of ownership, or indeed any systematic attempt to promote ownership among students, we must first wrestle with the meaning of "ownership." At the most basic, linguistic level, the word *ownership* requires an object. What is being owned? A particular mathematical topic? Mathematical knowledge in general? The learning process? Also, who is doing the owning? The student? The faculty? In designing, conducting, interpreting, and using the results of ownership-related research, investigators must first choose an area of focus: for example, student ownership of learning in general, ownership of a specific content area, or faculty ownership of fostering course objectives. NCTM (2000) charged mathematics teachers to empower students as mathematical thinkers and doers. Ernest (2002) argued that students who are empowered mathematically have a sense of personal ownership of mathematics. In this way, ownership and empowerment can be viewed as somewhat synonymous. The productive disposition strand of mathematical proficiency discussed previously as the "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (NRC, 2001, p. 11), is also closely tied to the idea of student ownership.

Faculty members interested in helping students take ownership of their learning may also consider situating their research in self-regulated learning theory—a theory focused on the notion that students should monitor, control, regulate, and reflect upon their own learning (Zimmerman, 2002). Self-regulated learners cycle recursively through a forethought phase (setting goals and objectives), a learning phase (choosing appropriate learning strategies), and a reflection phase (evaluating the learning process and self-monitoring its outcomes). With each cycle, the learner evaluates the effectiveness of the learning process and then makes adjustments for the next cycle (Zimmerman, 2002; Winne & Hadwin, 1998, 2008).

There is consensus among researchers and educators that students will benefit by becoming self-regulated learners. However, best practices for fostering self-regulated learning in college students are not well-understood or investigated. As early as the 1990s, when self-regulated learning was still an emerging theory, research reviews noted a shortage of useful studies on effective learning skills interventions (Greene & Azevedo, 2007; Hadwin & Winne, 1996; Hattie, Biggs, & Purdie, 1996). A further review of self-regulated learning interventions for K-12 students showed generally positive effects; however, in mathematics classes, the positive effect was larger for primary students than for older students (Dignath & Büttner, 2008).

There have been relatively few studies on self-regulated learning interventions in authentic classroom contexts for a meaningful educational objective (e.g., course grade, exam grade). Related studies have often involved psychology students in a laboratory setting, in which participants learn material not directly relevant to their class. For the two-year college level, where many students are first-generation college students and are struggling to balance the demands of work, school, and family, additional research is needed to know how mathematics faculty can assist their students to develop self-regulated learning skills.

Two-year college researchers interested in investigating how mathematics faculty can help students take greater ownership of their learning might consider the questions

- How can college students be guided toward self-assessing their own learning?
- How can they learn to see the value in self-assessment?
- How can we help our college students develop a welcoming attitude toward productive struggle (NCTM, 2014)?

- What are the distinctions between a student's ownership of his or her own learning process, and the student's ownership of mathematics? Is it possible to own one without also owning the other?

With increasing emphasis on active learning, collaborative learning, and technology, questions such as the following merit investigation

- How does individual ownership manifest itself and develop within collaborative learning settings?
- What characteristics of collaborative activities enhance individual ownership? When students are working in groups, what techniques are most effective for helping them individually "own" their learning of the material?
- For which student populations does active and collaborative learning help students acquire greater ownership of their learning?
- How does ownership develop in online learning environments, and how does this compare to face-to-face classes?
- What role does technology play in developing student ownership of mathematics? In what situations does technology advance or hinder the development of self-regulated learning?

Faculty Ownership

Faculty typically enjoy a great deal of autonomy in regard to how they teach their classes. However, we want them to be reflective about their practice as a means for improving instruction. Since we periodically assess student progress to support learning, similarly, faculty can systematically investigate the effectiveness of changes they make in their teaching. Ideally, such work is shared to gather peer and expert feedback through a cycle of professional reflection. In this way, faculty ownership of mathematical ideas, and the teaching and learning of them, is part of the collective whole, "the academy." As members of this academy, we disseminate the results of self- and shared research and evaluation, through departmental colloquia, conference presentations, and articles in academic and practitioner outlets. Faculty Ownership, thus, can be individual or shared. One area of collegiate mathematics education that is ripe for research lies in questions such as

- How do college instructors acquire and refine (that is, come to ownership of) the mathematics-specific knowledge and discourse skills used to effectively teach a concept, a topic, or an entire curriculum?
- For two-year college faculty who consistently engage in the scholarship of teaching and learning of mathematics, how does this mathematical activity affect their classroom practice?

Departmental Ownership

Mathematics departments are often charged with making decisions that affect instruction in all mathematics classes, including those taught by part-time faculty. Collective decisions may be about curricula, course materials, technology, assessment, institutional policy, accreditation requirements, as well as syllabus-type items such as attendance policies. When making such decisions, faculty can exercise collective ownership by gathering and analyzing related data systematically. Ideally, such investigations would be informed by available research, and would be shared with peers within or outside the department or institution. By incorporating data from multiple classrooms and instructors, such studies have the potential for widespread impact on the teaching and learning of mathematics in the first two years of college. In utilizing this approach to collective ownership, faculty will be making evidence-based decisions on policies that are within their collective control, or, well-informed decisions as opposed to anecdotal ones or individual opinions.

In order for such departmental-level investigations to happen, faculty will need access to research-related professional development resources and to relevant research literature, specifically in mathematics education. Ideally, they would also have support from their college administration and from an institutional research team. Instructors may also need to learn how to navigate the institutional review board process at their college if the college has one. Researchers who are focused on understanding faculty ownership may want to explore questions such as

- What factors are most important to building a culture of departmental research?
- Does a culture of individual-level research (action research, Scholarship of Teaching and Learning [SoTL]) have a synergistic relationship with a culture of department-level research?

The appropriate definition of ownership will depend on whose perspective we are examining (for example, students or faculty, individual or collective), and the related theoretical framework. Regardless of perspective or theory, research on ownership has the potential to bear much fruit in terms of having a positive impact on students' lives. Students who learn to seize ownership of their learning process may be better equipped to learn new topics in the future and ultimately achieve academic success.

Research on Engagement

Strengthening Intellectual Curiosity

The two-year college setting, with smaller class sizes and smaller campuses than most universities, are well-positioned for investigations on student and faculty engagement. While the Center for Community College Student Engagement (CCCSE) at the University of Texas, Austin, conducts large-scale research on engagement through student and faculty surveys, there are very few studies to better understand the complexities of engagement at the classroom and department level, specifically within the discipline of mathematics. In the following section we provide potential research areas and questions specific to two-year college mathematics education.

Student Engagement

Student engagement, an important field of inquiry, is a focus of many researchers across the country, from K-12 to postsecondary education (see Christenson, Reschly, & Wylie, 2012). Yet, there are limited studies pertaining to active engagement and the learning of mathematics specific to the two-year college setting. Sitomer et al. (2012) point out that

> we do not know how widespread these practices [about active engagement] are at community colleges, whether these types of engagement are indeed beneficial for community college students, or how easy or difficult it is for faculty to engage in teaching of this kind, given the different backgrounds of faculty and students (p. 36).

With various initiatives to improve content and practice standards, such as the Common Core State Standards in Mathematics (CCSSM) and NCTM's (2014) *Principles to Actions*, which promoted mathematics teaching practices, the shift in students' mathematical practices has been geared towards the notion that students are actively engaged in their own learning. For example, the third mathematical practice from the CCSSM (SMP3)—"Construct viable arguments and critique the reasoning of others"—sets the stage for classrooms to have high levels of discourse, where students debate the mathematics they are learning (NGA Center & CCSSO, 2010, p. 6). In *Principles to Actions,* a companion teaching practice that parallels SMP3 is "Facilitate meaningful mathematical discourse" (NCTM, 2014, p. 29). The idea is that if teachers can find ways to promote meaningful discourse among students through argumentation about and justification of mathematical ideas, then students will be actively engaged with each other and cognitively with the mathematics content.

This shift in K-12 has been a monumental step in the right direction, yet two-year colleges have largely ignored the advances in the teaching and learning of mathematics made in K-12 classrooms. In the coming years, students who graduate from high school having experienced learning mathematics in the ways intended by CCSSM will enroll in college mathematics courses with an expectation of active engagement, problem solving, and sense making. What is unknown is how two-year colleges are addressing the shifts in K-12 to better align their own teaching of mathematics to embrace, incorporate, and leverage promising mathematical practices. This challenge provides an area of inquiry for researchers in mathematics education.

Studying student engagement in the first two years of collegiate mathematics will inform us on how to better design our courses—from instruction to assessment—as we continue to seek to understand the complexities of learning mathematics. There are numerous questions centered around student engagement that can serve as focal points for researchers. Relative to students' learning, we propose

- In what ways is mathematical learning enhanced when two-year college classes implement a high level of student engagement?
- How do students' beliefs about learning mathematics change when they experience their learning in active and engaged ways in the classroom?
- In what ways do students succeed (or not) when they move from an engaged learning classroom to one where little student engagement occurs? In what ways do students take what they have learned about the learning process in an engaged classroom and apply it to a non-engaged classroom?

Faculty Engagement

For clarification, we begin first by differentiating between faculty engagement and faculty development. We define faculty development as a more concerted effort to develop faculty in some way (such as furthering their mathematical knowledge or their knowledge of teaching). Faculty engagement is defined as the involvement of faculty in a setting, such as in a department or institution. These activities can lead to faculty development, but faculty engagement measures something different, like involvement.

There has been research on the many reform efforts on faculty engagement for student success such as in calculus and pre-calculus courses (Bressoud, Carlson, Mesa, & Rasmussen, 2013; Sonnert, Sadler, P., Sadler, S., & Bressoud, 2015). Ahead for the research community is careful attention to courses before (and alternative to) calculus, yet general awareness of results from these efforts is slowly growing (Bailey, Jaggars, & Jenkins, 2015b; Carlson & Rasmussen, 2008; National Academies of Sciences, Engineering, & Medicine, 2016). Since 2005, CCCSE has been spearheading the implementation of the Community College Faculty Survey of Student Engagement (CCFSSE) survey through the Center for Community College Student Engagement (CCCSE, 2017). This survey solicits insights on both faculty and student engagement. The 2017 CCFSSE cohort included 86 institutions from 28 states and was completed by 9,577 faculty members. One way this survey is currently being used on a broader scale is to compare faculty engagement data to student engagement data. On a small scale at individual colleges, such comparisons can generate conversations on the impact of faculty engagement on student engagement. This could serve as a catalyst for institutional research.

While CCCSE provides useful information on engagement for participating colleges, more data is needed. In addition, there are many important questions for investigation. For example

- What are the characteristics that describe a highly engaged department of full-time and part-time faculty?
- How do student success, retention, and persistence rates in mathematics courses compare among departments with highly engaged faculty and departments with minimally engaged faculty?
- For departments that are focused on improving faculty engagement, what elements of student engagement are promoted and realized?

Furthermore, additional research is needed to understand the complexities of enacting high levels of student engagement when teaching mathematics. We propose the following:

- How do faculty in the first two years of college integrate active learning strategies into their teaching? In what ways are these strategies effective?
- What are the primary obstacles that prevent faculty from integrating active learning in their teaching? How do faculty overcome these obstacles?
- For those colleges that have a culture of actively engaging students, what did they do, and how is the culture of engagement maintained?

The CCFSSE survey does not provide a sense of the faculty climate on student or faculty engagement. However, in a 2014 special report titled *Contingent Commitments: Bringing Part-Time Faculty Into Focus*, the CCSSE discussed the results of 32 focus groups that aimed to "help colleges improve engagement with part-time faculty so more students have access to the experiences that will lead to success" (CCCSE, 2014, p. 2). Although the focus groups revealed a desire among part-time faculty for more professional development opportunities, they noted that part-time faculty members' views on professional development vary among focus group participants for several reasons. For some, scheduling is a concern, while others would prefer financial incentives. In addition to the research possibilities for students' belief, as described in the student engagement subsection above, research on faculty beliefs about engagement are just as important as they have a large impact on students' success. Some research questions to explore on faculty beliefs regarding student engagement are:

- How do faculty beliefs affect faculty engagement or student engagement?
- What influence do faculty beliefs have over their students' beliefs?
- Is there an efficient way to change faculty beliefs on student engagement to influence their pedagogy?

In researching expectations of faculty engagement in two-year colleges versus universities or K-12, it is very difficult to find definitions of expectations at each type of institution. This may be due to expectations varying from college by college. There was a lot more discussion and research on levels of engagement. Achieving the Dream (national level), California Acceleration Project (state level), and Carnegie Math Pathways (national level) are all large-scale initiatives that have successfully created a climate of faculty learning to propel student engagement at the college level. Potential research ideas include:

- What are the relationships among aspects of faculty professional learning, orientation towards teaching as a discipline, disposition towards mathematics as a discipline, and perceptions of students (as learners, as people, as stakeholders in two-year college education) and how do those shape the opportunities for engagement that an instructor is ready to offer students?
- What can we learn from successful community-building among online faculty to improve community among on-campus faculty? Conversely, what do we know about effective on-campus faculty interaction that can inform design of online professional learning communities?

Through the Integrated Planning and Advising for Student Success (iPASS Initiative), Achieving the Dream has provided assistance to "26 two- and four-year higher education institutions to leverage technology and human relationships to transform their advising and planning services at scale, with the goal of increasing retention and completion for all their students" (Hoang, Huang, Sulcer, & Yesilyurt, 2017). The California Acceleration Project (n.d.) involves all 114 two-year colleges in the state of California and Carnegie Math Pathways (Carnegie Math Pathways, n.d.) works with over 60 colleges and universities. They each focus on faculty-led professional development networks that support colleges and universities to transform remediation and increase student completion rates.

Inside Higher Ed's *Going Through the Motions? The 2015 Survey of Faculty Workplace Engagement* found that "engagement levels are about the same—roughly 30 percent—among faculty members teaching at private or public doctoral or master's degree-granting institutions, public baccalaureate institutions and public associate degree-granting colleges" (Flaherty, 2015, para. 14). Results also showed that that engagement seems to have a strong correlation with lower enrollment numbers. Essentially, Flaherty found that the smaller the institution in terms of student enrollment, the higher the level of faculty engagement. Given the positive results of the study, and that two-year colleges typically have lower enrollment than many universities, it is vital to research the phenomena of faculty engagement in two-year colleges to better understand how engagement plays a role in student success.

Research on Student Success

Reaching College and Career Readiness

What can mathematics faculty at two-year colleges, who may or may not be engaged in research, contribute to our understanding of what works, for whom, and under what conditions? Research on student success investigates instructional practices and structures that support student advancement, and examines the complex conditions that define and constrain "success" for students, instructors, and institutions. Some completed and continuing work on student success has been conducted by individual practitioners who are engaged in the scholarship of teaching and learning. Other studies are being conducted by small and large groups aimed at larger-scale questions about student success as it relates to department, college, and institutional levels. Still, some researchers are examining what it means to be successful in mathematics, including exploration of who participates in defining and designing for success (for example, students, faculty, administrators, policy-makers). Notwithstanding, there is more to learn about student success in mathematics courses offered in the first two-years of college. Thus, in this section after summarizing current research findings, we propose potential research topics.

Some findings from research on student success

For many, a significant factor in student success in the first two years of college is persistence, which is defined as finishing a course one enrolls in, enrolling in the next course, and successfully completing mathematics courses that are necessary for a program of study. As instructors, it is important for us to understand not only how successful students are in their current course, but how successful they are in future mathematics courses. Essentially, we need to understand how well-prepared students are for their future classes as a means for understanding the robustness of the prerequisite course(s). Several national studies in the U.S. have focused on student success in two areas: calculus and the pathway from pre-college to college-credit level mathematics in the two-year college setting. An NSF-funded study managed by the Mathematical Association of America, the *Characteristics of Successful Programs in College Calculus* (CSPCC) project (Bressoud, Mesa, & Rasmussen, 2015), included case studies of four community colleges that were identified as having a successful program in calculus. Burn, Mesa, & White (2015) identified three features of calculus programs that support student success: high quality instruction, students "coursing" into calculus by taking pre-calculus at the two-year college, and opportunities for students to form calculus study groups (since campus tutoring services frequently focus on classes below calculus).

A follow-up study of the CSPCC project is underway. *Transitioning Learners to Calculus in Community Colleges* (TLC3) (Burn, Mesa, Wood, & Zamani-Gallaher, 2016), is an NSF-funded research project aimed at transforming institutional approaches to matriculating STEM majors from underrepresented minority groups into and through Calculus II in community colleges. Two research questions guide the project: What types of programs, structures, and instructional strategies are community colleges currently implementing? and What are the effects (if any) of these programs, structures, and instructional strategies on the focal students' success in the sequence? A major goal of the study is to develop an evaluative change tool, the *institutional self-assessment*, which seeks to examine institutional readiness to facilitate successful outcomes for underrepresented minority students in the calculus sequence. The self-assessment tool will be tested at five institutions (four designated Minority Serving Institutions and one not) selected from the project's networked community.

Another national study*, Algebra Instruction at Community Colleges (AI@CC): An Exploration of its Relationship with Student Success* (Watkins, Strom, Mesa, Kohli, & Duranczyk, 2015) examines the relationship between instructional quality and student success in algebra classrooms in two-year colleges. In this project, both quantitative and qualitative data are collected from students and faculty from six two-year colleges in three states (Arizona, Michigan, and Minnesota), and then analyzed by a team of mathematics education researchers from two-year colleges and universities. The findings from this study will be used to design programs to improve instruction and to support student success in algebra at the two-year college level.

In the area of developmental mathematics, also at the national level, are the research studies completed on the Carnegie (2017) Math Pathways courses (for example, Quantway and Statway). A Pathways course is a two-semester course sequence designed to accelerate students who place into developmental mathematics to and through college-level mathematics in a single year. In a recent study across thousands of students in 12 states, Pathways pass rates were 60% or higher (as compared to the 21% pass rate through elementary and then intermediate algebra for traditionally remediated students) (Hoang, Huang, Sulcer, & Yesilyurt, 2017). Other strands of research in the developmental arena are delving into factors influencing course success such as instructional practices and student self-efficacy (self-evaluations about how well one will do in completing a task). For example, Zientek, Fong, & Phelps (2017) found that specific to the community college context, mastery experiences play a significant role for a student's self-efficacy and subsequent success; the authors suggest the use of instructional activities that provide students opportunities to gain mastery of particular mathematical concepts and skills early in a course.

Another recent project examines the variety of ways instructors implement online tools in a randomized controlled trial study of community college student learning in elementary algebra, when instruction included use (or not) of the mastery-focused web-based assessment and testing system available through the Khan Academy (Hauk & Matlen, in press; Hauk, Salguero, & Kaser, 2016). Like previous research about online homework in college algebra courses in four-year colleges, early results from this study suggest that cautious optimism about the efficacy of the online tools on the part of the instructor along with a transition to use of classroom time for group cooperation, collaboration, and consulting are the most supportive of student learning. Topics related to student learning through electronic and social media are ripe for further research opportunities, such as flipped learning and blended/hybrid learning approaches. Among the challenges in such research is that technology (e.g., aspects of learning environments) is not attended to, and perhaps not tracked, by institutional research offices. Additionally, it is difficult to conduct longitudinal investigations of the use of technology in education given its rapid pace of change.

Who defines student success in mathematics at two-year colleges?

This broad question covers several different avenues of inquiry. For example, recent work in curriculum design provides alternate pathways through developmental mathematics, such as statistical or quantitative literacy courses (Yamada, Bohannon, Grunow, & Thorn, in press; Yamada & Bryk, 2016). These efforts have explicitly defined student success as the completion of college-level mathematics coursework that prepares students to contribute as citizens and workers in the U.S. political and economic systems. In some cases, these opportunities for students to be successful in college-level mathematics steer them away from calculus. Part of future research might reproduce, in the developmental mathematics context, the designs used in existing studies that describe what a student needs to know and be able to do to be successful in calculus (see Carlson, Jacobs, Coe, Larsen, & Hsu, 2002; Carlson, Oehrtman, & Engelke, 2010; Thompson & Silverman, 2008). Is it possible that pathways to college-level mathematics that are not algebra-heavy, but are loaded with the development of mathematical reasoning and understandings of essential ideas, are viable alternative pathways to and through calculus?

Also important is rethinking which students are the focus of research on success. Many students who enroll in developmental courses are first generation students whose dominant language is not English. Fostering their success may depend on supporting faculty to embed language scaffolds in the design and delivery of mathematics (Gomez et al., 2015). Skills that first generation and low-income students bring with them to two-year colleges "include resiliency, ability to survive difficult situations, maneuvering multiple realities (for example, world of work, ghetto, barrio, reservation, gang culture, family and schooling) and negotiating social, political and economic hardships" (Rendón, 2006, p. 2). Across all of the mathematics curricula common in two-year colleges, pertinent research questions could ask how equity and inclusion is realized or challenged in the (sometimes) implicit definitions of student course-level success. Also, yet to be investigated fully is the following question: How do the stakeholders view the relationship between mathematics course design and other institutional supports for students (Cerezo & McWhirter, 2012), and in what ways are these consequential for student success?

In defining student success, stakeholders should include completion of certificates and degree programs that have mathematics as a component to serve client disciplines (such as a Python programming certificate or engineering degrees). As a result, there are many questions that need to be investigated and it is important to examine the varieties of ways colleagues in other disciplines define the characteristics, knowledge, and skills of students. Potential research ideas include

- How well are mathematics courses preparing students to be successful in client disciplines?
- If client disciplines and programs teach mathematics courses, why is this so?
- How can we as a mathematics community reach out to partners in client disciplines and programs and align our current definition of student success in mathematics with theirs?

Research about student and community member perceptions of what it means to be successful in a mathematics course at a two-year college are notably absent. As a community, we are now taking a critical look at *who* defines particular constructs around student success, such as the core skills, competencies, and content knowledge; what constitutes evidence of learning; and what we mean by *readiness* for future coursework or careers (Civil, 2007). Understanding these perceptions and constructs has the potential to uncover curricular content, instructional strategies, assessments, and feedback mechanisms that better serve students at two-year colleges (Flennaugh, et al., 2017).

Student success by design

The Achieving the Dream (n.d.-a) initiative has opened several avenues for research. Institutions that "pursue a cohesive strategy comprised of aligned whole-college solutions that support and promote the success of all their students, resulting in significant and sustainable institutional improvement" (Achieving the Dream, n.d.-b, para. 10) are often recipients of the Leah Meyer Austin Award. New research about designs for success at these colleges can be used to develop case studies that identify institutional strategies and structures that contribute to student success in mathematics at these institutions. This work has the potential to provide a better understanding of how to further support students. One current example is the Association of Public & Land-grant Universities' (n.d.) *Student Engagement in Mathematics through a Network for Active Learning* (SEMINAL) initiative. A variety of questions frame such case study research: How are mathematics placement decisions made? What are the features of the mathematics learning environment that contribute to positive student outcomes? How do the strategies and structures in the mathematics program align and interact with strategies and structures in other programs and with a college's mission as a whole?

The realities of supporting student success have led to many approaches that have been implemented in small pilot settings, yet the research about broad usage is lacking. For example, studies that explore claims about the impact of structures such as *precision scheduling* (that is, reducing the number of "late adds" or scheduling "late start" course offerings) and co-requisite courses is needed. Some studies suggest that co-requisite courses that explore concepts from the learning sciences—such as mathematics study skills, anxiety reduction, technology usage, and awareness of college academic support resources—help students develop tenacity (Johnstone, 2017; Kuh, 2007; Marshall, 2010). Thus, several research questions might be posed here:

- What is the evidence that precision scheduling reduces late adds and increases student success? How dependent on context is the evidence? How scalable or transferable is the solution? Are there data showing that allowing students to add late reduces their success?
- How might changes to scheduling impact instructors' decisions about the activities they use on the first day of class?
- What out-of-classroom student supports are effective for students' success in two-year college mathematics?

On a larger scale, Bailey, Jaggars, and Jenkins (2015a) described the current state of faculty development for supporting student success and proposed new models that will support changes to the fundamental design of two-year colleges. Their primary focus was on collaborative and institutional efforts to guide students on well-designed guided pathways to reach their educational goals. The authors positioned the guided pathways model against what they describe as the cafeteria college in which students select courses that may or may not help them achieve their goal.

Research on Faculty Development

Next Steps

Up to this point, the focus of this chapter has been on student experiences of Proficiency, Ownership, Engagement, and Student Success—PROWESS in mathematics. The overlapping types of knowledge faculty have and use in teaching form a subset in a larger collection of professional knowledge. A reflective practitioner teaches while also building skills for productive participation in one or more departments, local communities, and the national landscape of college and university teaching, research, service, and collegiality. Within the broad context of professional knowledge and learning is *instructional development*—that is, the growth of faculty instructional expertise. Research on the growth of faculty instructional expertise is our focus in this section.

Peer interaction and support are absent for many instructors (Masingila, Olanoff, & Kwaka, 2012, Golde & Walker, 2006), and all too often they are isolated in their teaching, without colleagues to collaborate with and learn from. The dearth of professional development for teaching is disheartening given its key benefits for faculty: for example, improving daily experiences in the classroom, maintaining interest in the profession, and professional advancement. In recent years, program directors at the National Science Foundation have championed multiple ways to support faculty to enact instructional innovations in their classrooms (see Khatri, Henderson, Friedrichsen, & Fryod, 2013). In addition, preparation for college teaching is rapidly becoming an expected component of graduate programs (Deshler, Hauk, & Speer, 2015).

When faculty are utilizing a new pedagogy, they need support from experienced instructors to get a sense of what is working and what needs to be improved. Instructional resources such as computers, and sample assignments and activities, may be needed. Instructors may want "colleagues with whom they can collaborate and commiserate. They need community" (Hern & Snell, 2013, p. 8). The same community building that we expect for students in an engaged classroom is important for faculty as well. "Widespread, lasting improvement requires everyone at a college to rethink their roles and build their skills in serving students. Professional development for everyone—staff, faculty, administrators, and governing board members—is essential for effectively implementing this level of change" (CCSSE, 2013, p. 4). The CCSSE (2014) stresses that

> college leaders who want to better serve their students should closely examine their expectations of and support for their part-time faculty. … professional development and support, including learning about effective teaching, having an assigned mentor, other intentional connections with colleagues, awareness of and access to college resources that support faculty work, and familiarity with resources that support students (p. 8).

In general, more engaged faculty, particularly part-time instructors, feel a sense of belonging to the college. This may subsequently lead to a more stable teaching workforce.

Purpose of investigating faculty professional development

Unlike the K-12 setting, until recently little rigorous research on effective development for teaching in higher education existed (Council of Scientific Society Presidents, 2012). However, research on faculty development in higher education, and in particular in the two-year college setting is an emerging research area. In higher education, broadly, Hayward, Kogan, and Laursen (2016) and Ebert-May and colleagues (2011) focused on mathematics faculty development in higher education. The first group surveyed and interviewed college mathematics faculty after their participation in faculty development on using inquiry-based learning. They found that intensive and immersive multi-day workshops coupled with ongoing follow-up activities fostered high rates of implementation of target practices. They also noted that broadly defining inquiry-based learning, by presenting its core features and desired outcomes rather than prescribing a rigid list of tasks, helped to scaffold and make its use more effective.

In the two-year college setting, Bickerstaff and Cormier (2015) examined faculty learning using faculty members' questions as a lens. They categorized faculty questions about instructional change into four categories: purpose and nature of the reform, reform implementation, classroom practice, and student learning. The researchers found that instructors' questions about teaching practice frequently involved course materials, use of class time, and sharing teaching tips rather than more nuanced questions about teaching practice. The authors conjectured that this finding was due to instructors' lack of experience communicating about teaching practices. Also, questions about student learning were infrequent and occurred more often in interviews with instructors with some experience of the reform initiative than in faculty development activities. Even when a faculty development activity was designed to focus on student learning, instructors' questions tended to focus on other aspects of the reform. The authors concluded that faculty development activities that are best aligned with the types of questions instructors pose about an educational reform have the potential to be sustained over time when focused on a particular goal. Workshops and faculty development activities offered prior to enacting a reformed curriculum or course structure are not as effective at addressing instructor questions. Bickerstaff and Cormier highlighted the need for further research that examines how structured faculty development opportunities elicit questions about the connection between instructional practices and student learning.

As noted earlier in this chapter, Bailey and colleagues (2015a) posited the guided pathways model for students against the traditional cafeteria college. Their research also found that faculty development at two-year colleges shares features with the cafeteria college; that is, faculty members select workshops and development activities that may or may not support their professional goals. A new vision for faculty development in higher education can be built upon scholarship on best practices in teaching development in the K-12 setting. Professional opportunities should be sustained over time, connected to practical problems faculty encounter, and be grounded on inquiry into teaching and learning.

Several ongoing and future projects are contributing to our understanding of professional learning opportunities for two-year college mathematics faculty. Building on scholarship on best practices in teaching development in the K-12 setting, Sitomer and Stein (2016) have undertaken a design-research study on a yearlong faculty inquiry group that is focused on ambitious teaching practices, such as planning instruction around essential ideas, facilitating students' collaborative work, and attending to and managing student progress in the classroom. Activities for the inquiry group have been designed, enacted, and evaluated. Currently, a retrospective analysis of the data is being conducted. This analysis is also examining the impact of the design on faculty learning (see IMPACT Live!).

Another project, *Promoting Excellence in Arizona Middle School Mathematics: Increasing Student Achievement through Systemic Instructional Change* (Strom, Vicich, Cox, Watkins, & Romero, 2012), has engaged two-year college faculty in an effort to transform the teaching of mathematics in the middle grades. This targeted Mathematics and Science Partnership project supported teachers and two-year college faculty in advancing their knowledge about the teaching and learning of middle school mathematics, as well as developmental mathematics in two-year colleges. The project provided a systemic model of sustainable professional development in partner schools and colleges to achieve the goal of increasing student achievement in middle school mathematics courses enabling students to make a successful transition to more challenging courses and curricula in high school. The project also produced research about the characteristics and mechanisms of a sustainable professional development program, as well as contributing to the body of knowledge for understanding teachers' and students' mathematical thinking and beliefs. This project was led solely by two-year college faculty and the resulting research provided important insights into how students and teachers extend their understanding of mathematics.

AMATYC's newly funded project, *Project SLOPE—Scholarly Leaders Originating as Practicing Educators in Two-Year College Mathematics* (Breit-Goodwin, Quardokus-Fisher, & Sitomer, 2017), consists of a feasibility study and pilot of a program within AMATYC to build and sustain a network of two-year college faculty engaged in the Scholarship of Teaching and Learning (SoTL). The research findings from this project will pave the way for extended investigations and efforts related to faculty development in two-year colleges. Other research focused on developmental mathematics explores the relationships among technology use, instructor views, faculty development, and student learning in developmental mathematics (see Hauk & Matlen, in press; Hauk, Salguero, & Kaser, 2016).

Potential research areas on faculty development

Faculty mathematical knowledge for teaching can be acquired in many ways: for example, through teacher-training programs, mathematics courses, student assessments, interactions with students and colleges, and self-reflection of teaching and learning practices (Kung, 2010; Speer & Hald, 2008; Speer & Wagner, 2009). The key to learning from these activities is attending to language and values about mathematical appropriateness, clarity, and precision. Building skill in orchestrating productive classroom conversations entails learning about different student contexts and developing intercultural awareness about how students think and learn (Palmer & Wood, 2013; Hauk, Jackson, & Tsay, 2017; Jeppesen, 2010; Kaser & Hauk, 2016). Examining mathematical knowledge for teaching mathematics in two-year colleges provides an opportunity for research on several questions. Two possible questions are

- In what ways does the construct of mathematical knowledge for teaching need to be reframed in the two-year college setting (Hill, Ball, & Schilling, 2008; Speer, King, & Howell, 2014)?
- In what ways does focusing on faculty development increase faculty's mathematical knowledge for teaching?

A promising direction for research on developing teaching practices involves working with mathematics graduate teaching assistants or novice instructors in their first few years of college teaching (Ellis, Deshler, & Speer, 2016; Speer, King, & Howell, 2014; Speer & Wagner, 2009; Hauk, Toney, Jackson, Nair, & Tsay, 2014). The College Mathematics Instructor Development Source (CoMInDS, n.d.) project is providing a home (through the Mathematical Association of America) for sharing materials for preparing mathematics instructors to teach. The project has offered summer workshops for stakeholders involved in graduate student and novice instructor teaching development (for example, professional development for people who are the providers of professional development for faculty). Among its collection of resources, the CoMInDS website includes links to a set of essays and video cases on college mathematics teaching (Hauk, Speer, Kung, Tsay, & Hsu, 2013). These efforts to develop materials to prepare graduate students for college teaching suggest several avenues for research:

- Do instructors who reflect on setting norms for participation and engagement with mathematics make changes to the first day of class that lead to student success in the course?
- What are the successes and challenges created when materials developed for novice instructors (graduate TAs) are used in professional learning among more experienced faculty in two-year colleges?
- What are the features of graduate student teaching development that impact educators' decisions to teach at a two-year college?

Another potential area of research might focus on the instructional leaders who work with faculty as well as evaluate their teaching. For example, an explanatory sequential mixed methods research might start with a survey that would give us a better idea of who evaluates mathematics teaching at two-year colleges, what evaluation strategies are used, and how these align with best practices in postsecondary teaching evaluation. Follow-up interviews could examine instructors' and evaluators' beliefs about mathematics and what it means to be a successful student in mathematics.

Summary and Future Work

The purpose of this chapter is to provide two-year college and university faculty with ideas for conducting research investigations within the context of two-year colleges where little research has been focused upon. We recognize that there are many more unknown critical questions, but this chapter aims to provide a foundation of questions from which to build and extend the research agenda set forth in Sitomer et al. (2012). Furthermore, Mesa, et al. (2014) have described high need areas for research in the coming decade: instruction, students, and curriculum, and in the rapidly expanding area of eLearning. The authors note that research in K-12 and postsecondary mathematics education have made substantial strides in advancing our understanding of teaching and learning. However, the needs, abilities, and socio-cultural perspectives of adult college learners in two-year colleges may be different. While we can learn from K-12 studies, more research work is needed to understand how to best assist students in two-year colleges to succeed. In looking to the future, we encourage faculty to engage in rigorous research investigations that will move this growing field of inquiry.

Have you ever tried to find meaningful research in mathematics at the two-year college level or mathematics in the first two years of college? Would you like to do research in mathematics at the two-year college and perhaps collaborate with someone? Do you already have great information or ideas on research? Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

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Chapter 9

IMPACTing the Future

Answering the Call

Never doubt that a small group of thoughtful, committed
citizens can change the world
~ Margaret Mead (Lutkehaus, 2008, p. 261).

As instructors, we hope to make an impact on our students' future. Whereas classrooms are instrumental to the creation of a community of students, national organizations have an ability to create a community of instructors. This document was developed and written by college mathematics faculty and administrators for faculty who teach mathematics in the first two years of college. Building on AMATYC's two historical standards documents, *IMPACT* was designed to inspire educators to improve mathematics instruction by developing PROWESS (Proficiency, Ownership, Engagement, Student Success) in their students and to assist instructors to view themselves as a key part of an extended educational community. We hope *IMPACT* encourages fruitful conversation and productive dialogue on how to create an environment of learning that is supported by research.

This document does not only introduce the concept of the four pillars of PROWESS, but also the importance of the role of stakeholders and of research specifically targeted for mathematics education in the first two years of college. We summarize key themes in the following tables:

Making an IMPACT on Mathematical PROWESS
Proficiency: *Developing Students' Mathematical Knowledge* Irrespective of a student's academic pursuits, mathematical proficiency is critical to being a functioning member of society. Students need to: know mathematics procedures, execute core computations fluently, view mathematics as relevant to their daily lives, demonstrate mathematical understanding, utilize the structure in the mathematics to solve problems, apply mathematics to everyday situations, and communicate mathematically.
Ownership: *Taking Responsibility and Showing Initiative* Faculty should work towards empowering students to take ownership of their learning by promoting self-regulated learning. For faculty, ownership involves being a reflective practitioner who examines curricula and teaching practices to identify areas that need improvement. For departments and institutions, ownership requires supporting faculty in their teaching.
Engagement: *Developing Intellectual Curiosity and Motivation in Learning Mathematics* Engaging students intellectually in the process of learning mathematics through active and cognitive activities is fundamental for improving student achievement. Likewise, engaging faculty in the pursuit of excellence in teaching through innovative best practices results in an invigorated commitment to teaching and innovation, which benefits students, the department, the college, and society as a whole.
Student Success: *Stimulating Student Achievement in Mathematics* Stimulating student success requires the entire college community to work together to advise and place students into appropriate pathways while creating a positive learning environment to maximize their success. Producing and sustaining a learning environment that promotes student success should be implemented by utilizing a collaborative spirit that unites college leadership, faculty, staff, and policy makers.

Table 1: Making an Impact on Mathematical PROWESS

Advancing the IMPACT

Continuing the Ripple:	Implications for Research:
Bringing the Community Together to Accomplish Change Making meaningful change involves multiple stakeholders working together. Such changes are not easy but examples of different institutions and groups working to influence the types of changes that this document advocates demonstrate what is possible.	*Moving the Research Agenda Forward in Mathematics in the Two-Year College* Research in mathematics education at the two-year college is emerging as a vital field of inquiry for understanding the complexities of teaching and learning mathematics at this level. The two-year college setting is a fertile environment for research and faculty at all levels are encouraged to engage in research investigations that meet the needs of both students and faculty. While ample research has been conducted in universities and K-12 settings, minimal research has been focused on two-year colleges.

Table 2: Advancing the IMPACT

Two-year colleges face unique challenges as they teach a diverse student population, many of whom are not prepared for college-level mathematics courses. This document contains more than merely a list of recommendations for making an impact. It is a document that can be used for professional growth as well as a framework to make significant changes at the individual, departmental, and college levels.

What are your next steps to have an impact on your students and professional environment? We encourage you to use and cite *IMPACT* as a reference to bring inspiration and to move mathematics education forward. Share the document with your colleagues so you may join in the movement to create the ripple effect. Here is a non-exhaustive list of ways to bring this document to life:

- *Try something different in your classes.* It may work well or it may not work as well, but it informs you on how your teaching practices can change. Remember that creative teaching is a process—when you learned to factor or integrate, you did not get every problem correct the first time around either! **Proficiency** is built on conceptual understanding, application of knowledge, and perseverance.
- *Have a book reading at department meetings*. Discuss different sections of the document at each meeting and brainstorm ways to implement recommendations on your campus. Your college will take **ownership** of the curricular and pedagogical ideas presented here and can discuss how to help students have ownership of their learning.
- *Present at a conference, whether your ideas worked or not.* If you are incorporating some of the ideas in this document, share with colleagues. Whether you do this on a local, state, or national level, others may be interested to know what you are doing that is innovative and is making a difference. Your **engagement** will be infectious.

- *Share this document and its ideas with your college administration*. Deans, provosts, and college presidents are receptive of ways to improve **student success** in mathematics. Highlight for your administration areas that will help you grow student success at your college.

While reading this document, you viewed many stories from students and faculty. We hope you identified with these vignettes and now are inspired to impact the lives of students. Consider your answers to the following thought-provoking questions:

- Are you an experienced mathematics instructor who has honed your craft over time? What have you seen over your years in the classroom that has changed?
- Are you just a few years removed from graduate school and at the start of your teaching career? Do you find yourself in agreement with others in your department or are you finding a need for change?
- In what way can the information in this document be useful to improve your teaching and foster change while maintaining mathematical rigor?
- Are you an administrator looking for ways to improve success rates in developmental mathematics courses? Is your college too worried about having college-ready students instead of being a student-ready college?

No matter where you are in your career, IMPACT Live! affords you to the opportunity to contribute to, or benefit from, the collective ideas and resources of the AMATYC community. As the online extension of *IMPACT*, IMPACT Live! allows us to expand our community and share our ideas. Head to AMATYC.org/IMPACTLive and find innovations your colleagues are using or contribute innovations and ideas of your own.

Share your story. Make an IMPACT!

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Acronyms

AACC	American Association of Community Colleges
ACCJC	Accrediting Commission for Community and Junior Colleges
AMATYC	American Mathematical Association of Two-Year Colleges
AMS	American Mathematical Society
AP	Advanced Placement
ASA	American Statistical Association
ATD	Achieving the Dream
CAT	Classroom Assessment Techniques
CBMS	Conference Board of the Mathematical Sciences
CCCSE	The Center for Community College Student Engagement
CCRC	Community College Research Center
CCSS	Common Core State Standards
CCSSM	Common Core State Standards for Mathematics
COMAP	Consortium for Mathematics and Its Applications
GAIMME	Guidelines for Assessment and Instruction in Mathematical Modeling Education
GAISE	Guidelines for Assessment and Instruction in Statistics Education
GTO	Guaranteed Transfer Option
HLC	The Higher Learning Commission
IMPACT	Improving Mathematical Prowess And College Teaching
LAT	Learning Assessment Techniques
LMS	Learning Management System
M^3 Challenge	Moody's Mega Math Challenge
MAA	Mathematical Association of America
MSCHE	Middle States Commission on Higher Education
NADE	National Association of Developmental Education
NCCBP	National Community College Benchmark Project
NCES	National Center for Education Statistics
NCTM	National Council of Teachers of Mathematics
NEASC	New England Association of Schools and Colleges
NGA Center & CCSSO	National Governors Association Center for Best Practices & Council of Chief State School Officers
NRC	National Research Council
NSC	National Student Clearinghouse
NSCRC	National Student Clearinghouse Research Center
NSF	National Science Foundation
NWCCU	Northwest Commission on Colleges and Universities
OER	Open Educational Resources
PROWESS	PRoficiency, OWnership, Engagement, Student Success

PTK	Phi Theta Kappa
SACSCOC	Southern Association of Colleges and Schools, Commission on Colleges
SIAM	Society of Industrial and Applied Mathematics
SMP	Standards for Mathematical Practice
STEM	Science, Technology, Engineering, and Mathematics
TPSE Math	Transforming Post-Secondary Education in Mathematics
UDL	Universal Design for Learning
USDE	United States Department of Education

Standards

Standards for Intellectual Development

Address desired modes of student thinking and represent goals for student outcomes.

Standard I-1 Problem Solving
Students will engage in substantial problem solving.

Standard I-2 Modeling
Students will learn mathematics through modeling real-world situations.

Standard I-3 Reasoning
Students will expand their mathematical reasoning skills as they develop convincing mathematical arguments.

Standard I-4 Connecting With Other Disciplines
Students will develop the view that mathematics is a growing discipline, interrelated with human culture, and understand its connections to other disciplines.

Standard I-5 Communicating
Students will acquire the ability to read, write, listen to, and speak mathematics.

Standard I-6 Using Technology
Students will use appropriate technology to enhance their mathematical thinking and understanding and to solve mathematical problems and judge the reasonableness of their results.

Standard I-7 Developing Mathematical Power
Students will engage in rich experiences that encourage independent, nontrivial exploration in mathematics, develop and reinforce tenacity and confidence in their abilities to use mathematics, and inspire them to pursue the study of mathematics and related disciplines.

Standards for Content

Provide guidelines for the selection of content that will be taught throughout introductory college mathematics.

Standard C-1 Number Sense
Students will perform arithmetic operations, as well as reason and draw conclusions from numerical information.

Standard C-2 Symbolism and Algebra
Students will translate problem situations into their symbolic representations and use those representations to solve problems.

Standard C-3 Geometry
Students will develop a spatial and measurement sense.

Standard C-4 Function
Students will demonstrate understanding of the concept of function by several means (verbally, numerically, graphically, and symbolically) and incorporate it as a central theme into their use of mathematics.

Standard C-5 Discrete Mathematics
Students will use discrete mathematical algorithms and develop combinatorial abilities in order to solve problems of finite character and enumerate sets without direct counting.
Standard C-6 Probability and Statistics
Students will analyze data and use probability and statistical models to make inferences about real-world situations.
Standard C-7 Deductive Proof
Students will appreciate the deductive nature of mathematics as an identifying characteristic of the discipline, recognize the roles of definitions, axioms, and theorems, and identify and construct valid deductive arguments.

Standards for Pedagogy

Recommend the use of instructional strategies that provide for student activity and interaction and for students constructed knowledge.
Standard P-1 Teaching and Technology
Mathematics faculty will model the use of appropriate technology in the teaching of mathematics so that students can benefit from the opportunities it presents as a medium of instruction.
Standard P-2 Interactive and Collaborative Learning
Mathematics faculty will foster interactive learning through student writing, reading, speaking, and collaborative activities so that students can learn to work effectively in groups and communicate about mathematics both orally and in writing.
Standard P-3 Connecting with Other Experiences
Mathematics faculty will actively involve students in meaningful mathematics problems that build upon their experiences, focus on broad mathematical themes, and build connections within branches of mathematics and between mathematics and other disciplines so that students will view mathematics as a connected whole relevant to their lives.
Standard P-4 Multiple Approaches
Mathematics faculty will model the use of multiple approaches−numerical, graphical, symbolic, and verbal−to help students learn a variety of techniques for solving problems.
Standard P-5 Experiencing Mathematics
Mathematics faculty will provide learning activities, including projects and apprenticeships, that promote independent thinking and require sustained effort and time so that students will have the confidence to access and use needed mathematics and other technical information independently, to form conjectures from an array of specific examples, and to draw conclusions from general principles.

Standards for Intellectual Development, Content, & Pedagogy taken from *Crossroads in Mathematics* (AMATYC, 1995, p. 9-17).

Standards for Implementation

Implementation Standard: for the Student Learning and the Learning Environment
Mathematics faculty and their institutions will create an environment that optimizes the learning of mathematics for all students.

Implementation Standard: Assessment of Student Learning
Mathematics faculty will use the results from the ongoing assessment of student learning of mathematics to improve curricula, materials, and teaching methods.

Implementation Standard: Curriculum and Program Development
Mathematics departments will develop, implement, evaluate, assess, and revise courses, course sequences, and programs to enable students to attain a higher level of quantitative literacy and achieve their academic and career goals.

Implementation Standard: Instruction
Mathematics faculty will use a variety of instructional strategies that reflect the results of research to enhance student learning.

Implementation Standard: Professionalism
Institutions will hire qualified mathematics faculty, and these faculty will engage in ongoing professional development and service.

Implementation standards taken from *Beyond Crossroads in Mathematics* (AMATYC, 2006, p. 13-14).

References

American Mathematical Association of Two-Year Colleges. (1995). *Crossroads in mathematics: Standards for introductory college mathematics before calculus*. Cohen, D. (Ed.). Memphis, TN: Author.

American Mathematical Association of Two-Year Colleges. (2006). *Beyond crossroads: Implementing mathematics standards in the first two years of college.* Blair, R. (Ed.). Memphis, TN: Author.