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Prime Online: Exploring Teacher Professional Development for Creating Inclusive Elementary Mathematics Classrooms

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Abstract

Enhancing all students' academic performance continues to be a national priority, and although achievement gains have been made overtime, shortfalls in mathematics learning for students with disabilities (SWD) remain. Research reveals that a substantial portion of the variability in students' mathematics achievement gains is due to the teacher. To address the need for teacher professional development (PD) in mathematics for SWD and other struggling mathematics learners, we designed and studied *Prime Online*—a yearlong, online, PD program with support from an Institute of Education Sciences (IES) Goal 2 Development and Innovation research grant. In this article, the development process and an exploratory study are discussed. Study findings suggest that *Prime Online* positively influenced general and special education teachers' reported beliefs and practices, and their learning of mathematics content for teaching, and generated high teacher satisfaction ratings. No difference in the performance of SWD on a state accountability measure of mathematics was found. Implications for further research are discussed.

Keywords

inclusive mathematics classrooms, teacher professional development

Although enhancing the academic performance of all students continues to be a national priority and achievement gains have been made overtime, data from the National Assessment of Educational Progress (NAEP; National Center for Education Statistics [NCES], 1992-2015) reveal shortfalls in mathematics learning for students with disabilities (SWD). Sizable differences persist in mathematics performance between students with and without disabilities. While 14% of fourth-grade students without identified disabilities fell below the *Basic* achievement level on the NAEP, 45% of SWD did not reach this minimum criterion. For eighth graders, the difference was even greater. More than two thirds (68%) of SWD scored below *Basic* compared with 24% of students without disabilities. Regardless of disability category, SWD attain low levels of mathematics achievement and typically have limited exposure to advanced mathematics (Bryant, Bryant, & Hammill, 2000; Wei, Lenz, & Blackorby, 2013). These deficiencies in access and achievement in mathematics education require

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thoughtful attention if attaining widespread mathematical preparedness for work and post-secondary education is to become a reality.

Convincing research evidence suggests that a substantial portion of the variability in students' mathematics achievement gains is due to the teacher (National Mathematics Advisory Panel [NMAP], 2008). Unfortunately, little is known from existing high-quality research reviewed by the NMAP for suggesting ways to promote teachers' effectiveness in mathematics teaching, or for identifying observable teacher characteristics that may account for the impact. Nevertheless, a positive relationship has been established between teachers' mathematics content knowledge for teaching and student achievement (Hill, Rowan, & Ball, 2005). As the NMAP panelists offer, "It is self-evident that teachers cannot teach what they do not know" (p. xxi). To address this problem, the panelists recommended that ". . . a sharp focus be placed on . . . ongoing professional development for teachers of mathematics at every level, with special emphasis on ways to ensure appropriate content knowledge for teaching" (p. 40).

In addition to the importance of teachers' knowledge of mathematics content for teaching, research conducted over several decades reveals the importance of teachers' beliefs about mathematics teaching and learning and its influence on classroom practice (Ball & Bass, 2004; Beswick, 2005, 2012; Cobb, Wood, & Yackel, 1990; Cohen, 1990), and ultimately, on student learning (Love & Kruger, 2005; Staub & Stern, 2002). Because teachers are thought to learn through existing belief systems, their beliefs can also be resistant to change (Cohen & Ball, 1990; Pajares, 1992), even after participation in teacher professional development (PD) programs (Garet, Porter, Desimone, Birman, & Yoon, 2001). Consequently, researchers are encouraged to evaluate both beliefs and practices in studies of teacher PD in mathematics, given the consistent associations between beliefs and practices (Stipek, Givvin, Salmon, & MacGyvers, 2001), as well as the influence these variables may have on teacher and student learning.

In this article, we describe an Institute of Education Sciences (IES) Goal 2–funded research project in which an online approach to teacher PD in mathematics was designed and evaluated. IES Goal 2 projects typically involve an iterative methodological process and a fully developed theory of change (see the Introduction to this special issue for further details about Goal 2 projects). The following discussion focuses on the theory of change and research that guided our efforts.

Theoretical Framework

Researchers (e.g., Borko, 2004; Desimone, 2009; Scher & O'Reilly, 2009) offer a trajectory, or theoretical sequence, for how teacher PD may influence teacher, and ultimately student, outcomes. These models begin with effective features of PD found in the extant literature. Teacher participation in PD is then expected to influence teachers' knowledge and beliefs (immediate outcomes), leading to changes in teacher instruction (intermediate outcomes) and then resulting in improvements in student achievement (long-term outcomes; Scher & O'Reilly, 2009). Most researchers, however, agree, "there is no single empirically validated theory of teacher learning to inform [PD] models" (Borko, Koellner, Jacobs, & Seago, 2011, p. 175).

Five features of teacher PD are associated with changes in teacher knowledge and practice, and to some extent, student achievement (Desimone, 2009); these include content focus, active learning, coherence, duration, and collective participation. In teacher PD, *content focus* appears to be the most influential feature; however, when a PD intervention addresses teachers' subject matter content knowledge as well as their content teaching, and teachers learn how to assess their students' response to their teaching, a larger positive impact on student learning can occur (Scher & O'Reilly, 2009). *Active learning* may involve teachers in observing experts, participating in interactive feedback and discussions, and reviewing student work rather than listening to a lecture (Desimone, Porter, Garet, Yoon, & Birman, 2002). *Coherence* relates to the extent to which what is taught and the experiences provided are consistent with (a) teachers' existing beliefs, knowledge, attitudes, and their learning goals for themselves and for their students, as well as (b) national, state, district, and school-level standards, goals, and assessments for student learning (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). *Duration* is the time teachers spend in PD programs. While studies have examined PD programs of widely varying durations, those that include more than 100 hours of PD and are distributed over a year or more have the most consistent effects on student achievement (Blank & de las Alas, 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Finally, *collective participation* refers to teachers working together to affect teacher and student learning.

Beyond these five features, the mode of delivery of teacher PD is also an important consideration. Although research on the effectiveness of online teacher PD has not kept pace with the rapid increase in its development and use (Tallent-Rennels et al., 2006), there appears to be a clear ". . . need for professional development that is tailored to teachers' busy schedules, that draws on valuable resources not available locally, and that provides work-embedded support . . ." (Whitehouse, Breit, McCloskey, Ketelhut, & Dede, 2006, p. 13). Emerging research suggests that online instruction is at least as effective as traditional ways of providing PD, and could be even more effective than face-to-face approaches for enhancing learning and critical thinking skills (Sendag & Odabasi, 2009). Moreover, recent reform documents, such as the National Educational Technology Plan, advocate strongly for increasing the development and use of online teacher PD (U.S. Department of Education, 2016).

In response to calls for ongoing teacher PD in mathematics, we designed and studied the *Prime Online* teacher PD intervention with guidance from a theoretical model of mathematics teacher learning in PD and the extant literature base in this area with grant funding from the IES in the U.S. Department of Education. We evaluated teachers' Content Knowledge for Teaching–Mathematics (CKT-M), as well as their self-reported beliefs and practices. In addition, we studied teacher satisfaction because teachers' satisfaction with the PD they experience may influence their responses to it and help explain teacher outcomes (Guskey & Yoon, 2009; Reeves & Pedulla, 2011). Finally, we evaluated the impact of *Prime Online* on a mathematics achievement outcome with SWD.

Overview of the Goal 2 Project

The aim of our 3-year, IES-funded Goal 2 research project was to determine the feasibility and impact of the *Prime Online* PD intervention by conducting two design-based research studies (Design-Based Research Collective, 2003). Design studies take place "through continuous cycles of design, enactment, analysis, and redesign" (p. 5). The focus of design research is theory building to explain how, in this case, teachers learn *Prime Online* mathematics content and associated practices, and translate this learning into their classroom work as teachers (Gravenmeijer & Eerde, 2009). Ultimately, these two design studies, implemented within a Goal 2 project, can offer preliminary findings for supporting causal research in an IES Goal 3 efficacy study.

The first three authors (i.e., teacher educators in special education, elementary education, and mathematics education, respectively) led the development of the *Prime Online* PD intervention and some of the data collection instruments (i.e., teacher satisfaction surveys, teacher focus group and individual interview protocols, and teacher practices and beliefs surveys) during Phase 1. In Phase 2 of the project, we enacted Design Study 1 with 10, third- through fifth-grade general and special education teacher participants who taught in classrooms in which students with and without disabilities, and other struggling learners not identified with disabilities, were taught the general education mathematics curriculum and assessed annually within the statewide accountability system. Design Study 1 focused on documenting teachers' successes and challenges as they accessed, navigated, and learned from our initial version of *Prime Online*. The primary focus of this study was on the functioning and refinement of the PD intervention, and involved the 10 teachers in extended conversations with the project research team. Project faculty conducted individual interviews with teachers, and an external evaluator facilitated focus group interviews with teachers to ensure anonymous feedback to project faculty. The 10 teachers also completed the satisfaction survey, practices and beliefs surveys, and assessments of their CKT-M. In addition, project faculty recorded participants' online PD access and usage, and reviewed teachers' module application assignments, such as their online forum discussions and reports of *Prime Online* activities implemented in their classrooms.

A thorough review of results from Design Study 1 informed the revisions of the PD intervention. Following Design Study 1 in Phase 2, we implemented Design Study 2 in Phase 3 of the project. This second study involved 23 general and special education, third- through fifth-grade teachers and their students in a single group, pretest–posttest design study to assess the feasibility and the impact of *Prime Online*. This second study was designed to reveal the promise of the PD intervention for studying the effectiveness of the *Prime Online* teacher PD intervention program with a two-group, random selection, pretest–posttest efficacy study in the future. We now turn to a more detailed discussion of Design Study 2, including the teacher participants and their students, PD intervention, outcome measures used, and a discussion of the key findings from this study.

Teacher Participants and Their Students

Thirty-two general and special education elementary school teachers of mathematics (Grades 3-5) from 18 schools in 14 school districts in one southeastern state participated in this study. We recruited teachers or co-teachers who taught in classrooms in which students with and without disabilities, and other struggling mathematics learners not identified with disabilities, were taught the general education mathematics curriculum and assessed annually within the statewide accountability system. Nine of the original 32 teachers did not complete the yearlong program primarily due to personal reasons (e.g., illness, pregnancy) resulting in a final sample of 23 teachers.

In general, teachers who participated in the study were predominately White females with approximately half holding bachelor's, and the other half with master's, degrees (see Table 1). The mean number of years teaching was 11.7 (SD = 9.6) with more than 78% of the sample having 6 or more years of experience. Six teachers taught mathematics in special education classrooms, while the remaining 17 teachers taught in inclusive, general education classrooms. Finally, a majority of teacher participants reported prior online learning experiences.

Students

Teachers were the primary focus of the Goal 2 project; however, mathematics achievement data were collected on teachers' current and former SWD to assess the impact of *Prime Online* on student achievement. SWD taught by participating teachers in two different school years (i.e., 2011-2012 and 2012-2013), before and after teachers participated in *Prime Online*, contributed data to the study as these students were assessed annually within the statewide accountability system.

Prime Online PD Intervention

Prime Online is a completely online teacher PD program, including the following general features aligned with the extant literature (i.e., Desimone, 2009): (a) mathematics content (content focus); (b) how SWD learn mathematics content, how to enhance mathematics learning via strategy instruction, and how to assess student responsiveness to the mathematics instruction provided (content focus); (c) the Common Core State Standards–Mathematics (CCSS-M; National Governors Association Center for Best Practices, Council of

Table 1. Demographic Information on Teacher Participants.

Variable	Teacher participants	
	n	%
Gender		
Male	2	8.7
Female	21	91.3
Ethnicity		
Hispanic	2	8.7
White	21	91.3
Highest degree earned		
Bachelor's	11	47.8
Master's	12	52.2
Online course experience	20	87.0
Teaching experience		
Ranges (years)		
2-10	13	56.5
11-38	10	43.5
Teacher certification		
Only EE	12	52.2
Only SE	1	4.3
Dual certification in EE and SE	10	43.5
Teaching assignment		
General education classrooms		
Grade 3	1	4.4
Grade 4	9	39.1
Grade 5	6	26.1
Grades 4 and 5	1	4.4
Special education classrooms		
Grades K through 5	3	13.0
Grades 4 and/or 5	3	13.0

Note. EE = elementary education; SE = special education.

Chief State School Officers [NGACBP, CCSSO], 2010) and National Council of Teachers of Mathematics (NCTM; 2000) standards (coherence); (d) PD content integrated into teachers' classrooms through activities such as teacher inquiry projects (active learning); (e) problem-solving opportunities and online forum discussions (collective participation); and (f) implementation of the PD intervention over one calendar year (duration).

Prime Online was designed and delivered using an online learning software program (i.e., Moodle; Dougiamas, 1999). The PD intervention consists of 35 learning modules delivered from May through April with breaks corresponding with a teacher's school schedule (e.g., school breaks in the winter and spring). Each module includes a consistent format with four components: (a) Introduction, (b) Anticipatory Activity, (c) Content and Discussion, and (d) Classroom Connections. When teacher participants log into the online site, they first encounter the *Introduction* including an overview of the week's activities, goals, objectives, and references to materials needed to complete learning tasks. The next component, the *Anticipatory Activity*, was designed to help teachers reflect on and connect their prior experiences and knowledge to the new content they are about to learn. The *Content and Discussion* sections of the modules consist of readings, video recordings, web-quests, and other activities accompanied by prompts for fostering online forum discussions among teachers during the week. Finally, the *Classroom Connections* portion of each module contains an application assignment in which teachers apply what they learned during the week to their classroom practice. At the end of each module, a facilitator's (one of the first three authors) announcement is posted that includes a summary of teacher participants' products and discussions with suggestions for enhancing their learning. Three integrated content segments comprise *Prime Online*, as listed in Table 2. Figure 1 provides a screen shot of Module 5. A brief description of each segment follows.

Segment 1 of Prime Online

Teachers complete the first nine modules of *Prime Online* during the summer prior to the beginning of the school year. Segment 1 content and activities provide an overview of the three integrated topics within *Prime Online* (i.e., mathematics content, students with learning disabilities [LD] and other struggling mathematics learners, and teacher inquiry) with an emphasis on the nature of mathematics LD, evidence-based practices, and assessment and instructional decision making. Segment 1 ends with an introduction to the teacher inquiry cycle.

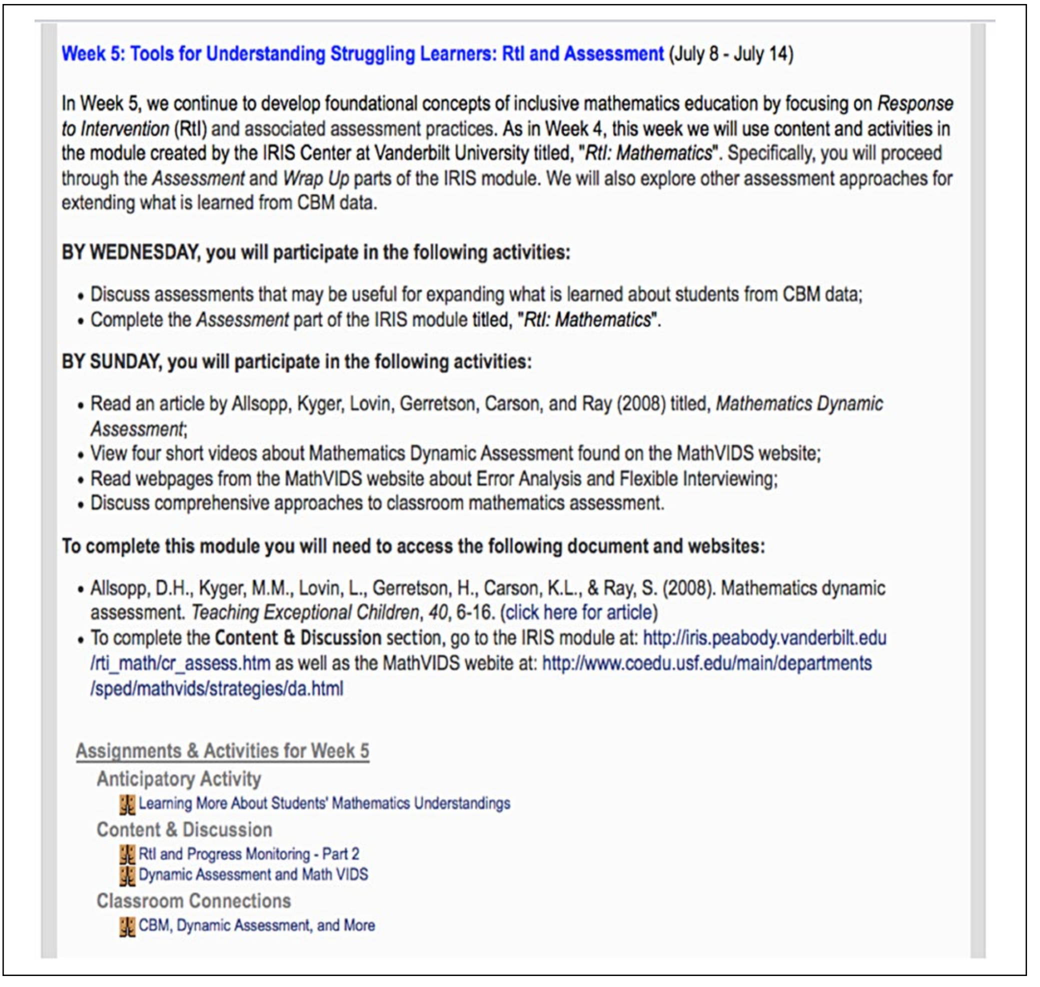
Table 2. *Prime Online* Professional Development Program Content by Segments and Modules.

Segment 1: Building a foundation for inclusive elementary mathematics education	
Module 1	Developing a vision for mathematics education
Module 2	Classroom practices that promote mathematical proficiency
Module 3	Characteristics of students with LD
Module 4	Tools for understanding struggling learners: RtI
Module 5	Tools for understanding struggling learners: RtI and assessment
Module 7	Creating inclusive mathematics classrooms: Differentiation
Module 6	Creating inclusive mathematics classrooms: Self-regulation
Module 8	Creating inclusive mathematics classrooms: Evidence-based practices
Module 9	The inquiry cycle
Segment 2: Deepening mathematics content and pedagogy	
Module 10	Number sense and building conceptual understanding of multiplication
Module 11	Building conceptual knowledge of multiplication
Module 12	Building conceptual knowledge of multiplication
Module 13	Building conceptual knowledge of division
Module 14	Using instructional strategies for teaching multiplication and division
Module 15	Fraction representation
Module 16	Fraction and decimal number representation
Module 17	Fractions and decimal numbers: Addition and subtraction
Module 18	Fractions and decimal numbers: Addition and subtraction
Module 19	Multiplication with fractions
Module 20	Multiplication with fractions and decimal numbers
Module 21	Division with fractions
Module 22	Division with fractions and decimal numbers
Segment 3: Studying the application of newly learned mathematics content and pedagogy to student learning	
Module 23	The start of your journey: Developing questions
Module 24	The start of your journey: Developing questions
Module 25	The road map: Developing the data collection plan
Module 26	Data collection, formative data analysis, and critical friends
Module 27	Data collection and reflecting on your inquiry journey (5-week module)
Module 32	Summative data analysis
Module 33	Summative data analysis
Module 34	Writing up your work
Module 35	Assessing the quality of teacher inquiry and sharing your work with others

Note. RtI = Response to Intervention; LD = learning disabilities.

Segment 1 includes the following content:

- An introduction to the Standards and Principles for School Mathematics put forth by the NCTM (2000) and NGACBP, CCSSO (2010)
- Five interrelated components for developing mathematically proficient students (Kilpatrick, Swafford, & Findell, 2001; Suh, 2007)
- Mathematics learning difficulties of students with LD (e.g., Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007)
- Foundations of curriculum-based measurement, instructional decision making, and other assessment practices (e.g., Allsopp et al., 2008; Fuchs, Hamlett, & Fuchs, 1999)
- Vanderbilt University IRIS Center modules on response to intervention (RtI) for mathematics (http://iris.peabody.vanderbilt.edu/module/rti-math/#content)



Week 5: Tools for Understanding Struggling Learners: RtI and Assessment (July 8 - July 14)

In Week 5, we continue to develop foundational concepts of inclusive mathematics education by focusing on *Response to Intervention* (RtI) and associated assessment practices. As in Week 4, this week we will use content and activities in the module created by the IRIS Center at Vanderbilt University titled, "*RtI: Mathematics*". Specifically, you will proceed through the *Assessment* and *Wrap Up* parts of the IRIS module. We will also explore other assessment approaches for extending what is learned from CBM data.

BY WEDNESDAY, you will participate in the following activities:

- Discuss assessments that may be useful for expanding what is learned about students from CBM data;
- Complete the *Assessment* part of the IRIS module titled, "*RtI: Mathematics*".

BY SUNDAY, you will participate in the following activities:

- Read an article by Allsopp, Kyger, Lovin, Gerretson, Carson, and Ray (2008) titled, *Mathematics Dynamic Assessment*;
- View four short videos about Mathematics Dynamic Assessment found on the MathVIDS website;
- Read webpages from the MathVIDS website about Error Analysis and Flexible Interviewing;
- Discuss comprehensive approaches to classroom mathematics assessment.

To complete this module you will need to access the following document and websites:

- Allsopp, D.H., Kyger, M.M., Lovin, L., Gerretson, H., Carson, K.L., & Ray, S. (2008). Mathematics dynamic assessment. *Teaching Exceptional Children*, *40*, 6-16. (click here for article)
- To complete the **Content & Discussion** section, go to the IRIS module at: http://iris.peabody.vanderbilt.edu /rti_math/cr_assess.htm as well as the MathVIDS webite at: http://www.coedu.usf.edu/main/departments /sped/mathvids/strategies/da.html

Assignments & Activities for Week 5

Anticipatory Activity

Learning More About Students' Mathematics Understandings

Content & Discussion

RtI and Progress Monitoring - Part 2

Dynamic Assessment and Math VIDS

Classroom Connections

CBM, Dynamic Assessment, and More

Figure 1. Screen Shot for Module 5 of *Prime Online*.

- Mathematics Dynamic Assessment supported by MathVIDS (Video Instructional Development Source; http://www.coedu.usf.edu/main/departments/sped/mathvids/strategies/da.html)
- Evidence-based mathematics practices for students with LD (e.g., Gersten et al., 2009; Jitendra, 2002; Steedly, Dragoo, Arafeh, & Luke, 2008; Woodward, 2006)
- Self-regulated learning (Wery & Nietfeld, 2010)
- An introduction to teacher research (Dana & Yendol-Hoppey, 2014; Beckett, McIntosh, Byrd, & McKinney, 2011; Cochran-Smith & Lytle, 2009)

Segment 2 of Prime Online

Teachers complete the next 13 modules during the first half of the school year. In Segment 2, teachers engage in activities to further develop their understanding of mathematics content typically taught in Grades 3 through 5. Specifically, mathematics topics include (a) number sense and building conceptual understanding of multiplication and division, (b) differentiated mathematics instruction for multiplication and division, (c) fraction and decimal number representation, and (d) addition, subtraction, multiplication, and division of fractions and decimal numbers. In Segment 2, teachers are also provided opportunities to connect their newly developed knowledge to their own classroom instructional practices. This connection is made in part through their engagement in several brief and highly structured teacher research cycles (or "mini-inquiry cycles") designed to help teachers uncover and address the instructional needs of students with LD and other struggling learners in their classrooms. In Segment 2, mathematics content is taught at the adult learner level integrating the instructional principles and teaching strategies described in Segment 1 above. After *Prime Online* teachers thoroughly process each mathematics topic through activities and discussion forums, for example, they consider the mathematics content and pedagogy learned in the topic-specific modules in relation to their own classroom practice problems. They formalize their problems of practice by creating research questions. These questions focus on a mathematics topic area (e.g., addition of fractions) and the unique needs of SWD and other struggling learners.

Segment 2 includes the following content:

- Number sense and building conceptual understanding of multiplication (Caliandro, 2000)
- Building conceptual understanding of division (DeGroot & Whalen, 2006)
- Differentiated mathematics instruction of multiplication and division fluency in a fourth-grade classroom (http://msml.florida-rti.org/)
- Fraction and decimal number representation (Barlow & Harmon, 2012; Fennell & Rowan, 2001; Siegler et al., 2010)
- Fractions and decimal numbers: addition and subtraction (Cramer, Monson, Wyberg, Leavitt, & Whitney, 2009; Mack, 2004; Ploger & Rooney, 2005; Siegler et al., 2010)
- Multiplication of fractions (Philipp & Vincent, 2003; http://www.sci.sdsu.edu/CRMSE/IMAP/pubs/Reflections_on_Fractions.pdf)
- Division with fractions and decimal numbers (Flores, Turner, & Bachman, 2005; Gersten et al., 2009; Siegler et al., 2010; http://illuminations.nctm.org/ActivityDetail.aspx?ID=80; see Pape et al., 2015, for further details).

Segment 3 of Prime Online

Teachers complete the final 13 modules of *Prime Online* during the second half of the school year. In Segment 3, teachers focus on the teacher inquiry process, attending to each step in the research cycle (i.e., developing a research question, collecting data, analyzing data, taking action, and sharing results with others). As teachers read about the process during the first four modules, they also start designing a personal research plan to study mathematics curriculum and instruction for their SWD and other struggling learners. Next, teachers share their students' progress with data collected from the Monitoring Basic Skills Progress (MBSP) measures (Fuchs et al., 1999) and other data sources. They also share their formative data analyses in small (3-4 teachers) online discussion forums by posting each week and responding to each other's posts. After 5 weeks of data collection, teachers read more about data analysis, continue to collect data, and begin applying the analysis process to their own data sets. In the final modules of Segment 3, teachers write summaries of their classroom-based research projects and prepare PowerPoint presentations given during the culminating experience in *Prime Online* (i.e., a synchronous online professional meeting). Teachers give their own PowerPoint presentations while fielding questions, and also participate in another session as an audience member.

Segment 3 includes the following content:

- Developing research questions or "wonderings" (*Revisiting* Beckett et al., 2011; Dana & Yendol-Hoppey, 2014)
- Developing a data collection plan
- Starting data collection and formative data analysis
- Use of "critical friends" during data collection and analysis
- Summative data analysis
- Writing up your work

- Assessing the quality of teacher research and sharing your work with others (see Dana, Pape, Griffin, & Prosser, 2017, for further details)

We now turn to a discussion about all measures used in Design Study 2 as well as a description of how we assessed program integrity as the *Prime Online* PD intervention was implemented.

Measures and Data Collection

Program Integrity

We addressed aspects of program integrity (Harn, Parisi, & Stoolmiller, 2013), including the quality of program delivery and teacher participation in *Prime Online*. Regarding quality of delivery, the Office of Distance Education in the College of Education provided technology support within 24 hours of receiving a teacher-generated online request to address hardware, software, Internet, video, and/or audio difficulties. To alleviate many of these problems, teachers satisfied specific hardware and software requirements to participate in *Prime Online*. For other program-related questions and support requests, project faculty and graduate research assistants were also committed to responding within the 24-hour time frame.

To evaluate teacher participation in the program, we collected data generated within the online learning software program. Moodle generates logs of information regarding users' access and usage of the instructional material, with each record in the log containing a timestamp for each activity accessed, and their actions (e.g., view, add, update, delete, upload). We collected data from this source to monitor teachers' participation in *Prime Online*. Specifically, teachers' participation was defined by their completion of module activities (e.g., application assignments, discussion forums) for all 35 modules over the yearlong program.

Data Collection

All teacher measures used in Design Study 2 were administered online either as a link within the online PD program shell or as an external link via *LimeSurvey* (www.limesurvey.org) sent to teachers' email addresses. Teachers completed measures within a specified time frame typically spanning 2 weeks. A project methodologist and a graduate assistant managed the administration of these measures. Scoring of all measures was automated within Moodle or *LimeSurvey*. The student measure used in Design Study 2 was the mathematics subtest from the Florida Comprehensive Assessment Test® (FCAT 2.0) administered at the time as part of the statewide student assessment program. FCAT 2.0 data were collected from district-level administrators and teachers. Descriptions of the teacher and student measures follow.

Prime Online *Beliefs Survey*

The 23-item *Prime Online* Beliefs Survey was used to evaluate teachers' reported beliefs about (a) mathematics teaching, (b) teaching SWD, and, (c) teacher inquiry. Responses were scored 1 to 5 using the following response scale: (1) *strongly disagree*, (2) *disagree*, (3) *neither agree nor disagree*, (4) *agree*, and (5) *strongly agree.*

Prime Online *Practices Survey*

We first conducted a pilot study with 28 elementary school–level teacher volunteers not involved in the study, 13 of the 28 teachers taught third-, fourth-, and fifth-grade students. Results of these field tests revealed internal consistency coefficients for all teachers at .945, and at .963 for the smaller group of third- to fifth-grade teachers. Individual items were revised using results from item-level analyses. The revised version of the 30-item *Prime Online* Practices Survey was used in Design Study 2 to evaluate teachers' reported frequency of instructional practices related to (a) mathematics teaching, (b) teaching SWD, and (c) teacher inquiry. Responses were scored 1 to 5 using the following response scale: (1) *never*, (2) *once a month*, (3) *once a week*, (4) *more than once a week*, and (5) *all or almost all lessons.* Both the *Prime Online* Beliefs and Practices measures are available from the first author upon request.

CKT-M. The CKT-M measures were developed as part of the Learning Mathematics for Teaching (LMT) project at the University of Michigan (Ball & Rowan, 2004; Hill, Ball, Blunk, Goffney, & Rowan, 2007). In this study, we used two subtests of the elementary (K-5) *Number Concepts and Operations* CKT-M measures: (a) Knowledge of Content (CK) and (b) Knowledge of Students and Content (KS). According to the authors, the CK subtest focuses on both the knowledge mathematicians possess and the specific mathematics content knowledge teachers need to know. The KS subtest combines knowledge of how students think about, learn, and understand mathematics with teachers' knowledge of the specific mathematics content taught in Grades K-5 (e.g., Hill, Ball, & Schilling, 2008). These two subtests were chosen as they aligned best with the content of *Prime Online* and had adequate reliabilities (coefficient alphas = .72-.80) and validity (Hill, 2006) as well as three equated forms. Teachers were assessed 3 times using the CKT-M subtests—before (pretest), during (midtest), and after (posttest) the intervention. The number of items on each of the six measures used in this study ranged from 18 to 26.

Prime Online Satisfaction Survey. The *Prime Online* Satisfaction Survey assessed teachers' satisfaction with the quality of the content and instruction of *Prime Online* as well as the ease with which they were able to access and use the online PD modules. Three slightly different versions of the Satisfaction Survey were developed to represent the content of each segment. Specifically, the survey administered after teachers completed Segment 1 addressed the content (24 items) and pedagogy (18 items) of *Prime Online* Segment 1, as well as nine items focused on the technology support provided. Only the content and pedagogy items changed in subsequent versions of the survey administered after teachers completed Segments 2 and 3 (i.e., 26 content items and 21 pedagogy items for Segment 2; 22 content and 15 pedagogy items for Segment 3). In addition, three items permitted an overall assessment of satisfaction with the PD program, and were included at the end of all three versions of the Satisfaction Survey. Responses were scored 1 to 4 using the following response scale: (1) *strongly disagree*, (2) *disagree*, (3) *agree*, and (4) *strongly agree*.

FCAT 2.0. The FCAT 2.0, a measure associated with the student assessment and accountability programs of the Florida Department of Education, served as the student measure in this study. FCAT assessments measure students' mathematics achievement and other content areas in Grades 3 to 10, and were aligned with the *Florida Sunshine State Standards*. FCAT mathematics tests provide mean scale scores, developmental scale scores (DSS; 100-500), and subscores in five mathematics topics: number sense, concepts, and operations; measurement; geometry and spatial sense; algebraic thinking; and data analysis and probability. FCAT-generated DSS are intended to measure growth and expected to increase as grade levels in school increase. The FCAT has reliabilities similar to those of other standardized and statewide tests (Florida Department of Education, 2007).

Florida students in Grades 3 to 10 take the FCAT mathematics test each year. We used FCAT 2.0 data to assess whether the mathematics achievement of SWD taught by teachers who received the *Prime Online* PD program was different from SWD taught by the same teachers in the previous year (i.e., before they participated in *Prime Online*). To that end, we collected FCAT scores from the 2013 administration for SWD taught by teachers who had received *Prime Online* and also scores from the 2012 administration to construct a comparison group of SWD.

Data Analysis

Analyses were conducted on each teacher's individual scores on the four measures (i.e., *Prime Online* Beliefs Survey, *Prime Online* Practices Survey, CKT-M subtests, *Prime Online* Satisfaction Survey) and each student's DSS score on the FCAT. Data collected

Table 3. Teacher Performance by Time and Measure.

Measures	*n*	*M*	*SD*	α	Estimate (*SE*)	*Z* (*p*)
Beliefs Survey						
Pretest	21	3.93	0.26	.60		
Posttest	21	4.08	0.37	.87		
Practices Survey						
Pretest	21	3.78	0.71	.95		
Posttest	21	4.21	0.40	.95		
CKT-M (CK)						
Pretest	23	−0.03	0.69	.67		
Midtest	20	0.21	0.67	.57		
Posttest	23	0.47	1.07	.81		
Initial status					−0.03 (0.14)	−0.21 (.84)
Growth					0.25 (0.07)	3.32 (.00)
CKT-M (KS)						
Pretest	23	0.04	0.71	.54		
Midtest	22	0.45	0.90	.69		
Posttest	23	0.02	0.51	.56		
Initial status					0.04 (0.15)	0.25 (.80)
Linear					0.82 (0.31)	2.63 (.01)
Quadratic					−0.41 (0.15)	2.97 (.00)

Note. *N* = participants contributing data on the Beliefs Survey, Practices Survey, and CKT-M measures. CKT-M (CK) = Content Knowledge for Teaching–Mathematics (Knowledge of Content); CKT-M (KS) = Content Knowledge for Teaching–Mathematics (Knowledge of Students).

from the Teachers' Beliefs and Practices Surveys at pretest and posttest were compared using dependent-samples *t* tests. Latent growth curve models were used to test for significant change on the CKT-M subtests, and a multilevel model was used for comparing students' FCAT scores. For pretest to posttest change effects, we calculated effect sizes (Cohen's *d*) to estimate the practical significance of the effects.

Key Findings

Program Integrity

Teachers' participation in *Prime Online* was generated for each of the three content segments in the program. Teachers completed 94% of the 28 activities (M = 26.26, SD = 2.93) included in the nine Segment One modules. For Segment 2, teachers completed 89% of the 43 activities included in the 13 modules (M = 38.17, SD = 6.71), and 89% of the 40 activities included in the 13 modules in Segment 3 (M = 35.70, SD = 5.16). Results for participation during the yearlong PD program revealed 90% (M = 100.13, SD = 13.50) across the 111 activities.

Teacher Beliefs

Descriptive statistics for the *Prime Online* Teacher Beliefs Survey are presented in Table 3. A frequently cited standard for acceptable reliability coefficients is .70 (Nunnally, 1978), revealing low alpha levels for the Beliefs pretest and several of the CKT subscales; however, the principal concern about lower reliability when means are to be compared is that power would be insufficient due to measurement error. In light of the results, low power was not a serious issue. Comparison of pretest and posttest means on the Beliefs survey indicated that the difference between means was significant using an upper tailed dependent-samples *t* test at the conventional .05 alpha level, $t(20) = 1.82$, $p = .042$, $d = .47$, where d is Cohen's effect size.

Teacher Practices

Table 3 also reveals results from the *Prime Online* Teacher Practices Survey, indicating that (a) internal consistency reliability was excellent for this sample and (b) a positive change in teachers' self-reported use of practices occurred. The difference between the pretest and posttest means are significantly different, $t(20) = 2.56$, $p = .038$, $d = .75$.

Teachers' CKT-M

Descriptive statistics for the CKT-M measures are provided in Table 3 for the two subtests (i.e., CK and KS). By Nunnally's criterion, coefficient alpha was low for both subtests and on most occasions. Nevertheless, significant differences among means emerged for both subtests. As reported elsewhere (Griffin et al., 2014; Pape et al., 2015), latent growth curve modeling was used to test for significant changes across administrations of the CKT-M subtests. As indicated in Table 3, the growth in CK means was approximately linear across the three occasions. Therefore, a linear growth curve model was used to analyze the three CK scores with occasions coded 0, 1, and 2. The nonsignificant Z test suggests that the estimated average initial status on the CK of −0.03 at pretest was not significantly different from 0 (i.e., the approximate mean for the test equating sample provided by the LMT; Hill, 2006; Phelps, 2004). The 0.25 growth estimate on the CK subtest indicates significant linear growth over the yearlong PD program.

The means for the KS subtest increased from pretest to midtest, and then declined. Therefore, a quadratic model was used to analyze the KS scores. The occasions were coded 0, 1, and 2. These results are presented in Table 3. The estimated average initial status for the KS score of 0.04 at pretest was not significantly different from 0. The linear estimate was positive and significant indicating a statistically significant increase from pretest to midtest on the KS subtest. The significant quadratic estimate indicated that change in the means was not linear, and reflects the fact that the mean KS score increased from pretest to midtest but then declined at posttest.

Table 4. Descriptive Statistics for FCAT DSS Mathematics Scores for SWD by Grade and Year.

	School years					
	Year before teachers participated in *Prime Online*			Year after teachers participated in *Prime Online*		
Grades	*n*	*M*	*SD*	*N*	*M*	*SD*
3	7	169.6	13.6	3	208.0	33.0
4	94	204.4	15.7	70	206.1	18.9
5	64	216.7	18.7	74	211.2	21.4

Note. FCAT = Florida Comprehensive Achievement Test; DSS = developmental scale scores.

Teacher Satisfaction

The *Prime Online* Satisfaction Survey was administered 3 times over the course of the yearlong PD program, after teachers completed each of the three content segments. Combined results for all items on each segment assessment are provided as follows: Segment 1 ($M = 3.41$; $SD = 0.90$); Segment 2 ($M = 3.41$; $SD = 1.01$); and Segment 3 ($M = 3.45$; $SD = 0.59$). These results suggest consistent and high levels of teacher satisfaction with the *Prime Online* PD program (range = 2.83-3.71 on a 4-point scale, with 4 as the highest rating).

Mathematics Achievement of SWD

Data for SWD taught by only 14 participating teachers were included in the sample due to unanticipated difficulties collecting FCAT 2.0 data. We analyzed DSS scores to compare mathematics achievement of SWD taught by participating teachers from the 2012 and 2013 FCAT administrations. The number of SWD with DSS scores included in the analysis was 165 in 2012 and 147 in 2013.

Table 4 provides descriptive statistics for DSS scores by grade and year. Inferential data analysis was conducted by using a multilevel model including a teacher and a Teacher Year random effect and grade, year, and Grade

Year fixed effects. To take into account the unequal sample sizes across grades, the estimate of the treatment effect was a weighted average of the effects defined at Grades 3 to 5, where the weights were the inverse of the sampling variances of the grade-specific effects. Comparing means within a grade indicates that for the grades with more than 10 students in a particular year, mathematics achievement was not consistently higher or lower in the year after teachers participated in *Prime Online* than in the year before teachers participated in *Prime Online*. The estimated treatment effect was −1.06 and was not significantly different from 0, $t(9) = -.037$, $p = .72$, $d = -.05$.

Discussion

Prime Online was designed by combining features of teacher PD informed by theory and the extant literature base. We hypothesized that the PD intervention would positively influence teachers' reported practices and beliefs, their CKT-M, and their satisfaction with the program. Encouraging results were achieved on all teacher measures. For students, we anticipated improvements in achievement but did not find a difference between groups on the state accountability measure. Findings from Design Study 2, however, must be viewed as preliminary due to the exploratory, rather than confirmatory, nature of IES Goal 2 projects. Results of the current study suggest the promise and feasibility of *Prime Online*, and a starting point for further research. A discussion of findings and implications for further research are provided.

We begin with teacher beliefs and knowledge of mathematics for teaching, as changes in beliefs and knowledge are presumed prerequisites for affecting teacher practices (e.g., Beswick, 2012). Findings from the current study revealed positive changes from pretest to posttest on the *Prime Online* Beliefs Survey, suggesting that participation in *Prime Online* over the yearlong intervention altered teachers' beliefs (effect size = 0.47). Effect sizes of 0.25 or larger are considered "substantially important" (What Works Clearinghouse [WWC], 2017, p. 77). This shift in beliefs was accomplished despite research suggesting that teachers' existing beliefs are difficult for PD programs to overcome (Garet et al., 2001). Given the relatively high mean rating at pretest, we presume that teachers entered *Prime Online* with beliefs about teaching and learning that closely aligned with those communicated in the PD program. As discussed earlier, addressing program *coherence* and designing PD that is consistent with teachers' beliefs and professional goals are more likely to affect their outcomes (Desimone, 2009; Garet et al., 2001). We conjecture that achieving program coherence at the beginning allowed teachers to use their existing "interpretive frames" (Penuel et al., 2007, p. 931) to facilitate closer alignment of their own views with those of the program and to ultimately enhance their content learning (Hochberg & Desimone, 2010). In addition, *Prime Online* included "Classroom Connections" assignments throughout the PD program to encourage teachers to practice using the new strategies they learned in their classrooms with struggling mathematics learners and discuss these experiences with their teacher colleagues within online forums. When teachers are able to reflect upon and monitor their students' responses to their teaching, as in *Prime Online*, teachers' beliefs can be altered (e.g., Cohen & Ball, 1990).

As beliefs and knowledge are closely linked and contribute to teachers' conceptual frameworks about teaching and learning, we also evaluated teachers' mathematics knowledge for teaching using the CKT-M measures. Results revealed that for the CK subtest of the CKT-M, *Prime Online* positively affected participating teachers' general understanding of mathematics content for teaching elementary students from pretest to midtest and also from midtest to posttest. On the KS subtest, a significant increase occurred from pretest to midtest but declined from midtest to posttest. This decrease in performance from midtest to posttest was surprising because the final segment of *Prime Online* allowed teachers to apply their knowledge of mathematics teaching and student learning to the development and implementation of their teacher inquiry projects. Within this portion of the PD, teachers focused exclusively on their students' mathematics learning by evaluating student errors, misconceptions, and their approaches to teaching mathematics content associated with the KS subtest. Although several extraneous variables may have influenced this result, we speculate that teacher motivation and fatigue may have influenced the outcome. The final administration of the CKT-M subtests occurred at the end of the yearlong PD program and near the end of the school year (i.e., May). In addition, if teachers took the subtests in the order in which the links were presented in *Prime Online*, they would have completed the KS posttest last, after the CK measure. Taken together, these circumstances may have influenced the effort teachers expended on the final subtest as they managed the demands of the PD program and their school duties at the end of the year.

Despite the decline on the final KS subtest, overall findings are encouraging. We attribute *Prime Online's* mathematics *content focus* to teachers' improvement on the CKT-M measures. Evidence continues to accumulate in support of teacher PD that includes a specific content focus, content specific teaching practices, and the development of teachers' understandings of students' content learning for strengthening teachers' knowledge and practice (Desimone, 2009; Garet et al., 2001). The PD design feature of *collective participation* may also explain these improvements. *Prime Online* teachers engaged in online forum discussions and online problem-solving activities with each other throughout the year and also shared findings from their inquiry projects at the end-of-the-year online professional learning conference. By participating in a collaborative PD experience, teachers had many opportunities to share what they were learning with each other, thereby creating opportunities for enhancing their understanding of the new content (Garet et al., 2001).

Once teachers' knowledge and beliefs are affected, the influence of PD turns to the intermediate outcome of changes in practice. In the current study, teachers' reported knowledge and use of teaching principles and strategies emphasized in *Prime Online* improved on the Practices Survey from pretest to posttest. Specifically, teachers reported using the following practices more frequently and/or intensely after participating in *Prime Online*: flexible interviewing, visual and manipulative representations, differentiated instruction, data to assess students' learning needs, strategies to motivate students, and strategies appropriate for student learning at varying achievement levels. In addition, teachers reported teaching students to understand mathematics conceptually instead of focusing on procedural knowledge only, exploring students' correct and incorrect answers to problems by asking students to justify their responses, and providing opportunities for students to talk and learn from one another. Observing positive results in their students' learning can produce important changes in teachers' learning and practice (Guskey & Yoon, 2009). The apparent alignment of *Prime Online* with teachers' beliefs could have also contributed to significant changes in teachers' reported practices as these teachers may have perceived the PD intervention as consistent with their own goals and were thus committed to adopting the *Prime Online* practices rather than resisting them (Penuel et al., 2007).

Results from our satisfaction surveys also reveal that teachers appreciated the adaptability and applicability of *Prime Online*. Findings indicated consistently high mean ratings across three administrations of the survey, suggesting that teachers were satisfied with the content, pedagogy, and online technical aspects of the PD overtime. The highest ratings were for items pertaining to opportunities for *Prime Online* teachers to adapt and apply what they were learning to their own classroom teaching and to engage in online discussions with their *Prime Online* colleagues. Consistent with prior research on online PD, "ease of content transferability" is a critical variable contributing to teacher satisfaction (Reeves & Pedulla, 2011, p. 602). Reeves and Pedulla's study also supported our finding that teachers appreciate learning with their peers in online discussion forums. *Prime*

Online teachers were based in communities and schools across the state (i.e., 23 teachers from 18 different schools), and appeared to appreciate and benefit from communicating with other professionals about *Prime* content and activities as they implemented the practices with their students in their particular classrooms and schools.

With changes in beliefs, knowledge, and practice, Scher and O'Reilly's (2009) theoretical sequence suggests that teachers have changed in ways conducive to affecting the long-term outcome of improving student achievement; however, results of comparisons of the FCAT scores were not significantly higher or lower for SWD taught by participating teachers across 2 school years. That is, students taught by these teachers after they received *Prime Online* compared with earlier groups of students taught by participating teachers before they received *Prime Online* did not differ in their performance on the state accountability measure. Although we theorized that student achievement would increase after teachers received *Prime Online*, we were also aware of the difficulties associated with affecting a standardized, or distal, measure of achievement, rather than one more proximal to the intervention (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). Distal measures assess national standards, and tend to focus on particular domains or mathematical topics. Moreover, treatment effects have been found to diminish as the difference between the assessment content and the nature of the curriculum or intervention used increases (Ruiz-Primo et al., 2002). *Prime Online* emphasized multiplication and division of whole numbers and fractions, and excluded other topics that appear on the FCAT (e.g., geometry, measurement, algebra). To more appropriately evaluate *Prime Online* and its impact on students, both distal measures, such as the FCAT, and measures more closely aligned with the content of *Prime Online* should be used in future studies.

The timing of the FCAT was also less than ideal. Teachers in this study completed *Prime Online* in May, but their students took the FCAT 1 month earlier as required by the state. Although teachers had completed most of the PD content by the time their students were tested, teachers may have benefited from more time to practice implementing what they learned to affect student achievement. Assessing student achievement near the end of *Prime Online* (as in this study) and also following teacher participants into the next year to gather their current students' scores might reveal a more positive outcome for the PD, after teachers had additional time to implement what they learned with their students.

As noted earlier, Goal 2 studies are exploratory, intending to offer preliminary findings for supporting future causal research. Findings from the current study offer important insights for researchers pursuing similar research. First, the intervention, *Prime Online*, was designed using research-based features of teacher PD, and focused on mediating outcomes (teacher knowledge, beliefs, and practices) for understanding the process by which PD programs might affect student learning. We recommend that future studies incorporate proximal student measures closely aligned with the PD mathematics content taught to teachers. In addition to the assessment of students' mathematics learning, measures of actual teacher performance (e.g., video-recorded classroom observations) will be important to include in future studies to determine teachers' authentic rather than self-reported practices. Future experimental and quasi-experiential studies will require a comparison condition, or control group, and random assignment of participants to conditions. Pending additional research findings, this study and the research base supporting it, endorse PD programs that complement teachers' beliefs, professional goals, and include national, state, and/or district standards. Teacher PD with a content focus, classroom applications, and opportunities for teachers to interact with and learn from each other in online contexts are also supported.

Authors' Note

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