# Chapter 5

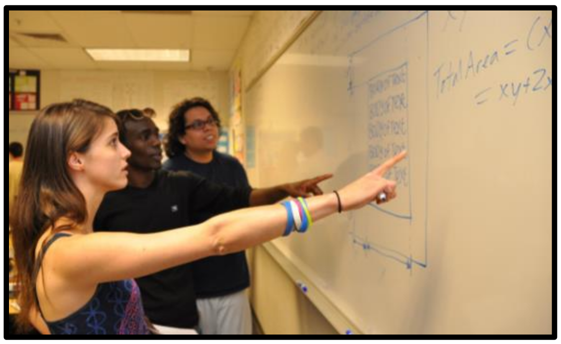
## Engagement

*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.

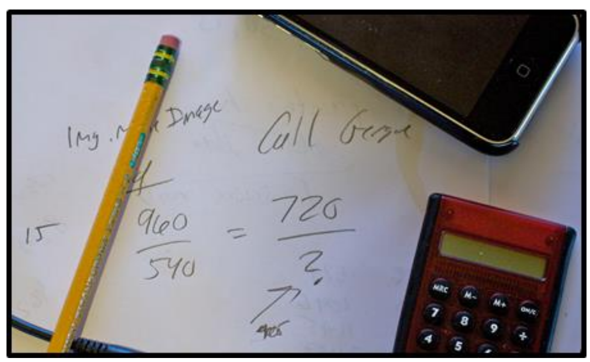
## Engaging Faculty in the Pursuit of Excellence

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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