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This chapter describes a promising new approach to teaching developmental arithmetic and prealgebra, and presents research findings that demonstrate how a faculty support network helped instructors adopt new teaching strategies and gain confidence in teaching the reformed course.

Redesigning Arithmetic for Student Success: Supporting Faculty to Teach in New Ways

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Among the strategies to improve college completion, reforms to course curricula and pedagogy may be among the most challenging to implement. Faculty bring unique knowledge, skills, and dispositions to their classrooms, and individual instructors differ in their willingness and ability to adopt new instructional approaches. Further, long-held norms in higher education encourage faculty autonomy and independence in ways that stymie collaborative efforts to improve curriculum and pedagogy.

Yet refining classroom practice holds significant promise to improve outcomes for students (Ingvarson, Meiers, & Beavis, 2005). This is particularly true in developmental education, where students may benefit from a learning environment that is expressly tailored to their academic and nonacademic needs (Karp, 2011; Perin, 2013). Thus an increasing number of reforms ask faculty to apply new strategies and take on new roles in the developmental education classroom. For example, in mathematics these include Carnegie's Statway, the Dana Center's New Mathways Project, the CUNY Start program, and Path2Stats. To secure buy-in, increase instructor comfort with these approaches, and facilitate high-quality implementation, faculty development structures and practices are needed to support faculty to make changes to their teaching practice.

This chapter presents a case study of a redesign of a developmental arithmetic and prealgebra course titled *Concepts of Numbers for Arithmetic and Prealgebra* at Montgomery County Community College (MCCC) in Blue Bell, Pennsylvania. The course seeks to foster students' conceptual

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understanding of numbers through an instructional approach that differs significantly from what is commonly seen in traditional postsecondary mathematics classes. Findings for this chapter draw on data from a mixed-method research project studying the implementation and outcomes of the course. We begin with a detailed description of the course curriculum and pedagogy and the story of its implementation at MCCC. We then present qualitative analysis, demonstrating that while instructors faced challenges in adopting new pedagogies, a faculty support network helped them try new strategies and gain confidence with the reform. The chapter concludes with a summary of quantitative analyses, which show that *Concepts of Numbers* has improved outcomes for students referred to arithmetic at MCCC. Overall, the lessons learned from the implementation have implications for increasing the success of students referred to developmental math and for supporting faculty to make changes to their pedagogy across a range of disciplines and college contexts.

Research Context: Addressing the Challenges of Students Referred to Developmental Arithmetic

Nationally, approximately 60% of incoming community college students place into developmental mathematics courses, but only about one third ever move on to college-level mathematics (Bailey, Jeong, & Cho, 2010). At MCCC between 2003 and 2008, success rates for the arithmetic/prealgebra course were between 35% and 45%, among the lowest of any course at the college. Based on these outcomes, it was clear to Barbara Lontz, the creator of *Concepts of Numbers*, that developmental arithmetic was a barrier to degree attainment and needed to be addressed.

Lontz began the reform process with an extensive investigation of arithmetic and prealgebra courses, including the review of over 50 textbooks. This search revealed that these courses were all taught by progressing through a sequence of topics, such as whole numbers, fractions, decimals, percents, signed numbers, and solving basic equations. Within this format, algorithms are presented by instructors; students practice these procedures and ultimately demonstrate mastery with skill assessments. However, students who struggle in arithmetic typically have difficulty connecting one topic to another. Students reported to Lontz and her colleagues that they spent hours on long homework sets practicing procedures, but they did not understand how particular topics fit together. For instance, they were unable to understand how fractions relate to decimals and decimals to percents. To them, mathematics was a collection of rules with many different algorithms to memorize and apply in order to obtain the correct answers. Previous attempts at MCCC to improve developmental math courses (through learning communities and supplemental instruction) did not address this lack of connections, nor did they fundamentally alter instructors' teaching

style. Therefore, Lontz envisioned a radical change to both curriculum and instructional delivery.

Concepts of Numbers sets out to address the challenges of students referred to arithmetic in two ways. First it presents course content thematically rather than topically. This reordering is designed explicitly to help students make connections across ideas that may have seemed disparate previously. This focus addresses the concern that most math students understand procedures not concepts, and thus cannot build on them (Givvin, Stigler, & Thompson, 2011). For example, fractions, decimals, and percents appear together in almost every chapter of the course text, which reinforces their relationship to one another. Second, it employs a discovery-based pedagogy that explicitly builds on students' prior knowledge, allowing them to organize their thinking around existing schemas and to clarify concepts they did not understand in the past (Benson & Findell, 2002; Epstein, 1998). Combined, these two components aim to increase students' confidence and foster a newfound appreciation of how numbers work.

Research Design

Concepts of Numbers was examined as part of *Scaling Innovation,* an implementation and research project that investigated how instructional reforms in developmental education are initiated, adapted, and scaled. We draw on two categories of data for this mixed-method analysis. The first is student transcript data from 2,169 students attempting arithmetic at MCCC between fall 2008 and fall 2011. The data set includes student demographics, English and math placement test scores, courses taken and grades received, as well as information on each course, such as course number, course section number, subject, and delivery format. During the time period under investigation, MCCC offered arithmetic/prealgebra using both the reformed and traditional curricula. Students were unaware of which type of section they were enrolled in, allowing for a quasi-experimental design comparing outcomes of students enrolled in *Concepts* with those enrolled in sections using the traditional approach. The second category is qualitative data focused on faculty experiences with the reform. Specifically we analyze 11 interviews with MCCC developmental math faculty and a range of institutional, curricular, and professional developmental documents including written faculty reflections. We also draw on information gleaned from classroom observations and observations of faculty development activities at MCCC and two other colleges implementing *Concepts*.

A Closer Look at the *Concepts* Curriculum

A unique feature of *Concepts* is its innovative course textbook, written by Lontz and published by Pearson. It is comprised of eight units covering the material typically taught in an arithmetic/prealgebra course. These units

include: History of Math, The Real Number System, Comparisons, Addition, Subtraction, Multiplication, Division, and Combinations. When students place into arithmetic, they often feel demoralized, assuming they will begin with the traditional arithmetic topics and instructional methods they equate with their lack of past success. Yet the new textbook begins differently. The first unit focuses on the history of math, including information on African, Egyptian, Roman, and Babylonian numeration systems. Students see how our present numeration system evolved from the ideas of many cultures and nations. In addition to laying the foundation for the connections that will be made throughout the semester, this unit was created to promote a positive tone in the class. A new beginning to the course promotes a different understanding of the nature of mathematics and aims to create hope in students that they will experience new, better results.

In the second unit, students investigate all real numbers. By locating various types of numbers on the number line and classifying them as whole numbers, integers, rational or irrational, students begin to see relationships between types of numbers. For example, they begin to see that fractions are no different from decimals—rather, they represent different forms of the same quantity, providing a viable alternative to students' previous negative experiences in math and dispelling myths such as "I can't do fractions." In unit three, numbers are compared using "less than," "greater than," or "equal to." This establishes the premise that it is easier to compare like quantities, providing a meaningful purpose for changing numbers to equivalent forms.

These opening units provide a foundation for the four operations: addition, subtraction, multiplication, and division. All of the arithmetic topics covered in a traditional course are included but rearranged within these conceptual units. For instance, students learn how to add fractions, decimals, signed numbers, and algebraic terms as a collective group. In the next unit, the focus is on subtraction. The course ends with a combination unit that deals with multiple-step problems, synthesizing many of the skills introduced and learned in the course.

Once the history of math has been presented, discovery becomes the main teaching tool. Instead of taking the traditional approach to teaching algorithms, in which the instructor presents definitions, provides examples, and then assigns practice problems, *Concepts* asks students to solve problems by drawing on previous mathematical experiences and knowledge before a rule is given. Adult students referred to arithmetic have holes in their mathematical knowledge, but most have been exposed to the course content in their previous educational experiences. There are always some students in the class who know something about each lesson. When the teacher facilitates discussion among students through the discovery approach, that prior knowledge emerges.

Under this model, instructors encourage students to experiment. By looking at patterns, students discover algorithms as shortcuts. Rules are

reconceptualized as memory aids and may or may not be used, depending on the student. Formulas are applied only when necessary. A calculator is a tool to be used only when the calculations become cumbersome, which is rare. Instructors listen to student discussion in class as a means to answer the important question—do they understand? If they do not, then the teacher must tailor class discussions to fill in the blanks and bridge any gaps that remain. Students are involved in the learning process: They ask questions, they are given time to ponder, and their wrong answers are nonetheless considered in class discussion. *Concepts* instructors thus allow students to take ownership for what they are discovering and become active participants in their education.

The *Concepts* textbook has a number of features to facilitate this approach to teaching and learning. For example, the text has minimal narrative and explanation, which facilitates the teacher's use of the discovery approach. Having less prescription allows the lesson to evolve according to the needs and knowledge of the students in the class. The number of homework problems is radically reduced as compared to a traditional textbook. Homework problems are intended to help students assess their own understandings rather than to drill procedures. Faculty teaching *Concepts* report an increase in completed assignments and more consistent attendance, compared with students in traditional arithmetic courses. They attribute this change in students' academic behavior partially to the smaller homework sets. For students or instructors who believe that additional practice is needed, supplemental problems are available in a workbook format and via an online resource aligned with the text. The layout of the textbook is intended to support first-time college students. For example, assignments are found on blue pages; white pages are for instruction and class work. This distinction makes clear to students the expectations for what should be completed outside of class.

Reform Implementation: Moving From Pilot to Scale

Over the span of four years, *Concepts* moved from being a single section pilot to the only arithmetic course offered at MCCC. In fall 2008, *Concepts* was first piloted at MCCC in one arithmetic section after the proposed course redesign had been shared with math faculty and vetted by the mathematics department. Course outcomes from this first semester indicated strong pass rates and suggested this might be a promising approach. Subsequently, the course was piloted in a single section through the fall 2009. During this time, the course text was formalized and revised. In spring 2010, the number of *Concepts* sections was expanded to 14 out of 26 sections. Positive course pass rates prompted the department to further expand to 20 sections in fall 2010. By this time, a significant subset of MCCC math faculty had taught *Concepts*, including a cadre of full-time faculty and adjuncts who were each teaching between one and three sections each semester. With this

momentum as a backdrop, in fall 2011 the department voted to replace the traditional arithmetic/prealgebra course with *Concepts*.

As *Concepts* expanded at MCCC, the orientation of new faculty was a critical activity for ensuring that faculty implemented the curriculum as designed. The course's reorganization of subject matter and, most importantly, the change in teaching methods required faculty to move away from a lecture, drill, and practice approach. To change from a lecture-based mode of instruction to a discovery-facilitation format requires time, practice, and support from those with some experience.

Beginning in spring 2010, each new *Concepts* instructor was oriented in a one-to-one or small group meeting before the start of the semester. Faculty were encouraged to reach out to one another with questions, and informal conversations among *Concepts* faculty about the curriculum and discovery approach were not uncommon. However, it soon became evident that the "once and done" orientations only touched the surface of the range of issues *Concepts* faculty might face. They also became increasingly unwieldy as new course sections were added each semester. In addition, last minute course assignments and turnover among adjuncts and tutors made it challenging to ensure that all instructors were adequately prepared, particularly within an orientation system facilitated by a single person. Critically, one-to-one orientations neglected the ongoing needs of returning *Concepts* instructors. To address these needs and to assist instructors in their use of the discovery approach, which many reported as challenging, faculty leadership developed a unique and in-depth learning opportunity to support changes to classroom practice.

Connecting *Concepts* Faculty for In-Depth and Innovative Professional Development

During the 2011–2012 academic year, MCCC refined *Concepts*, expanded faculty development, and supported other colleges in its adoption through funds provided by *Scaling Innovation*. Part of this process involved creating a *Concepts* implementation team comprised of three faculty members. In spring 2012, the team launched CON-NECT (Concepts of Numbers—Networking Educators' Collaborative Thoughts) to create more intensive and ongoing support for faculty teaching *Concepts*. During the first semester, seven MCCC instructors—representing a range of experiences (full-time, adjunct, and varying levels of experience with the course)—volunteered to join the group and met five times to discuss topics related to teaching the course. This model was replicated in fall 2012 and spring 2013 with different groups of *Concepts* faculty; over the course of the three semesters, most full-time and adjunct instructors who regularly teach the course as well as representatives from the tutoring center participated in CON-NECT.

One of the functions of CON-NECT was to support ongoing course refinement efforts. Each cohort offered feedback on the textbook and other course materials, and their input shaped subsequent revisions. The group contributed to the assessment of learning outcomes. CON-NECT faculty were invited to administer a common multiple choice final exam in their classes, which was used to identify areas of weakness in the curriculum. The data from this assessment guided subsequent discussions of course materials and teaching practices. For a less resource-intensive and more sustainable approach to orienting new *Concepts* faculty at MCCC and other institutions, the implementation team developed a stand-alone orientation PowerPoint presentation with a voice-over. CON-NECT participants' feedback on this resource was instrumental in its development and refinement.

To explore the discovery pedagogy of *Concepts* in depth, CON-NECT participants viewed and discussed classroom video from *Concepts* classes, gave teaching demonstrations on lessons identified to be challenging, reflected regularly in an e-journal that was shared with the group, and observed another faculty member's *Concepts* class. In addition, CON-NECT offered a venue for more general discussion of teaching and learning. Participants discussed their participation at conferences and read articles and books on topics related to teaching developmental mathematics. At the conclusion of the semester, CON-NECT faculty wrote a culminating reflection paper documenting what impact the group had had on them as educators.

At MCCC these types of activities continue although the refinement grant ended and CON-NECT has formally disbanded. Participants from all three cohorts informally continue to have conversations about the discovery approach and conceptual learning via email and in person. Their input was critical to the development of a new edition of the textbook that includes faculty teaching tips, supplemental and review exercises, computer-based support, a glossary of terms, more application problems, better graphics, and more challenging exercises. Now *Concepts* instructors are invited to attend biannual meetings to provide continued input into course improvements and to offer and receive support from colleagues.

Supporting Pedagogical Change: Lessons Learned From *Concepts*

The story of *Concepts* at MCCC suggests that a motivated group of faculty willing to try something new can successfully launch and scale a substantial change to curriculum and pedagogy. Interviews reveal that faculty enjoy teaching the course, and they believe students enjoy learning arithmetic in *Concepts*. Yet faculty also report significant challenges in adapting their teaching styles to this course. These challenges, and the way that CON-NECT supported faculty to experiment and embrace new ways of teaching, are relevant for reformers working to improve instruction in higher education.

The primary challenge faculty reported in teaching *Concepts* was their uncertainty about how to implement the discovery approach. For example, one instructor with several semesters of experience teaching the course explained that he was allowing "more conversation" in class, but he was still not sure if this was really facilitating discovery. Instructors reported that it is difficult to allow students to take the lead, particularly when the instructors have refined their explanations of mathematical rules over the course of their careers. As one instructor described, "I have ways of explaining a concept beautifully, but I'm learning they may need to make mistakes in order to understand the material." Another instructor, halfway through his first semester teaching *Concepts*, admitted that he was spending much of the class time lecturing, largely because he was afraid students might fail if the information was not presented to them.

Many interviewees reported that it was only after they had begun participating in CON-NECT that they gained confidence in the discovery approach. As one instructor explained, "When I first went through the [one-on-one] orientation, I wasn't ready to hear it. The first time I remember getting [the discovery approach] was in a CON-NECT meeting." Overall, instructors reported a deeper understanding of the rationale for the redesign, the goal of the course, and teaching methods for building on student knowledge as a result of CON-NECT. Furthermore, faculty described increasing comfort with facilitating class discussions, moving away from lecture, and allowing students to take responsibility for their learning.

The ongoing nature of CON-NECT, as compared to a single orientation session, provided participants with more in-depth information about the instructional approach. In addition to the intensity, two features of CON-NECT seem salient in providing instructors the support they needed to make changes to their practice. First, the group offered participants visible examples of discovery learning through classroom observations, video review, and teaching demonstrations. "Seeing" the curriculum in action appears to be essential for faculty to adopt a new teaching style. Second, CON-NECT allowed for self-reflection on pedagogy in ways not typically afforded in higher education. Faculty leaders were intentional in modeling self-reflection and vulnerability (e.g., in video recording their own classrooms for analysis) and, in doing so, fostered a sense of collegial trust which grew over the course of the semester. This set the tone for nonevaluative, constructive self- and peer-feedback in the e-journals, peer observations, and reflection papers. One instructor reported: "[The] sharing established a sense of connectedness and refreshed my outlook by allowing me to analyze my personal teaching style and see what I am doing right and what I need to enhance." Participants reported that these activities had a profound impact on their teaching practice.

The lessons learned from faculty teaching in *Concepts of Numbers* have implications for other reforms in other courses and other disciplines. The features of CON-NECT correspond to features of high-quality professional

learning opportunities identified in previous research (e.g., Garet, Porter, Desimone, Birman, & Yoon, 2001). The work of the group was *meaningful*, as faculty engaged in substantive discussions about the course (including edits to the textbook), and their conversations were highly *contextualized* (as they discussed specific features of practice highlighted in videos and observations). Additionally, participants were provided significant *structure and guidance* in how to reflect on their practice, which is important because many faculty have little experience talking about their pedagogy. In these ways CON-NECT provides a model that could be adapted to support faculty to change or refine their teaching in both reform and nonreform contexts.

Sustaining Change: Improving the Outcomes for Students in Arithmetic and Beyond

Concepts course pass rates indicate that this new curricular and pedagogical approach is effective for many students referred to the lowest level of developmental mathematics. Comparative analysis completed for this study shows that students enrolled in *Concepts* ($N = 866$) were more likely to be successful than their peers enrolled in the traditional arithmetic/prealgebra course ($N = 1{,}303$). Specifically, we find that *Concepts* students were more likely to earn a C or higher, less likely to withdraw from the course, and more likely to enroll in algebra, the subsequent developmental math course (for a full description of the methods and findings, please see the forthcoming Community College Research Center Working Paper "Concepts of Numbers: Improving Outcomes in Arithmetic Through Curricular and Pedagogical Reform"). These analyses control for student and course-level characteristics, including student scores on the placement exam. The results suggest that many students benefit from a conceptually oriented curriculum and an instructional approach that aims to allow student understandings of mathematics to emerge.

However, analysis of longer term outcomes suggests the need to look beyond individual course-level reforms to find ways to improve learning and classroom experiences at every stage of a student's college career. In our sample, students enrolled in *Concepts* and their peers in the traditional model completed algebra and gatekeeper math courses at approximately the same rate. During the follow-up period, they did not differ in the total number of college-level credits earned. Many college instructors from across disciplines are experimenting with new ways of teaching to meet their students' needs; however, most often this occurs in isolation, resulting in improvements for individual classrooms rather than in a coordinated increase in success across the college (Nakabugo & Sieborger, 2001). Infrastructure like CON-NECT, which promotes in-depth and ongoing collaborative opportunities for self-reflection on pedagogy, has the potential to impact larger numbers of faculty and thus larger numbers of students,

potentially improving student learning and outcomes across course sequences in developmental education and beyond.

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