Investigating the Effectiveness of an Intensive Professional Development Program in Math Education

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Abstract

The present study was conducted to examine the effectiveness of a yearlong, content-based professional development (PD) program on teachers' teaching efficacy and student achievement in math. Participants were 22 K-3 elementary school teachers in a high-need school district. A mixed-methods approach was employed to collect and analyze both quantitative and qualitative data focused on teachers' teaching efficacy beliefs and student performance on standardized tests prior to and after the implementation of this PD program. The results indicated that the PD program had positive impacts on teachers' confidence in teaching math to young learners and their pedagogical content knowledge in math, which resulted in positive impacts on student learning and performance on the standardized tests.

Key Words: Professional development, teacher education, teaching efficacy beliefs, math education

1. Introduction

While most teachers in high-need school districts are committed to promoting the critical thinking and problem-solving skills required by the Common Core State Standards for Mathematics (CCSS-M), many need additional high-quality professional development (PD) in order to achieve this goal. To address this urgent need, we designed and implemented a yearlong, intensive professional development program for 22 K-3 elementary school teachers in a high-need school district. This article reports our findings regarding the effectiveness of the program, using measures of participants' teaching efficacy beliefs as well as their students' achievement on mathematics standardized tests to determine whether the program contributed to improved efficacy in mathematics instruction.

Despite the growing number of teachers who endorse the Common Core State Standards for Mathematics (CCSS-M), many are not adequately prepared with the knowledge or practical experience necessary to develop advanced curricula and to promote critical thinking and problem-solving skills among their students as required by the CCSS-M (Bay-Williams, Duffett, & Griffith, 2016).Teachers need opportunities to learn new teaching strategies and practices distinct from the traditional rote, fact-based instruction (Gulamhussein, 2013). Nevertheless, mounting evidence suggests that the vast majority of professional development (PD) activities offered to date are ineffective or useless (Guskey & Yoon, 2009; Marzano & Toth, 2014). A major factor in this lack of efficacy is the prevailing model used for PD – short and isolated "one-shot" workshops, which have proven to be ineffective at changing teachers' practice and student learning (Darling-Hammond, Wei, Andree, & Richardson, 2009). Therefore, the immediate and pressing challenge facing schools is about providing effective professional development (Darling-Hammond, Hyler, & Gardner, 2017; Gulamhussein, 2013).

2. Theoretical Framework

Teachers are the most important factor in mathematics learning for elementary school students (Van de Walle, Karp, Bay-Williams, & Wray, 2019). In the document *Principles and Standards for School Mathematics*, the National Council of Teachers of Mathematics (NCTM, 2000) articulates, "effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (p. 16). Researchers consistently identify essential characteristics of effective teachers in three interrelated aspects: skills, disposition, and knowledge (Burden & Byrd, 2009; Van de Walle et al., 2019), all of which require the support of a strong PD program. While most teachers have strong pedagogical skills in terms of basic concepts, they often lack the distinct skill set to foster critical thinking, problem solving, and application in mathematics (Kane & Stainger, 2012).

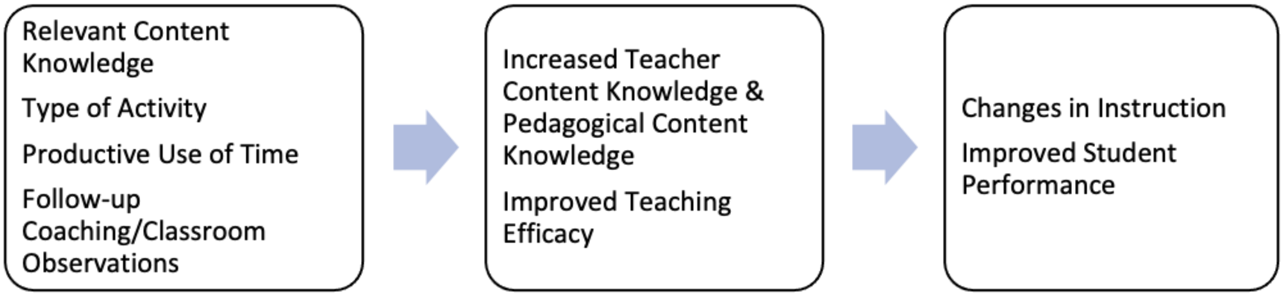
Teachers' dispositions toward mathematics instruction also have profound impact on their effectiveness. In particular, teachers with low levels of *self-efficacy* with regard to mathematics lack confidence in their own ability to teach math effectively (Evans, 2011).

Effective teachers of mathematics must have four types of knowledge, including content knowledge, professional knowledge related to teaching in general, pedagogical knowledge, and pedagogical content knowledge (Ball, Thames, & Phelps, 2008; Burden & Byrd, 2009; Shulman, 1987). Professional and pedagogical knowledge apply across all subjects and are frequently addressed in PD, but content knowledge and pedagogical content knowledge (PCK) are often under-supported in mathematics. While most teachers understand the mathematical concepts appropriate to the grade levels that they teach, many elementary teachers lack a deep conceptual understanding of the mathematics that they intend to teach as well as its connections with that of prior and later grades (Ball, Hill & Bass, 2005; Philipp et al., 2007). PCK, which Shulman (1987) describes as a "special amalgam of content and pedagogy that is uniquely the province of teachers" (p. 8), is the knowledge of which pedagogical strategies are most effective for a given concept or subject area. Many teachers have a limited repertoire of PCK, which cannot be enhanced simply by adding teaching experience (Lee, Brown, Luft, & Roehig, 2007). One of the goals of the project described in this report is to strengthen the body of research linking growth in content knowledge and PCK contribute to improved skills and increased self-efficacy.

The introduction of Partnership for Assessment of Readiness for College and Careers (PARCC) and Northwest Evaluation Association's (NWEA) Measures of Academic Progress (MAP) tests, standardized assessments whose math sections are aligned with CCSS-M, has revealed that most PD offerings do not provide teachers with adequate training to prepare students for the math skills being assessed, such as critical thinking, problem solving, communication, and application. In response to teachers' instructional needs, a multitude of initiatives have attempted to expand opportunities for PD (Workman, 2012; Marzano & Toth, 2014). However, many studies have noted that sizable PD approaches were ineffective in meeting needs for instructional shifts (EPERC, 2013; Gulamhussein, 2013). In a comprehensive literature review with 643 studies related to math PD interventions in grades K-12, researchers found only 32 of them assessed the effectiveness and used a research design, and within the 32 studies, only two found positive effects on student math performance (Gersten, Taylor, Keys, Rolfhus, & Newman-Gonchar, 2014). The root causes for the paucity of effective PD approaches could be: 1) many trainings used a one-size-fits-all approach without applicable strategies for individual content subjects; or 2) the prevailing PD model is short and isolated "one-shot" workshops that have been shown to have little to no impact on student learning or teacher practice (Darling-Hammond et al., 2009).

Nonetheless, PD is the most systematic and readily available solution to teacher deficiencies in knowledge, skills, and disposition. PD should expose teachers to techniques and knowledge that they have never experienced themselves and that they rarely see their colleagues engage in (Gulamhussein, 2013; Darling-Hammond et. al., 2017). Building upon past research findings (Darling-Hammond et. al., 2017; Garet et. al., 2001; Gersten et. al.,2014), the PD program described in this article was structured to take full consideration of: 1) relevant content knowledge (various content-based topics assigned for each session, 2) type of activity (a combination of workshops and follow-up class observations), 3) productive use of time (a year-long duration with activities pertaining to content and instruction on problem-solving and critical thinking skills, and 4) follow-up coaching/mentoring opportunities (classroom observations conducted by the school curriculum coaches and program facilitators). The conceptual framework for the program design is outlined in Figure 1.

Figure 1. PD Program Design Framework



3. Data Sources/Methods

This investigation was part of a yearlong program aimed at developing and providing a content-based PD that enables teachers to meet and exceed CCSS-M's high expectations for mathematics instruction and to improve their satisfaction with and confidence in delivering CCSS-M content to enhance student math achievement. This program was supported through a math initiative grant funded by the CME Group Foundation to improve teaching quality in school districts in the Chicago metropolitan area.

In order to evaluate the effectiveness of the PD program, a "sequential explanatory" mixed-methods approach was employed to collect and analyze both quantitative and qualitative data (Creswell, Clark, Gutmann, & Hanson, 2003). A pre/post design was used to gather quantitative data measuring growth in teacher knowledge, teaching efficacy, and student performance on standardized NWEA MAP tests (Northwest Evaluation Association, n.d.). Qualitative data included end-of-session evaluation forms, classroom observations, interviews, and end-of-program survey. For this study, teachers' end-of-program survey results were used to: 1) confirm or explain the quantitative findings in teacher efficacy and student performance on standardized exams, and 2) inform the summative evaluation of the optimal context and components that lead to improvements in teacher efficacy and knowledge as well as increases in student achievement. Quantitative and qualitative data were given equal priority and were integrated in the Results and Discussion section. Three research questions were addressed accordingly:

1. Did teachers' teaching efficacy beliefs increase as a result of participating in the content-based professional program?
2. Did student performance on standardized tests improve as a result of their teachers' participation in this professional program?
3. How did teachers describe their experiences in the professional development program and its impacts on their professional career?

3.1. Participants

Twenty-two teachers of grades K-3 participated in this PD program during the 2018-19 school year. All but one participant were drawn from three elementary schools within a suburban public school district whose student population consists primarily of low-income, high-risk children. The student population in that school district was 58% Hispanic and 36% African-American; 92% were from low-income families. Table 1 shows the number of participants who were teaching at each grade level. The number of years that participants had been teaching at their present school ranges from 1-28 years, with an average of 7.6 years. All participants had Bachelor's Degrees, and 60% had Master's Degrees. Research suggests that PD designed for groups of teachers from the same school, department, or grade level allows more opportunities for teachers to work together and discuss concepts, skills, and problems, which leads to sustained changes in teaching practice (Nishimura, 2014; Garet et al., 2001).

Table 1. Participant Number and Percentage by Grade Level

Grade Level	Number of Participants	Percentage of Participants
K	6	27%
1	4	18%
2	3	14%
3	5	23%
K-2/3	2	9%
Coaches	2	9%

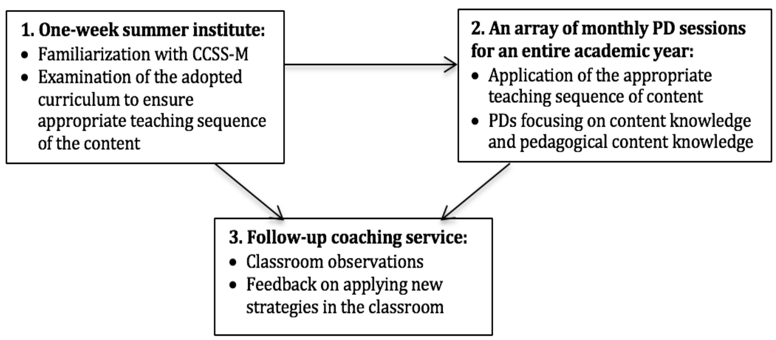
3.2. Professional Development Facilitators

The program facilitators were two professors of mathematics education with extensive experience in providing in-service trainings to math teachers. The primary facilitator has more than 30 years' experience working with classroom teachers and modeling instructional strategies for conceptual understanding and procedural proficiency. She has also devoted substantial efforts toward facilitating teachers to develop and implement a grade-specific spiral mathematics curriculum (GSMC), an essential part of this PD program, described in detail in the following section. The other facilitator, who is also the first author of this article, has successfully conducted many grants focused on long-term PD programs for Prek-8th grade teachers in south suburban school districts of Chicago. Her focus was to present research-informed teaching strategies for each content strand on the monthly trainings in the program.

3.3. Professional Development Intervention Design

This PD program was geared to teachers' pedagogical content knowledge and instructional needs for critical thinking and problem-solving skills aligned with the CCSS-M. Three essential program components are illustrated in Figure 2, concerning the content and duration as two primary factors in the program design. The program began in Summer 2018 with an intensive week-long workshop consisting of five full-day. During the summer workshop, teachers were first asked to examine the CCSS-M and corresponding adopted curriculum in their school district; next, the primary facilitator introduced a way to reorganize the curricular topics from basic to complex levels along a spiral path at several points of time in each grade. Upon completion of the summer workshop, teachers of each grade level collaboratively developed a grade-specific spiral mathematics curriculum (GSMC) with lesson topics in the sequence from basic to medium, and then to advanced levels. In the following fall, the program continued to provide monthly two-hour trainings, on Wednesday afternoons following the conclusion of the school day, to the same teacher participants throughout the 2018-19 academic year. In the meantime, two curriculum coaches in the school district periodically met with teachers at each grade level to assess their progress with the GSMC implementation and also conducted classroom observations for consultation. In addition, two program facilitators visited each teacher participant's classroom and provided feedback on their teaching in Spring 2019.

Figure 2. Three essential components for the professional development program



3.3.1. Grade-specific spiral mathematics curriculum (GSMC).

The concept of a grade-specific spiral mathematics curriculum (GSMC)is rooted in Jerome Bruner (1960)'s cognitive theory that students can understand any complex information through properly structured instruction.

Bruner (1960) related this type of instruction to a spiral curriculum through which complex ideas are taught at a simplified level first, and then re-visited at a higher level with greater sophistication. This program extended Bruner's spiral curriculum idea to a grade-specific, spiral mathematics curriculum (see Figure 3). In particular, we emphasized that a mathematical topic must be taught along a spiral path with incremental difficulties at several points of time within each grade level. Therefore, students can grasp a math topic in a logical progression from simple to complex. Meanwhile, the spiral learning process ensures that students reinforce prior learning and make connections to more sophisticated new knowledge. An equally important advantage is that spiral instruction prevents students from developing "learning fatigue" by concentrating on a single topic for too long.

Figure 3. Grade-specific spiral mathematics curriculum (GSMC)

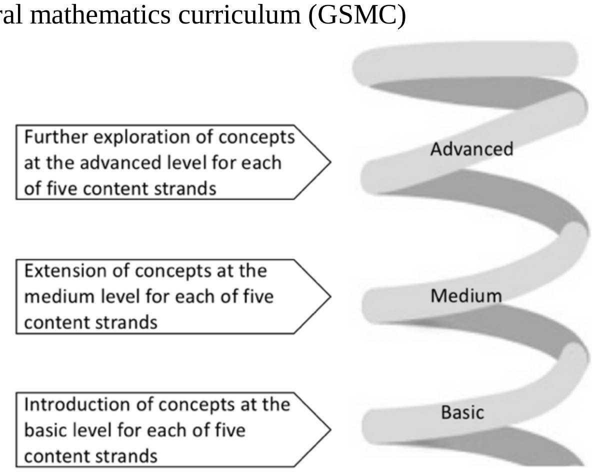
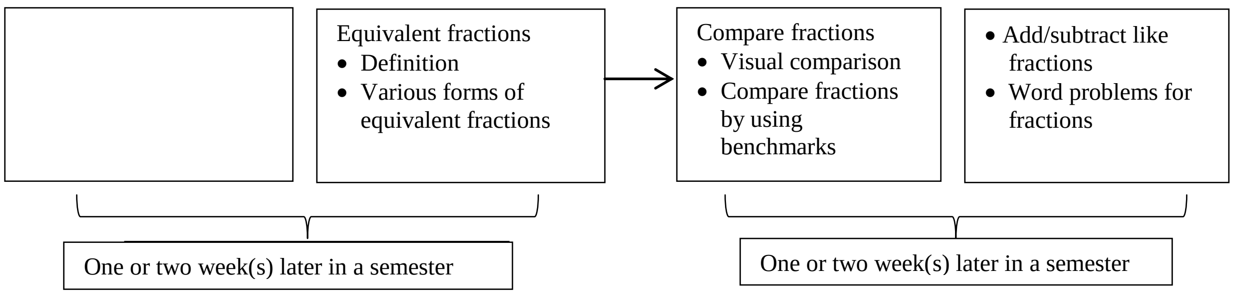


Figure 4 displays how a third-grade teacher develops the GSMC for the topic of fractions. First, the teacher spends one or two weeks introducing basic terminology and concepts of fractions and then moves on to basic topics in other content strands (e.g., algebra, geometry, measurement, and statistics) for a cycle of learning. Later in the semester, the teacher will revisit the fraction topic to extend students' previous understanding by showing how to compare fractions and how to apply fractions in real-world problems. The spiral learning process optimizes the efficient use of time, allowing teachers to cover all required topics from basic to advanced levels and enabling students to solidify their learning by adding complexity and application to concepts they have already studied in the spiral sequence.

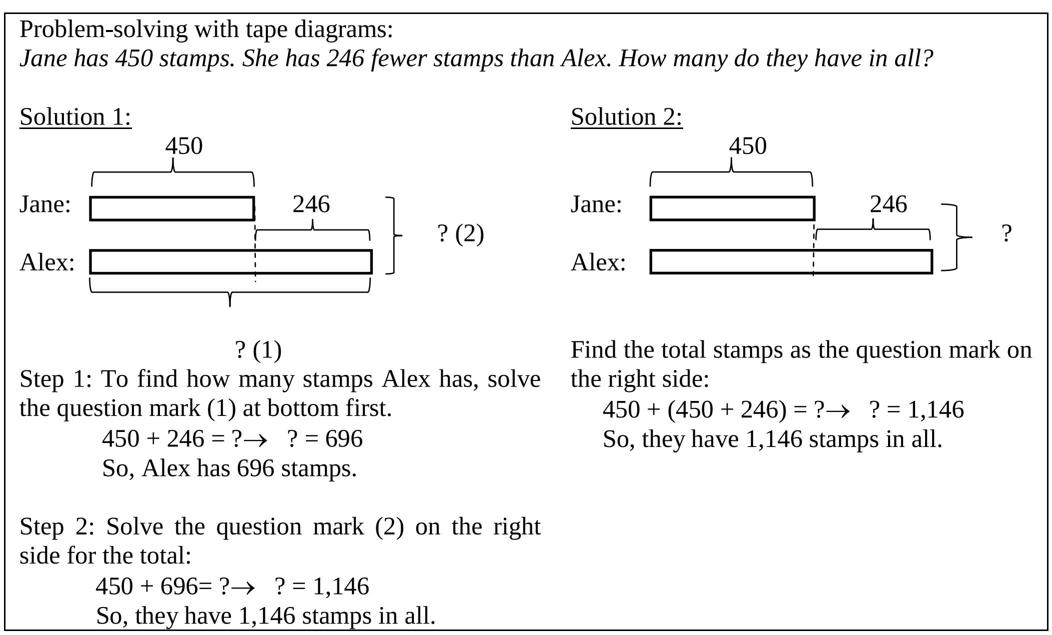
Figure 4. Teaching fractions in a spiral curriculum



3.3.2. Key topics of professional development sessions.

In addition to the grade-specific spiral mathematics curriculum, this PD program incorporated other applicable ideas based on research studies. The content knowledge and teaching strategies introduced in the PD were designed to nourish critical thinking and problem-solving skills among students. For instance, in response to the long-existing issue regarding students' poor performance on word problems, the facilitators spent two sessions on how to use the tape diagrams as an effective strategy to solve word problems. The tape diagram, also called the bar model, has been conventionally taught in Japan, Singapore, and China, and was recently adopted by the CCSS curricula in Kentucky and New York (Murata, 2008; Ding, 2018). Drawing tape diagrams enables students to visualize the numerical relationships as a more comprehensible strategy compared to the traditional 'identifying the key words' strategy which has been long criticized as ineffective but widely used in the U.S. curriculum (see Figure 5).

Figure 5. Example of tape-diagram solutions



The PD sessions integrated the elements of mathematics content, pedagogy, and knowledge of child development, as well as best practices, such as hands-on instruction, small-group exploration, and modeling. Key topics of the summer workshop and each monthly session (based needs survey results from teachers) are outlined in Figure 6.

Figure 6. Key Topics of professional development sessions

- Summer Workshop: Classroom management, Six Aspects of Learning, Introduction to spiral curriculum, Word problem strategies, Task analysis, Approaches to addition and subtraction, Approaches to multiplication and division
- Monthly Session 1: Spiral Curriculum, Assessment design
- Monthly Session 2: Questioning techniques
- Monthly Session 3: Geometry, Shapes
- Monthly Session 4: Time, Sequencing
- Monthly Session 5: Bar models, Word problems
- Monthly Session 6: Money, Sequencing, Word Problems
- Monthly Session 7: Measurement, Using Manipulatives
- Monthly Session 8: Volume and Area, Hands-on and visual strategies
  Monthly Session 9: Multiplication, Concept-based approach

3.4. Evaluation on Program Effectiveness

Examination of the program effectiveness was conducted through a "sequential explanatory" mixed-methods approach, in which the quantitative data analysis was followed by the qualitative data to further interpret and clarify the quantitative results (Creswell, et al., 2003). Two program evaluators met with two facilitators in May 2018 and decided to measure participants' teaching efficacy levels using a *Teacher Beliefs Scale* (TBS) at three times: 1) upon the participant's entry into the program (pre-test); 2) at the conclusion of the intensive summer workshop (midterm test); and 3) at the conclusion of the program (posttest). All survey items were carefully developed and approved by program facilitators and evaluators together to ensure the content validity. In the instrument, 48 items specifically targeted the main goals of the program: confidence in teaching math to young learners, pedagogical content knowledge, and implementing mathematics in daily practice. A fourth scale examined overall comfort in teaching young learners. Teachers rated each item on a five-point scale, with 1=strongly disagree and 5=strongly agree. Four scale scores and a total score were calculated as follows:

- Scale 1: Confidence in Teaching Math to Young Learners (average of 33 items)
- Scale 2: Pedagogical Math Content Knowledge (average of 8 items)
- Scale 3: Implementing Mathematics in Daily Practice (1 item)
- Scale 4: Teaching Young Children (average of 6 items)
- Total Score (average of the sum of Scales 1-4).

Here is a sample question for each subscale: (1) I am comfortable teaching the relationship between numbers and quantities (Question 5, Scale 1); (2) [Indicate how comfortable you are implementing] Reason abstractly and quantitatively (Question 2, Scale 2); (3) I teach mathematics daily to my students (Question 1, Scale 3); and (4) I am comfortable motivating and sustaining children's involvement in activities (Question 2, Scale 4).

In addition, the school district provided students' NWEA-MAP test scores for Fall 2018 and Spring 2019 for the teachers who participated in the program, as well as the overall scores of the previous Year (2017-18) for the purpose of comparing student achievements over years.

As noted earlier, the MAP testis a Common Core-aligned online assessment, which assess students' comprehensive skills within all five mathematical content strands. The difficulty of each question is based on how well a student answers all of the previous questions. As the student answers correctly, questions become more difficult whereas the questions become easier if the student gives more incorrect answers. In general, the test is individuated assessment for student ability rather than a uniform test. Results from MAP tests are available with 48 hours of when the student completes the test. The comparison of students' MAP scores provide evidence to address the research question whether teachers' participation in the intensive professional development program has impact on their students' performance on standardized tests.

4. Results

This section is organized to answer three research questions regarding the effectiveness of the professional development program. The quantitative data were primarily based on results from the *Teacher Beliefs Scale* (TBS)and student performance on standardized NWEA-MAP tests. The subsequent qualitative data were gleaned from responses on the end-of-program (EOP) survey. Information for 22 teacher participants and 427 students were analyzed and reported.

4.1. Research Question 1: Did teachers' teaching efficacy beliefs increase as a result of participating in the content-based professional program?

The first research question was answered using data on the TBS and the end-of-program survey. The TBS pretest was administered to participants on their first day of attendance, while the posttest was administered on the last session of the year. Paired t-tests were calculated for all four subscales, and for the total score (see Table 2).

Table 2. *Teacher Self-Efficacy Beliefs Matched Pretest and Posttest Comparisons (N=22)*

	Pretest		Posttest		Mean Difference	t	Prob.
Item/Scale	Mean	Std. Dev.	Mean	Std. Dev.			
Total Teacher Self-Efficacy	3.95	0.31	4.62	0.34	0.67	6.91	.001
Scale 1: Confidence in Teaching Math to Young Learners	3.59	0.36	4.45	0.39	0.86	8.86	.001
Scale 2: Pedagogical Math Content Knowledge	3.64	0.58	4.50	0.47	0.86	5.38	.001
Scale 3: Implementing Mathematics in Daily Practice	4.59	0.59	4.82	0.50	0.23	1.31	NS
Scale 4: Teaching Young Children	3.99	0.50	4.72	0.39	0.73	6.78	.001

The pre-post mean scores on the TBS reveals a significant change of the total teaching efficacy beliefs ($p < .001$), with an increase of 0.67 point (17%) on the overall scale. In particular, participants scored significantly higher from the pretest to the posttest on three subscales: the Confidence in Teaching Math to Young learners ($p < .001$), the Pedagogical Math Content Knowledge Scale ($p < .001$), and the Teaching Young Children Scale ($p < .001$). The average pre-scores ranging from 3.59 to 3.99 on the three subscales indicates teachers felt uncertain to somewhat confident in their teaching efficacy levels before participating in the program; in contrast, the post averages from 4.45 to 4.72 revealed teachers became much more confident in their mathematical teaching abilities. Drawing on these comparisons, we concluded that the intensive, content-based PD program had a positive impact on teachers' confidence in teaching math content, pedagogical content knowledge, and teaching young learners. No significant difference was identified regarding the extent to which teachers implemented mathematics on daily practice, possibly because the school district had already arranged a substantial amount of time for daily math instruction, so that no significant schedule change was needed.

The data in the end-of-program survey largely supported the findings of the TBS. All participants generally believed they were more knowledgeable about teaching math to young children as a result of participation in this program. In response to the most important things learned from the program, the answers varied, including general teaching strategies (e.g., "scaffold instruction appropriately so that students can build on concepts and understand them completely," "differentiate your instruction and centers," and "the order in which to teach various concepts"),topic-specified strategies (e.g., "multiplication strategies to promote continued learning," "different addition/subtraction strategies," "six aspects of learning," and "bar models in problem solving"), creating teachers' own assessments, and developing/implementing the spiral curriculum, which was most-mentioned item in the survey. The grade-specific spiral mathematics curriculum (GSMC) was positively embraced by teacher participants. One teacher wrote, "Implementing spiral math (my kids really improved using this)," and another teacher expressed a similar view as "We were able to spiral our curriculum. It helped to know where to go next for students, who were ready for more or students who needed to go back to simpler concepts/skills."

4.2. Research Question 2: Did student performance on standardized tests improve as a result of their teachers' participation in this professional program?

To address this research question, both quantitative and qualitative data were collected and synthesized. Table 3 compares student performance on Fall/Spring MAP tests for Year 2017-18 (a year before the professional development program was implemented) to corresponding student performance scores for Year 2018-19 (the year the professional development program was implemented). Although no significant difference of gains was identified between two academic years, student average gain in 2018-19 (MD = 23.45) was slightly more compared to 2017-18 (MD = 22.42).

It is also worthwhile to note that the average test scores were around five points higher for 2018-19 compared to 2017-18 on both pretest (161.82 vs. 157.03, d=4.79) and post-tests (185.28 vs. 179.46, d=5.82). (M=161.82).

Table 3. *Overall Student NWEA MAP Math Score Comparisons*

	Pretest		Posttest		Mean Difference	t	Prob.
Time Period	Mean	Std. Dev.	Mean	Std. Dev.			
Year 2017-2018	157.03	22.76	179.46	19.72	22.42	12.35	.001
Year 2018-2019 (N=427)	161.82	23.42	185.28	21.73	23.45	44.51	.001

Since the pretest (Fall MAP test) was administered in September 2018, one month after the implementation of the 5-day summer intensive professional development program, it was possible that the professional development helped teachers better prepare their students for mathematics learning and testing with basic concepts in five content strands.

Table 4. *Student NWEA MAP Math Score Comparisons by Grade Levels*

	Pretest		Posttest		Mean Difference
Time Period	Mean	Std. Dev.	Mean	Std. Dev.	
Total					
Year 2017-2018	157.03	22.76	179.46	19.72	22.42
Year 2018-2019	161.82	23.42	185.28	21.73	23.45
Kindergarten					
Year 2017-2018	129.83	1.34	155.33	4.40	25.5
Year 2018-2019	132.26	8.80	162.28	13.04	30.02
Grade 1					
Year 2017-2018	154.85	1.91	179.65	1.76	24.8
Year 2018-2019	155.92	11.98	180.83	16.09	24.91
Grade 2					
Year 2017-2018	174.85	2.05	198.55	1.48	23.7
Year 2018-2019	178.31	13.7	199.83	15.10	21.52
Grade 3					
Year 2017-2018	182.2	1.13	196.35	4.45	14.15
Year 2018-2019	185.63	9.53	202.28	11.30	16.65
Special Ed.					
Year 2017-2018	NA	NA	NA	NA	
Year 2018-2019	139.44	13.54	157.22	22.14	17.78

Table 5. *Analysis of Covariance for Math Achievement as a Function of Grade Levels, Using Pretest Scores as a Covariance*

Sources	*df*	*MS*	*F*	*p*	Partial eta(squared)
Pretest Score	1	46716.49	481.35	0.001	.53
Grade Levels	4	559.54	5.77	0.001	.05
Error	421	97.05			

Table 4 compares student performance gains within each grade level. Grades K, 1, and 3 had greater gains in 2018-19 compared to 2017-18. Results for Grade 2 were less clear-cut; second-grade students in 2018-19 performed slightly better than their previous-year counterparts at the end of the academic year (Spring test), but their overall academic gains were smaller. Table 5 displays an analysis of covariance (ANCOVA) to assess whether the PD program had different impacts on student math performance based on grade levels, controlling for students' Fall 2018 scores (covariate).

Results indicate that after controlling for the pretest scores, there were significant differences in gains among grade levels, suggesting that the intensive, content-based PD program might have impacted teachers differently in their content knowledge and teaching strategies as well as indirect impacts on student achievement in mathematics.

In the EOP survey, when asked about whether they believe that their students had increased understanding of math, 19 out of 20 teachers wrote “yes” (excluding 2 curriculum coaches), which accounted for 95% of positive confidence in student performance gains. Those who answered “yes” were asked to give examples as a result of using skills learned in the program to promote student learning. In response, seven teachers (35%) pointed to the improved NWEA MAP test score as one example, with sample comments as “My scores on NWEA are at a 90%, students can explain their thinking,” “NWEA score went up. I see more students understanding a skill/concept. Not just memorizing. They can explain their thinking more,” and “My students’ NWEA scores [and] my students’ interest levels in math.” Four teachers (20%) attributed student’s gains to the successful use the grade-specific spiral mathematics curriculum (GSMC), with sample comments as “Spiral math allowed me to cover more concepts. And it seemed to help them understanding the concepts more” and “Their NWEA scores went up because of the spiral math.” Other examples were provided as “more manipulatives and hands-on as they relate to real life” (5%), “break down [the concept]” (5%), “the six concepts of learning” (10%), “bar models to show understanding in problem solving” (10%), and “more confident when approaching new skills and are more willing to attempt tasks give” (5%).

A math coach for grades 3-5 also addressed the question using students in her school as a whole. She wrote, “Yes, the students are more excited about learning concepts (new concepts) either weekly or bi-weekly. The proof is in the Winter NWEA data where the students increased in their RIT [scores]. Students are all more verbal using math vocabulary.”

Overall, student performance on standardized tests had somewhat improved during the implementation of the PD program. The majority of teachers attributed the positive results to the implementation of the grade-specific spiral curriculum and teaching strategies learned in the program.

4.3. Research Question 3: How did teachers describe their experiences in the professional development program and its impacts on their professional career?

Qualitative findings from the EOP survey were used to address this research question and to provide insights into teachers’ experiences and challenges throughout their program participation.

In responding to the question regarding how they integrated the learned concepts and strategies into their curriculum, all teachers reported implementing the grade-specific spiral mathematics curriculum (GSMC). One teacher wrote, “I made sure to spiral the concepts as well as made sure to use a variety of methods to enhance student understanding.” The two curriculum coaches were extraordinarily supportive of all ideas presented in the professional development program. While attending each session and learning along with their supervised teachers, the coaches also met with groups of teachers at the same grade level in each school bi-weekly to ensure they understood how to create and implement the GSMC in their classrooms. One coach wrote, “Teachers were able to find strategies and concepts that adhered to what they decided as a grade level to teach. Teachers referred to the GO MATH [the adopted curriculum] to see how they were able to reach the concepts and strategies.”

When inquired about what opportunities the program facilitators provided to help teachers reflect on their teaching, all teachers replied that the feedback after the classroom observation in Spring 2019 helped them recognize some needed changes for instruction, including tiered differentiation, break-up the lesson into smaller parts, building on students’ prior knowledge, creating stations with different content strands, fully understanding the standards, motivation talk, time management, and classroom management.

To reflect on the least successful/useful strategies in the program, most teachers wrote “all were useful” or left the space blank, except for eight responses. Within the 8 responses, 7 lower-grade teachers reported multiplication and division as less useful since they would not teach them, and another teacher thought of the teacher-created assessment as an unnecessary topic. In addition, all teachers would like to recommend other teachers to participate in the professional development program with various reasons, including “our results in student performance are better than they have EVER been,” “it helped me to have a clearer mindset and organization of how/what to teach for each concept,” “it was a great learning experience,” “it taught me somethings and allowed us to collaborate as a K-3 team, rather than grade level,” “I felt that I had support and guidance when I needed it,” “great teaching strategies and great questioning skills,” and “It allows your students to see how one concept relates to anther concept. It shows building blocks of their learning,” The data revealed positive learning experiences among teachers throughout their participation in the professional development program. Based on the responses to the EOP survey, we believe that this program helped teachers become more confident in their content knowledge and pedagogical content knowledge, which resulted in positive impacts on student learning and performance on the standardized tests.

5. Discussion and Conclusions

This professional development program was designed to respond to the urgent national need for effectiveness professional development through designing, implementing, and evaluating a yearlong, content-based professional development program for K-3 math teachers. Drawing on findings from prior studies, this program encompassed three essential components: (1) one week-long summer workshop to allow teachers to familiarize themselves with the CCSS-M and to develop a grade-specific spiral mathematics curriculum (GSMC) aligned with the CCSS-M, (2) an array of monthly 2-hourworkshops throughout one academic year, and (3) follow-up coaching service, including classroom observations conducted by the program facilitators and periodically grade-specific meetings summoned by the curriculum coach at each school. A mixed methods design was used to examine whether changes were observed in teachers' teaching confidence, student performance on standardized tests, and teachers' learning experiences as indicators for the effectiveness of the professional development program.

The quantitative results revealed significant increases in teachers' confidence in teaching math to young learners, pedagogical content knowledge, and teaching young learners in general, as measured by the subscales on the Teacher Beliefs Scale (TBS). The subsequent qualitative data from the end-of-program (EOP) survey confirmed the quantitative findings with evidence that all teachers believed that they were more knowledgeable about teaching math to young children. They felt the implementation of the GSMC, the general teaching strategies, and topic-specific teaching strategies learned in the program were relevant and useful in their teaching practice, which in turn boosted teachers' teaching confidence in math.

Data for student performance on the NWEA MAP tests were compared between the year with the professional development program (2018-19) and the previous year without the intervention (2017-18). Although no statistical difference in academic gains was identified between the two years, students of the professional development year performed around five points higher compared to their counterparts of the previous year on both pretest (161.82 vs. 157.03, d=4.79) and post-tests (185.28 vs. 179.46, d=5.82). In addition, after controlling for the pretest scores, there were significant differences in gains among grade levels, suggesting that the intensive, content-based professional development program might have indirect impacts on student achievement in mathematics. The following qualitative findings further affirmed the quantitative results, with 19 out 20 teachers believing that their students had increased their understanding of math.

On the EOP survey, teachers reported positive experiences with learning and implementing ideas and strategies from the program in their own classrooms. All teachers regarded the implementation of the grade-specific spiral mathematics curriculum (GSMC) as an effective way to organize the content and topics for the purpose of effective student understanding. Most teachers reported the PD topics were useful, with only a handful of participants commenting that a few topics relevant to some of their colleagues were not relevant to their own practice. In addition, all participants said they would recommend that other teachers participate in the professional development program, citing a variety of benefits, such as better organization of concepts, improved student performance on tests, collaboration across grade levels, more support and guidance, and effective teaching strategies to cultivate student learnings.

Based on the findings above, we conclude that this year-long, content-based professional development program was effective in enhancing teachers' teaching confidence and student performance in math.

6. Implications

Previous studies on professional development in math education have mainly focused on improving teacher content knowledge and teaching confidence (Gersten et al., 2014). This study extends the existing research by examining the effectiveness of a PD program on teachers' teaching efficacy beliefs and student performance. Since PD does not necessarily lead to professional learning and enhanced student performance in math (Darling-Hammond, et. al., 2017; Gersten et al., 2014), this study added important research-based evidence to the structure of an effective PD program in diverse school districts – especially those serving under-prepared, minority students – in order to reduce existing student achievement gaps in mathematics. The results confirm the importance of PD that focuses on relevant content knowledge, varied types of activities, productive use of time, and follow-up coaching/mentoring opportunities.

7. Limitations

This study was limited to one elementary school district located in southern suburban area of Chicago, and it only focused on lower grade levels from K to 3, with 20 teachers and 2 curriculum coaches. In order to generalize the effectiveness of this PD design, more teachers at varied grades and school districts should be involved. In addition, this study merely reported teacher beliefs and student performance within the academic year during the PD implementation. More follow-up data should be collected to examine long-term effects of the PD program on teachers' teaching efficacy levels and student performance in math.

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