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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