Learning Our Way into Effective Professional Development: Networked Improvement Science in Community College Developmental Mathematics

Carlos Sandoval, Haley McNamara, Ann Edwards

Every year, hundreds of thousands of college students are placed into, and do not complete, developmental math courses. The Carnegie Math Pathways, a nationwide initiative aimed at addressing this problem, is comprised of a student-centered instructional system that forefronts mathematical sense-making and conceptual understanding; structural changes to course offerings; and a system of faculty professional development. This paper reports on the use of Improvement Science, an approach grounded in methods and tools of quality improvement, to design, improve, and scale a professional development program for first-time Pathways instructors. We also report on insights derived from the improvement approach about effective professional development in the Pathways and findings related to common challenges faced when teaching the Pathways. We conclude with implications for professional development in higher education and the use of improvement science to scale effective professional development.

Keywords: Developmental mathematics, professional development, community college, improvement science, continuous improvement

Introduction

Over 14 million students are enrolled in community college, seeking an educational pathway to a productive career and better life. Between 50 and 70% of incoming community college students must take at least one developmental math course before they can enroll in college-credit courses (Bailey, Jeong, & Cho, 2010; Complete College America [CCA], 2012). However, 80% of the students who place into developmental mathematics do not complete a college-level math course within 3 years (Bailey et al., 2010). The pattern is similar in comprehensive 4-year institutions, where 20% of incoming students are placed into developmental math, and 63% do not complete a college-level math course within 2 years (CCA, 2012). Taken together, roughly 1.7 million first-time undergraduate students are placed into developmental math each year (CCA, 2012). Many of these students spend large amounts of money and long periods of time repeating courses; most simply leave college without a credential or developing a sufficient command of the mathematics needed to engage as productive citizens.

To address this national issue, the Carnegie Foundation for the Advancement of Teaching together with the Dana Center at the University of Texas at Austin developed an innovative, transformative strategy in undergraduate mathematics education: the Carnegie Math Pathways [CMP] program. The CMP consists of two distinct course sequences—Statway and Quantway, referred to collectively as the Pathways—that are designed to accelerate developmental students to and through college-level mathematics in one year. Their instructional design provides students with opportunities to learn mathematics content that is more engaging and relevant to their goals than they would encounter in traditional remediation and do so in pedagogical environments that are student- and problem-centered and that support students' persistence and engagement. The CMP initiative is organized as a Networked Improvement Community (NIC), a collection of institutions centered on addressing a particular problem and disciplined by the rigor of an approach called Improvement Science (LeMahieu, Edwards, & Gomez, 2015). The CMP NIC, currently comprised of over 65 IHE's (largely community colleges), organizes its collective

efforts to dramatically improve the outcomes and quality of learning of their developmental math students.

We report here on an examination of a key component of CMP: the Faculty Support Program (FSP), professional development aimed at preparing and supporting first-time Pathways instructors. We address how Improvement Science is used to learn about effective professional development and for continuous program improvement. We begin with a discussion of the community college environment as it pertains to instruction and professional development. We then describe the FSP and our use of Improvement Science in the FSP. We then present a brief description of our findings pertaining to professional development in community colleges and conclude with implications, limitations, and directions for future research.

Background and Context

The Developmental Math Challenge

The reasons for the low success rates in developmental mathematics are complex. The structure of the traditional developmental math course sequence (Hodara, 2013) and the complexity of the course options are significant barriers to student retention and completion (Cullinane & Treisman, 2010). Also, developmental math instruction often does not employ research-based learning materials and pedagogical practices that can foster deeper student learning (Bransford, Brown, & Cocking, 1999). Many developmental math classrooms resemble the content-focused, knowledge transmission model so prevalent in undergraduate instruction (Bailey, Jaggars, & Jenkins, 2015; Grubb et al, 1999; Grubb & Gabriner, 2013). Instructional activities tend to focus on factual and procedural knowledge as opposed to conceptual content and mathematical sense-making (Mesa, 2011). Many developmental math curricula do little to engage students' interest and demonstrate the relevance of mathematical concepts to everyday life (Carnevale & Desrochers, 2003). In addition, instructors who may be open to alternative approaches, such as learner-centered models, are often skeptical of their efficacy for developmental students, who they perceive as weakly prepared and resistant to such strategies (Grubb & Grabiner, 2013). Many developmental math students have had negative prior math experiences leading to the belief that they are "not math people." These beliefs often trigger anxiety in students who encounter difficult math problems (Blackwell, Trzesniewski, & Dweck, 2007; Haynes, Perry, Stupnisky & Daniels, 2009).

Carnegie Math Pathways "Change Package"

To address these long-standing challenges, the CMP NIC developed the CMP instructional system: a "change package" organized around Statway and Quantway. In Improvement Science (IS), a "change package" is a well-defined, evidence-based set of "change ideas" and associated metrics. The CMP change package consists of the following components:

Accelerated pathways: Rather than being faced with a maze of possible course options (Zeidenberg & Scott, 2011), students are offered an accelerated pathway that meets developmental math requirements and provides college math credit upon successful completion (Cho, Kopko, Jenkins, & Jaggars, 2012; Jaggars, Hodara, Cho, & Xu, 2015).

Mathematics content relevant to college, career, and citizenship: Statistics and quantitative literacy, respectively, are the core college-level content and conceptual organizers for Statway and Quantway, with developmental math learning goals integrated throughout. Both courses emphasize core mathematics skills needed for work, personal life, and citizenship, and stress conceptual understanding and its application in a variety of contexts (e.g., Gillman, 2006; Madison & Steen, 2008; and GAISE College Report ASA Revision Committee, 2016).

Pedagogy supporting deep and flexible mathematics understanding: Grounded in research on teaching for mathematical understanding and the development of mathematical practices (e.g., Bransford, Brown, & Cocking, 2000), CMP pedagogy emphasizes productive struggle with challenging problems (Schmidt & Bjork, 1992), making conceptual connections explicit (Hiebert & Grouws, 2007), deliberate as opposed to routine practice (Ericsson, 2008; Pashler, Rohrer, Cepeda, & Carpenter, 2007), opportunities for rich mathematical discourse (Moschkovich, 2007), and the role of collaborative learning in promoting mathematical sense-making (Esmonde, & Langer-Osuna, 2013; Webb, 2009).

Productive Persistence supports: Integrated throughout the CMP is an evidence-based package of interventions and practices to increase student motivation, tenacity, and learning skills. Based on research from social psychology, strategies focus on reducing student anxiety (Jamieson, Mendes, Blackstock, & Schmader, 2010), increasing a sense of belonging (Walton & Cohen, 2011), and countering fixed mindset (Dweck, 2006).

Reducing language and literacy barriers: Given students' diverse linguistic backgrounds, supports and interventions are interwoven into the curricula and pedagogy to assist students with the complex language and literacy demands of mathematics, with its different forms of representation and grammar (Gomez, Rodela, Lozano, & Mancevice, 2013; Gomez et al., 2015).

Faculty professional development: A robust professional development system has been crucial as the CMP have moved from early adopter colleges to institutional contexts with more adjunct and inexperienced faculty and limited institutional capacity—this is the focus of the analysis reported on in this paper.

Teaching and Professional Development in Community College Mathematics

The shifts in pedagogy that the Pathways demand are challenging for many instructors due in part to their professional backgrounds and the availability of professional learning opportunities. Despite the emphasis on teaching in community colleges (Grubb et al., 1999), community college faculty are no more likely to have completed pedagogical coursework than faculty in research institutions. Heavy teaching loads and the low budget priority given to professional development prevalent in community colleges are not conducive for creating opportunities to learn about and develop instructional practices (Bailey, Jaggars, & Jenkins, 2015; Grubb et al., 1999; Tinberg, Duffy, & Mino, 2007). The problem is exacerbated in developmental education, where adjunct faculty, who often have heavier teaching loads, reduced access to professional development, and are assigned lesser status by their peers (Grubb, Badway, & Bell, 2003), constitute 76% of all developmental instructors (Center for Community College Student Engagement, 2014). Although evidence suggests that high quality professional development is critical for sustaining the impacts of systemic reform (Desimone, 2009; Fishman, Marx, Best, & Tal, 2003; Supovitz, Mayer, & Kahle, 2000), professional development in community colleges is described as ad hoc and lacking significant institutional support (Twombly & Townsend, 2008). Additionally, it typically consists of one-shot workshops that do not provide meaningful opportunities for professional learning (Bailey, Jaggars, & Jenkins, 2015; Huber, 2008).

Faculty professional development remains a critical and underutilized driver for improving student outcomes. Little research details the design of effective professional development centered on instructional improvement for developmental math instructors; nor has prior research documented challenges in trying to implement research-based professional learning experiences in community colleges (Twombly & Townsend, 2008). This paper focuses on efforts to address barriers to meaningful and effective professional development in community colleges, reporting

on a specific professional development component, the Faculty Support Program (FSP), to prepare first-time Pathways instructors.

The Carnegie Math Pathways Faculty Support Program (FSP)

The design of the FSP is informed by the following set of principles derived from research on effective professional development, primarily from K-12 settings (Hawley & Valli, 2007; Hunzicker, 2010; Guskey, 2002; Garet, et al., 2001; LeMahieu, Roy & Foss, 1995): (1) program structure provides for sustained opportunities for professional learning; (2) learning activities are job-embedded, supporting emergent problems of practice; (3) learning activities are context/discipline specific; (4) learning activities provide opportunities for collaborative reflection; and (5) learning activities are centered around artifacts of classroom practice.

The context of the CMP NIC creates specific challenges for program design. CMP faculty are spread throughout the country and tremendous variability exists in the availability of campus resources. Participation in the FSP is voluntary and outside of professional obligations. Therefore, FSP offerings must be flexible and responsive to the needs of faculty, demonstrate clear value to faculty (and administrators), while also providing meaningful opportunities to develop practice. Thus, the FSP includes multiple modalities for faculty engagement, comprised of online activities and resources; intensive, face-to-face workshops, such as national and locally-based workshops; and one-on-one mentoring from designated Pathways faculty mentors who provide support in planning and teaching, including ongoing, just-in-time support.

The design principles and structural components of the program serve as critical guidelines in the spread, and scale of the FSP, particularly as the NIC grows rapidly. In 2015-2016, student enrollment quadrupled to 6220 students, resulting in 222 faculty members teaching the Pathways across 36 institutions nationwide (Hoang, Huang, Sulcer, & Suleyman, 2017). Additionally, the Pathways is spreading to settings widely variable in policy and culture. What is needed is an approach to learning about effective professional development across settings for program improvement. To do so, we employ an Improvement Science approach, detailed next.

Approach and Methods: Improvement Science as an Approach to Theory Development, Knowledge Generation and Program Improvement

Educational interventions and programs demonstrate limited efficacy at scale (Elmore, 1996), potentially because traditional approaches to research and development often rely on promising interventions whose evidence for efficacy is limited to experiments conducted in controlled settings (Bryk, Gomez, & Grunow, 2011). As a result, such interventions usually rely on the fidelity of implementation by local actors. While appropriate for simple interventions that are procedural and artifact-centric in nature, complex interventions relying on individuals and their expertise across disparate institutions require a different approach (Bryk & Gomez, 2008). Thus, we employ Networked Improvement Science as an approach to improving and scaling the Pathways' system of professional development. Broadly, Improvement Science (IS) prioritizes addressing complex problems through learning deeply about causal systems; developing theories of action for achieving specific and measurable aims; iterative testing of promising ideas connected to theories of action; the use of measurement to determine performance and improvement; and scaling solutions (Bryk, Gomez, Grunow, & LeMahieu, 2015, p. 7). IS consists of a specific set of methods and tools aimed at improving outcomes through the generation of knowledge of what works, for whom, and under what conditions. In IS, theories—of the nature of the problem, of the local settings and systems, and of improvement—are explicated, tested, and refined over time, using diverse types and sources of data.

The generation of knowledge and development of theory using IS are accelerated through leveraging networks organized around a common aim. Thus, the CMP initiative is organized as a Networked Improvement Community (NIC), a group of institutions that share a common aim, a shared understanding of the problem being addressed, and use IS as a common approach (Russell et al., 2017). This network structure is comprised of individual faculty, institutions, and members of a central, organizing hub. The hub is an organization, the Carnegie Foundation for the CMP NIC, that collects and analyzes data from faculty and institutions to learn about implementation and drive improvement efforts. This affords the initiative the opportunity to accelerate the development, testing, and refinement of theory for and of improvement. The hub manages knowledge generated about problems being experienced and tested interventions so that efforts are not duplicated. We now illustrate one way that IS was utilized in the spreading and scaling of the FSP—the common measurement system we developed to manage and improve the program.

The Faculty Support Program Measurement System

Traditional mechanisms for feedback and evaluation of professional development programs are blunt tools; they inform program designers and facilitators about whether or not a program "worked" or how well it was received (Guskey, 2000), but often do not provide actionable feedback that can inform ongoing improvement. They generally do not provide insights into faculty's needs, resources, and constraints relative to the design and implementation of professional development programs.

In contrast, the management of the FSP utilizes Bryk et al's (2015) conceptualization of measurement for improvement. Measurement for improvement (a) creates a common language and cohesive vision of program quality across stakeholders; (b) includes an associated set of routines, protocols, and processes for reviewing the program performance, and (c) allows designers and managers to continuously examine and improve the program for its audience. The FSP leverages this framework to a) design structures and activities around a common vision of effective professional development and b) gauge program performance. The FSP measurement system framework was derived from the Institute for Healthcare Improvement's (IHI) system-level measures approach. IHI devised a suite of system-level outcome measures organized around a set of quality dimensions to assess the quality of healthcare and determine improvement priorities across a network of hospitals (Martin et al., 2007). The FSP's system-level measures (13 in total) are organized around the five dimensions of quality, represented in Table 1. These dimensions, along with our design principles, constitute the FSP design framework.

Table 1 Faculty Support Program Quality Dimensions

Quality Dimensions	**Definition**
Effective	New faculty implement the Pathways with integrity and efficaciously
Efficient	Preparation and support structures are not wasteful of time, money
Responsive	The specific needs of new Pathways faculty are surfaced and met
Community-oriented	New faculty seek support from other faculty, new and experienced
Faculty-centered, faculty-owned	Faculty are centrally involved in the process of designing and improving FSP activities

Leveraging Network Structure and the Common Measurement System to Improve

Comprising the FSP improvement infrastructure (in the form of its networked organization and measurement system) are a set of routines, protocols, and social processes for collecting and

reviewing incoming data about the performance of the FSP as defined by the quality dimensions. Our current data sources and collection timeline are represented in Figure 2 below.

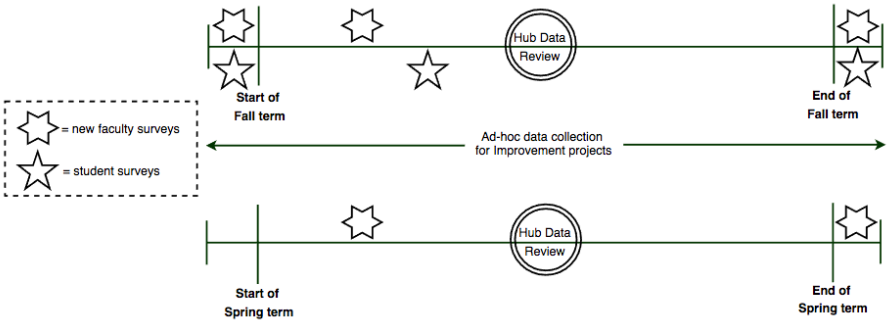

Figure 1 FSP Measurement Sources and Timeline

In 2015-16, data were collected from 222 faculty at 36 institutions nationwide. In 2016-17, 462 faculty members from over 65 institutions nationwide are participating. Using the FSP quality dimensions as a guiding framework, data are collected from the network and analyzed by the hub. Data are reviewed twice a year by a diverse set of stakeholders (faculty, institutional leaders, and hub members). During these reviews, stakeholders determine high leverage priorities for improvement, that is, problems that have potential to produce large improvements with relatively lower costs of time and financial resources. Stakeholders then launch improvement projects, often beginning with an investigation into the problems and then progressing towards small tests of changes that may eventually become stable components of the program. The knowledge generated through this process informs the ongoing refinement of our theories of teacher change and the design of professional development driving the work.

Discussion of Findings

Through this improvement work, three major findings emerged related to the implementation of professional development for mathematics faculty in community colleges. First, the Pathways instructional materials were found to be a critical touchpoint for supporting professional learning. Second, common instructional challenges instructors face in enacting Pathways pedagogy were identified. Third, new instructors' existing relationships at their institutions were often primary sources of support and mentoring. This proposal addresses the first in depth and touches on the others ; if accepted, the final paper will elaborate on all.

Leveraging Instructional Materials

In our interviews with Pathways faculty in the process of designing and improving the program, the curriculum materials emerged as a core source of instructional support. First-time instructors used the materials as references to better understand lesson tasks and goals and also to guide their implementation of specific pedadgogical moves and decisions within lessons.

CMP instructional materials include student lesson handouts presenting in-class tasks and brief readings and instructor notes, which are instructor-facing materials that contain all content in the student handout along with a) notes about tasks and lesson goals; b) guidance for the implementation of the lesson's activity structures, such as group work or whole-class discussion; c) facilitation guides for whole-class discussion; d) suggested activities or "scripts" for promoting productive persistence; and e) anticipated student responses to rich problems. The manner in and extent to which new Pathways instructors use these materials appears to depend on their familiarity and comfort with the Pathways instructional approach. For those whom the

instructional approach is more novel, instructor notes act as a standard protocol to which the instructor adheres for at least the first time. Faculty have reported increased familiarity, comfort, and confidence in teaching the Pathways after using the instructor notes, and they relied on them less in subsequent courses. Instructors more familiar with Pathways pedagogy use the instructor notes as a reference for understanding the lesson objectives, the purpose of each task, and how the lesson is situated within the curriculum broadly. These instructors also annotate the notes with learnings and ideas for future reference, which are often later adapted or omitted upon further trial and reflection.

These findings signaled that, to at least some extent, the materials promoted engagement in some form of reflection on teaching. Although variation existed in how instructors used the materials, we found that nearly all first-time Pathways faculty had studied the instructor notes for each lesson. This finding has broad implications. First, the design of the instructor notes should address specific needs of the faculty. This finding spurred a comprehensive redesign of the instructor notes, in order to better meet the needs of new Pathways faculty and to more effectively surface resources, activities, and opportunities for professional development. Second, while faculty traditionally do not have much pedagogical training in or experiences critically reflecting on their teaching, adjunct and full-time instructors can and often do readily take up opportunities to reflect on their teaching and experiment with instructional moves and practices with which they are not familiar, particularly when those opportunities are accessible.

Common Challenges When Teaching the First Time

In a redesign of the FSP, the hub conducted 30 interviews with new faculty in the fall of 2014 to better target resources and design based upon evidence of faculty needs. Five common challenges faced by first-time Pathways instructors emerged: lesson pacing, promoting productive struggle, facilitating group work, sustaining productive persistence beyond the first 4 weeks of a term, and homework completion. If accepted, we will elaborate on this further.

Leveraging Existing Social Relationships

Key data collected by the hub as part of program improvement are measures of new instructors' engagement with their assigned Faculty Mentors. A program review in the fall of 2015 revealed low engagement. Through the resulting improvement process, we found that faculty saw local colleagues as a critical source of professional learning and support, and thus resources and structures that leverage existing local support systems were developed, tested, and widely implemented. This finding will also be elaborated upon acceptance.

Conclusion

The organization of the Carnegie Math Pathways as a networked improvement community has facilitated the design, testing, refinement, implementation, and scaling of the professional development supporting first-time Pathways faculty. Specifically, the NIC organization provided the hub with access to faculty from a wide range of institutions and thus insight into their work processes and needs as Pathways instructors. Additionally, the FSP measurement system aided in specifying areas for improvement, examining how colleges adapt program components to better fit their local context, and determining whether those adaptations resulted in improvement. In sum, engaging users and institutions in collective improvement work around specific problems, and then testing changes to the program to address those problems, provided us with key opportunities to learn about what effective professional development can look like across diverse community college campuses and diverse groups of faculty.

References

Bailey, T., Jaggars, S.S., & Jenkins, D. (2015). *Redesigning America's Community Colleges*. Cambridge, MA: Harvard University Press.

Bailey, T., Jeong, D. W., & Cho, S. W. (2010). Referral, enrollment, and completion in developmental education sequences in community colleges. *Economics of Education Review, 29*(2), 255-270.

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78,* 246–263.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How People Learn: Brain, Mind, Experience, and School. Washington*, DC: National Academies Press.

Bryk, A. S., & Gomez, L. M. (2008). Ruminations on reinventing an R&D capacity for educational improvement. In F. M. Hess (Ed.), *The future of educational 40 entrepreneurship: Possibilities of school reform* (181-206). Chicago: University of Chicago Press.

Bryk, A. S., Gomez, L. M., & Grunow, A. (2011). Getting ideas into action - Building networked improvement communities in education. *Frontiers in Sociology of Education* (127-169). Springer Publishing.

Bryk, A., Gomez, L., Grunow, A., & LeMahieu, P. (2015). *Learning to Improve: How America's Schools Can Get Better at Getting Better.* Cambridge, MA: Harvard Education Press.

Carnevale, A. P., & Desrochers, D. M. (2003). *Standards for what?: The economic roots of K-16 reform.* Princeton, NJ: Educational Testing Service.

Center for Community College Student Engagement. (2014). *A matter of degrees: Practices to pathways (High-impact practices for community college student success).* Austin, TX: The University of Texas at Austin, Program in Higher Education Leadership.

Cho, S., Kopko, E., Jenkins, D., & Jaggars, S. S. (2012, December). *New evidence of success for community college remedial English students: Tracking the outcomes of students in the Accelerated Learning Program (ALP).* New York, NY: Community College Research Center, Teachers College, Columbia University. Retrieved from http://ccrc.tc.columbia.edu/publications/ccbc-alp-studentoutcomes-follow-up.html

Complete College America. (2012, April). *Remediation: Higher education's bridge to nowhere.* Washington, DC: Author. Retrieved from http://completecollege.org/docs/CCA-Remediation-final.pdf

Cullinane, J., & Treisman, P. U. (2010). *Improving developmental mathematics education in community colleges: A prospectus and early progress report on the Statway initiative.* An NCPR Working Paper. National Center for Postsecondary Research.

Desimone, L. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199. doi:10.3102/0013189x08331140

Dweck, C. S. (2006). *Mindset: The new psychology of success*. New York: Random House.

Ericcson, K. A. (2008). Deliberate practice and acquisition of expert performance; A general overview. *Academic Emergency Medicine,15,* 988-994.

Esmonde, I., & Langer-Osuna, J. M. (2013). Power in numbers: Student participation in mathematical discussions in heterogeneous spaces. *Journal for Research in Mathematics Education, 44*(1), 288-315.

Fishman, B., Marx, R., Best, S., & Tal, R. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19(*6), 643-658. doi:10.1016/s0742-051x(03)00059-3

GAISE College Report ASA Revision Committee. (2016). *Guidelines for Assessment and Instruction in Statistics Education College Report.* Retrieved from http://www.amstat.org/education/gaise.

Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What Makes Professional Development Effective? Results From a National Sample of Teachers. *American Educational Research Journal, 38*(4), 915-945. doi:10.3102/00028312038004915

Gillman, R. (Ed.) (2006). *Current Practices in Quantitative Literacy, MAA Notes #70.* Washington, DC: Mathematical Association of America.

Gomez, K., Gomez, L. M., Rodela, K. C., Horton, E. S., Cunningham, J., & Ambrocio, R. (2015). Embedding language support in developmental mathematics lessons: Exploring the value of design as professional development for community college mathematics instructors. *Journal of Teacher Education, 66,* 450-465. doi: 10.1177/ 0022487115602127.

Gomez, K., Rodela, K., Lozano, M., & Mancevice, N. (2013). Designing embedded language and literacy supports for developmental mathematics teaching and learning. *MathAMATYC Educator, 5*(1), 43-56.

Grubb, W. N., Badway, N., & Bell, D. (2003). Community Colleges and the Equity Agenda: The Potential of Noncredit Education. *The Annals of the American Academy of Political and Social Science, 586*(1), 218–240. https://doi.org/10.1177/0002716202250226

Grubb, W. N., & Gabriner, R. (2013). *Basic skills education in community colleges: Inside and outside of classrooms.* New York, NY: Routledge.

Grubb, W. N., Worthen, H., Byrd, B., Webb, E., Badway, N., Case, C., Goto, S., Villenueve, J. C. (1999). *Honored But Invisible: An Inside Look at Teaching in Community Colleges.* New York, NY: Routledge.

Guskey, T. (2000). *Evaluating professional development.* Thousand Oaks, Calif.: Corwin Press.

Guskey, T. (2002). Professional Development and Teacher Change. *Teachers And Teaching, 8*(3), 381-391. doi:10.1080/135406002100000512

Hawley, W. D., & Valli, L. (2007). Design principles for learner-centered professional development. *The keys to effective schools: Educational reform as continuous improvement, 2,* 117-137. Chicago.

Haynes, T. L., Perry, R. P., Stupnisky, R. H., & Daniels, L. M. (2009). A review of attributional retraining treatments: Fostering engagement and persistence in vulnerable college students. In J. C. Smart (Ed.), *Higher Education: Handbook of Theory and Research* (pp. 227–272). New York, NY: Springer.

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371–404). Charlotte, NC: Information Age.

Hoang, H., Huang, M., Sulcer, B., & Suleyman, Y. (2017). *Carnegie Math Pathways 2015- 2016 Impact Report: A Five-Year Review*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching.

Hodara, M. (2013). *Improving Students' College Math Readiness: A Review of the Evidence on Postsecondary Interventions and Reforms.* A CAPSEE Working Paper. Center for Analysis of Postsecondary Education and Employment. <http://files.eric.ed.gov/fulltext/ED544544.pdf>

Huber, M. (2008). *The promise of faculty inquiry for teaching and learning basic skills.* Stanford, CA: Strengthening Pre-Collegiate Education in Community Colleges.

Hunzicker, J. (2010). Effective professional development for teachers: a checklist. *Professional Development In Education, 37*(2), 177-179. doi:10.1080/19415257.2010.523955

Elmore, R. (1996) Getting to Scale with Good Educational Practice. *Harvard Educational Review, 66*(1), 1-27.

Jaggars, S., Hodara, M., Cho, S., & Xu, D. (2015) Three Accelerated Developmental Education Programs. *Community College Review, 43*(1), 3 - 26.

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology, 46,* 208-212.

LeMahieu, P.G., Edwards, A.R., & Gomez, L.M. (2015). At the nexus of improvement science and teaching: Introduction to a special section of the Journal of Teacher Education. *Journal of Teacher Education, 66*(5), 446-449.

LeMahieu, P.G., Roy, P.A., & Foss, A. (1995). *The characteristics of effective professional development.* Newark, DE: Delaware Education Research and Development Center. University of Delaware.

Madison, B. L., & Steen, L. A. (2007). Evolution of numeracy and the National Numeracy Network. *Numeracy, 1*(1), 2.

Martin L.A., Nelson E.C., Lloyd R.C., Nolan T.W. (2007). *Whole System Measures. IHI Innovation Series white paper.* Cambridge, MA: Institute for Healthcare Improvement.

Mesa, V. (2011). Similarities and differences in classroom interaction between remedial and college mathematics courses in a community college. *Journal on Excellence in College Teaching, 22*(4), 21-55.

Moschkovich, J. (2007). Examining mathematical discourse practices. *For the learning of mathematics, 27*(1), 24-30.

Pashler, H., Rohrer, D., Cepeda, N. J., & Carpenter, S. K. (2007). Enhancing learning and retarding forgetting: Choices and consequences. *Psychonomic Bulletin & Review, 14*(2), 187-193.

Russell, J. L., Bryk, A. S., Dolle, J., Gomez, L. M., LeMahieu, P. & Grunow, A. (2017). A framework for initiation of Networked Improvement Communities. *Teachers College Record, 119(*7).

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*(4), 207-217.

Supovitz, J., Mayer, D., & Kahle, J. (2000). Promoting inquiry-based instructional practice: The longitudinal impact of professional development in the context of systemic reform. *Educational Policy, 14*(3), 331-356. doi:10.1177/0895904800014003001

Tinberg, H., Duffy, D. K., & Mino, J. (2007). The scholarship of teaching and learning at the two-year college: Promise and peril. *Change: The Magazine of Higher Learning, 39*(4), 26-33.

Twombly, S., & Townsend, B. K. (2008). Community college faculty: What we know and need to know. *Community College Review, 36*(1), 5–24.

Walton, G. M., & Cohen, G. L. (2011). A brief social-belonging intervention improves academic and health outcomes of minority students. *Science, 331*(6023), 1447-1451.

Webb, N. M. (2009). The teacher's role in promoting collaborative dialogue in the classroom. *British Journal of Educational Psychology, 79*(1), 1-28.

Zeidenberg, M., & Scott, M. (2011). *The Context of Their Coursework: Understanding Course-Taking Patterns at Community Colleges by Clustering Student Transcripts. CCRC Working Paper No. 35.* New York, NY: Community College Research Center.