The Impact of Sustained, Standards-Based Professional Learning on Second and Third Grade Teachers’ Content and Pedagogical Knowledge in Integrated Mathematics

Lora B. Bailey

Abstract This 3 year longitudinal study reports the feasibility of an Improving Teacher Quality: No Child Left Behind project for impacting teachers’ content and pedagogical knowledge in mathematics in nine Title I elementary schools in the southeastern United States. Data were collected for 3 years to determine the impact of standards and research-based teacher training on these aspects of teacher quality. Content knowledge for the scope of this research study refers to the knowledge that teachers have about subject matter. Teacher quality is directly related to teachers’ “highly qualified” status, as defined by the No Child Left Behind mandate. According to this mandate, every classroom should have a teacher qualified to teach in his subject area and be able to “raise the percentage of students who are proficient in reading and math, and in narrowing the test-score gap between advantaged and disadvantaged students.” Participants were six second grade and seven third grade teachers of mathematics from nine schools within one failing school district. The implementation of standards-based methods in the nine Title I Schools increased teacher quality in elementary school mathematics. In fact, qualitative and quantitative data revealed significant gains in teachers’ mathematics content and pedagogical knowledge at both grade levels.

Keywords Early numeracy · Mathematics education · Teacher quality · Standards-based mathematics professional learning

Introduction

The purpose of this research project was to determine if a sustained standards-based professional learning project would improve second and third grade teachers’ content and pedagogical knowledge in mathematics. Activities were intended to bridge the gap between teachers’ current knowledge and that which was needed to impact their highly qualified status and effectiveness at teaching mathematics. The project continued over the course of 3 years to increase the likelihood that the project might positively impact teachers’ mathematical content and pedagogical knowledge (Hill et al. 2004). Teacher and student data were gathered over the same period of time. However, this report focuses solely on teacher-based data.

The project objectives were to demonstrate the effectiveness of standards and research-based practices on early childhood educators’ content knowledge in mathematics, and pedagogical practices. A project development team was formed to plan and design the professional development activities, one of which was a course offered each summer over 5 days per summer. The course was intended to increase teachers’ knowledge of second and third grade mathematics content standards (number and operations, algebra, measurement, geometry and data analysis and probability) and pedagogy in order to increase the likelihood that they might impact student learning. The project focused on enabling teachers to use standards-based instruction to promote the use of National Council of Teachers of Mathematics (NCTM) principles (equity, curriculum, teaching, learning, assessment and technology) and National Association for the Education of Young Children (NAEYC) standards. Such practices have been deemed effective for impacting early childhood teachers’ mathematics practices, as noted within the NAEYC-NCTM...
position statement (NCTM 2000). The implementation of these methods in the nine Title I Schools was deemed sufficient for increasing teachers’ content and pedagogy knowledge in mathematics. In fact, qualitative and quantitative data revealed significant gains in teachers’ mathematics content and pedagogical knowledge at both grade levels. The following sections detail specific elements of the standards-based professional development activities used to impact teaching and learning in nine early childhood/early elementary mathematics settings.

Teacher Professional Learning

The training sessions focused on enabling teachers to understand NCTM content standards and principles suitable for early childhood settings and pedagogy endorsed by NAEYC to impact their practices. Project activities emphasized methods for facilitating: (a) teachers’ understanding of the effective strategies for facilitating children’s problem solving; (b) teachers’ knowledge about NCTM standards, NAEYC standards, and state mathematics standards; (c) teachers’ understanding of NCTM principles relevant for developing an appropriate second and third grade math curriculum (i.e., technology, equity, and etc.), and (d) teachers’ content knowledge related to authentic assessments in these grades. This section will summarize elements of the training that were used to accomplish each of the aforementioned objectives for the teacher professional development sessions. We will examine methods researchers used to facilitate teachers’ understanding of effective strategies children frequently use to solve problems without teacher intervention, and then transition to methods used to enhance teacher knowledge about NCTM and state mathematics standards. The report concludes with recommendations for helping teachers understand and use NCTM principles relevant for developing an appropriate math curriculum (i.e., technology, equity, teaching, and etc.) and research-based methods for enhancing teacher knowledge related to authentic assessments.

Improving Teachers’ Content and Pedagogical Knowledge across All Standards and Principles

Effective teaching requires knowing and understanding mathematics, students as learners and pedagogical strategies (NCTM 2000).

During this phase of the project we gathered pre-assessment data needed to detect teachers’ content and pedagogical knowledge. This was essential for finalizing the selection of professional learning activities deemed appropriate for fostering teachers’ development of more complex second and third grade mathematics content and pedagogy knowledge. The project team examined recent research on early childhood mathematics that revealed what teachers should know about mathematics in order to effectively impact student learning at the Prek-2 and 3–5 grade levels (NCTM 2000). Relevant standards and principles were incorporated into the teacher training—both state and national. The school district in which this training took place used curriculum maps loosely tied to content standards to ground teachers’ instruction. Thus, the district’s curriculum maps were also used to reacquaint teachers with mathematics principles and standards important to their school district. Integrated curriculum was emphasized as a strategy for helping participants acquire the knowledge they need to immerse children in an appropriate subject matter and pedagogy (Harts et al. 1997; Katz and Chard 2000). Within the study of integrated curriculum, which is often referred to as interdisciplinary studies, researchers emphasized ways to address multiple principles and content standards using a single lesson. This technique was deemed essential for equipping teachers to strand or synthesize the teaching of many standards simultaneously for the sake of efficiency and developmentally appropriateness (NCTM 2000). Teachers were also immersed in the study of developing and using interactive homework assignments to improve student learning and build stronger home-school connections (Bailey et al. 2004; Bailey 2006).

During each session, teachers were assigned to small groups and worked collaboratively to design standards-based lessons based on the research-based content of professional learning activities. Each small group was responsible for immersing their peer groups in the standards-based learning activities using interactive, instructional techniques. At the end of each day, teachers engaged in dialogue intended to enrich their understanding of the day’s lessons and to clarify misunderstanding or to uncover misconstructions. Teachers wrote daily journal entries to reflect upon their own problem solving and participated in sharing seminars related to each standard or principle addressed during a particular session. During the final year of the study, participants developed and led a teacher showcase to demonstrate their new content and pedagogical knowledge to the nine school principals and school district administrators. Particular elements of the training related to each standard are detailed in the following section. Qualitative and quantitative data were gathered throughout each phase of the standards-based training.

Embracing NCTM Standards and Principles

Standards and Principles Relevant to Second and Third Grade Mathematics Concepts

Based on a thorough review of research to uncover methods proven to impact elementary teachers’ content and
pedagogical knowledge, it was determined that professional learning activities that focus on preparing teachers to understand and use research-based methods are most effective. For example, when research teams infused a study of NCTM and state approved mathematics content standards and NAEYC principles to design instruction intended to improve mathematics learning for young children, teachers’ content knowledge increased (Hill et al. 2004; NCTM 2000; Fennema et al. 1996; Peterson et al. 1989; Swars et al. 2007). This project immersed teachers in rich, peer-to-peer and trainer-teacher discussions and activities that equipped them to prepare effective math instruction proven to impact student learning. Although this aspect of the study began with the pre-assessment of teachers’ knowledge of the NCTM principles and standards, it immediately transitioned to the immersion of teachers in sessions that facilitated their exploration and use of research-based methods found to impact participants’ ability to design appropriate mathematics lessons for second and third grade students.

At each stage of training, teachers completed content and pedagogy knowledge surveys to determine appropriate points for introducing new, more complex professional learning. When ample data were gathered and analyzed to substantiate teachers’ ability to understand and use principles and standards, they were immersed in activities that facilitated practical uses for this new knowledge in their daily teaching. This process began with the evaluation of textbooks to uncover grade-level specific concepts, and then progressed to matching identified concepts to pertinent principles and standards. These exercises were intended to facilitate teachers’ ability to connect grade specific or relevant concepts to teaching principles and content standards, and provided rationale for teaching specific concepts (Hill et al. 2004; NCTM 2000). Finally, teachers were involved in exercises that focused on addressing multiple principles and standards while teaching one concept. The objective of this phase of the workshop was to enable teachers to design one mathematics lesson involving one concept and then identify multiple principles and standards being addressed within the lesson—as mentioned in the previous section, this process is called stranding standards. This aspect of the project required a level of researcher finesse and teacher-trainer collaboration so that teachers would be willing to consider the relevance of using NCTM principles and NAEYC standards to improve teaching and learning. This intensive planning was needed to adequately engage teachers in activities that led to the development of skills needed to match principles and standards to concepts, and then finally to strand to address multiple principles and standards (Hill et al. 2004; Fennema et al. 1996).

Understanding Effective Strategies Children Might Use to Solve Problems

Effective teachers understand what students know and challenge students to keep learning…students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge… research provides evidence that students will rely on their own computational strategies (NCTM 2000).

When participants were adept at understanding and using NCTM content and process standards and NAEYC principles and standards, teachers were introduced to methods children use to construct their own understanding of number. For example, teachers were presented with professional learning that helped them to understand that children’s acquisition of number is internal and thus students acquire their own sense about number as they interact with their environment. Throughout the lessons teachers found that children construct their own mathematical sense through their own problem solving experiences. Kamii (2000) states, “Piaget’s theory provides the most convincing scientific explanation of how children acquire number concepts. It states, in essence, that logico-mathematical knowledge, including number and arithmetic, is constructed (created) by each child from within, in interaction with the environment.” Thus, a teacher’s role is to arrange a rich environment, equipped with opportunities for children to encounter and solve real problems using their senses. It is the teachers’ role to understand the mental relationships about number each child constructs. This understanding is crucial if teachers are to assist children in their quest to construct more logical understandings of number and thus acquire new and more complex knowledge resulting from what they already know. This section will provide examples of experiences used to broaden teachers’ understanding of children’s thinking about number, their problem solving and practices used to help children build new knowledge about mathematics concepts across all five mathematics standards.

Using Children’s Strategies to Engage Them in Learning Across Mathematics Standards

NCTM principles and standards are relevant for all grades, Prek-12 (NCTM 2000). However, indicators and competencies are grade band specific. For example, it is important for children to grasp the notion of systems of ten in order to construct sense about number and operations, especially in Prek-12 and grades 3–5 (Cobb and Wheatley 1988; Kamii 2000). The present study initiated this phase of the project by introducing teachers to standards-based activities that
are used routinely to help children construct and separate systems. Teacher groups were presented with research-based recommendations proven to effectively engage children in grouping and regrouping, i.e., base-ten activities. These methods are similar to those used in daily mathematics routines within high-quality early childhood settings. Word problems such as the following were used frequently to help teachers understand how to design developmentally appropriate mathematics problems, and to immerse children in rigorous problem solving:

There were seven apples in a bowl. There are 16 children in our classroom. We need to slice the apples so that each child will have an equal number of slices. Explain how will you slice the apples. How many slices will you make out of each apple? How many pieces will you give to each child? Show at least two ways to solve this problem.

Participants were encouraged to (a) solve such problems in groups of four; (b) demonstrate at least two methods for solving the problems and to explain their solutions and to (c) emphasize base-ten methods. They were given a variety of materials such as Cuisenaire Rods, building blocks, Popsicle sticks, mathematics journals, various writing tools, and miniature dry erase boards. The purpose of the base-ten tasks was twofold—to demonstrate whether teachers had a generic acceptance of algorithms as “the” way to solve problems, and to demonstrate the difficulty that some children might face during their attempts to explain a system of tens, or base-ten with inadequate teacher support or facilitation.

This base-ten exercise served as a pre-assessment to understand teachers’ content and pedagogical knowledge relative to division, and multiplication. However, teachers incorporated their natural use of addition and subtraction skills—those employed as second or third grade learners. Within this session both groups began solving the problem using methods that were in direct contrast to found to be used by children naturally to solve addition problems, where there is little to no teacher intervention (Kamii 2000; Peterson et al. 1989; Swars et al. 2007). Rarely do young children naturally solve division or multiplication problems using algorithms as the teachers did. Rather, they focus on thinking about separating wholes into parts using real concrete objects.

Following this professional learning session, participants observed videotaped depictions of children solving problems using their own methods, most of which were facilitated by teachers who demonstrated keen knowledge of constructivist teaching practices (Kamii and Clark 2000). Before viewing the video, teachers were given specific tasks to complete to better understand the implications for the use of these practices to facilitate and support children’s development of mathematical knowledge. For example, teachers were asked to (1) observe keenly the methods children used in the video as they solve problems, and (2) to note the terminology used by children they explained their solutions. Teachers’ work also involved observing how children argued for positions. Iterations of children’s video-based arguments document their attempts to understand each other’s thinking and to arrive at potential solutions to problems posed during each session. Additionally, teachers observed children’s processes, which included children’s explanations presented during peer-to-peer arguments that followed their struggles to arrive at class consensus around strategies for problem solving and solutions (Kamii and Clark 2000). They were also encouraged to observe the teachers depicted within each video. Participants were asked to notice teacher’s role during children’s problem solving, and in doing so, record questions the instructor used to facilitate children’s thinking about number. They were asked to documents methods used to encourage rich dialogue during whole group discussions about the problems and solutions. This task had a profound impact on teachers’ pedagogical knowledge using professional learning focused on understanding and practicing methods children use to solve problems (Hill et al. 2004).

**Dangers of Introducing Algorithms Before Children’s Construction of Number**

The results of the professional learning experiences, as illustrated above, led project directors to introduce research findings that demonstrate the ill-effects of introducing algorithms to children before they construct their own knowledge about mathematics concepts. Findings show that children must be given multiple opportunities to connect any new knowledge about concepts to knowledge they have already constructed (Kamii 2000; Swars et al. 2007). This process allows children to understand and explain how a new concept is connected to their prior knowledge, thereby increasing the child’s ability to understand and apply the new concept to their own problem solving. In contrast, when children are asked to use algorithms invented by others, primarily their teachers, they are required to memorize specific orders of operation, and then decide when those memorized concepts might be used to solve a particular type of problem whether it be written as a word problem or posed as an algorithm. This process increases the complexity of problem solving, given that it diminishes the opportunity for teachers to amply facilitate the development of children’s logico-mathematical constructions. Thus, the child is unable to construct mathematical relationships between number concepts learned earlier to those he needs to grasp. Instead, the child is
forced to attempt to “remember” teachers’ steps or tricks used to “get the right answer” (Cobb and Wheatley 1988).

In conclusion, teacher participants were immersed in research-based activities suitable for engaging children in their own learning relative to number. They were presented with methods proven that impact teachers’ content and pedagogy knowledge, as well as research focused on how children learn math concepts across all Prek-2 and 3-5 standards.

Enhance Teacher Knowledge Related to Authentic Assessments

Developing skills needed to understand and use NCTM principles and standards to design effective mathematics lesson is important (Allexsaht-Snider and Hart 2001; Apple 1992, Cobb and Wheatley 1988; Fennema et al. 1996; NCTM 2000). Once teachers demonstrated their ability teach these concepts in peer group settings and reported such knowledge on teacher quality surveys, it was critical that they be able to determine their impact on student learning. Research indicates that even teachers who are adept at designing high-quality instruction need support developing assessments that match their mathematics lessons (NCTM 2000). Therefore, it was important to dedicate a portion of the professional development activities to assessment. This aspect of the project began with an evaluation of teachers’ current practices. Researchers also gathered samples of the assessments teachers used to understand student learning prior to their involvement in this study. This process led to the development of activities needed to bridge the gap between teachers’ current content knowledge and the knowledge needed to design effective assessments. Sample activities included the review and development of rubrics, checklists, and interview questions, which were directly related to specific mathematics lessons. The goal of each exercise was to help teachers understand the need for authentic assessments and how these tools can be used to assess student learning and inform future instructional practices and content.

Teacher Professional Learning-Scope and Sequence

It should be noted that while the teacher quality sessions were divided into the separate study of individual standards and principles for the sake of facilitating teachers’ acquisition of knowledge related to specific indicators within each standard, emphasis was placed on facilitating teachers’ understanding of stranding and integrating standards and principles to promote instructional efficiency and to facilitate student learning. We will begin with an examination of activities used to facilitate teachers’ understanding of each standard, starting with number and operations and concluding with a discussion about data analysis and probability.

Number and Operation

This portion of the professional learning focused on research-based strategies proven to impact teachers’ understanding of appropriate methods to assist children to “understand number systems, ways of representing numbers, relationships among numbers, and number system; understand meanings of operations and how they related to one another; and compute fluently and make reasonable estimates” (NCTM 2000). Teachers were immersed in the study of activities that facilitate children’s thinking in a way that supported their construction of number systems and operations. Using NCTM and NAEYC published texts and resources, teachers investigated how children’s knowledge progressed from constructing knowledge about rote counting and advancing to understand and use to rational counting to solve problems. They examined strategies children used to solve number and operation problem beginning with their use of invented methods, using concrete objects to performing mental operations. Emphasis was also placed on understanding the importance of accepting and using strategies and inventions children employ to solve problems associated with this standard. In doing so, we explored ways to design lessons associated with one-to-one correspondence, a critical concept that children must construct in order to eventually count rationally. Teachers worked to design naturalistic, informal and structured one-to-one experiences to ensure they could create lessons to meet all learners’ needs. Naturalistic experiences are those that require the adult to arrange the learning environment in such a way that encourages children to explore and initiate their own learning without structured direction from the teacher, whereas informal and structured experiences are designed in a way that require greater degrees of adult facilitation and adult-child interaction (Charlesworth and Lind 2007).

Acquiring knowledge about number and operations also requires teachers to build a keen sense about systems of tens, parts and wholes, ordering, time, logic and classifying as well as symbols. To assist teachers with their acquisition of this knowledge we began with an investigation of base-10 and designing lessons to help children construct knowledge about systems of ten (Schifter et al. 1999). We focused on base-10 blocks, Cuisenaire rods, creating and solving word problems using this content and other concrete materials that children might use to build models to represent number, and construct deeper understanding of number and operations.
Algebra

Similar to the strategies used to enhance teachers’ number and operations content and pedagogy knowledge, we began this session with a focus on the very foundation of children’s algebraic thinking and helped teachers to make connections between algebra concepts across second and third grade levels. We initiated an examination of patterning and how children’s acquisition of these skills can lead to their development of the more complex knowledge they needed to solve for missing values such as “x” and “y.” The session ended with a focus on the connection between solving for missing values and solving algebraic equations (Charlesworth and Lind 2007; NCTM 2000). Activities included ordering number, patterning and building more complex models to represent number. Specifically, the key concepts for second grade and third grade algebraic teacher training were modeling simple equations, using symbols and properties of operations. We introduced the concept of using graphs and tables to help second grade children construct knowledge about algebraic thinking and placed an emphasis on the use of building and growing and extending patterns. Third grade teachers were introduced to activities that immerse children in the use of variables and interpretation of variables, which are concepts that require the acquisition of more logical thinking about complex algebraic problem solving (Guillaume 2005).

Measurement

The third standard addressed was measurement, and similar to the methods used to facilitate teachers’ understanding of algebra in the early grades, the project team began with the basic premise of how children think about and use measurement concepts prior to teacher intervention. Research was presented that indicated children in grades Prek-2 and even in third grade should in fact be encouraged to invent and use their own methods for solving their own problems (Kamii 2000). Incorporating activities that incorporated elements of these findings was critical. Therefore, strategies were presented with non-standard means for facilitating children’s understanding of measurement and tools for detecting what they already know about this concept. This was a crucial element to discuss given that at best, early childhood teachers graze over measurement as they encounter chapters in text that address this standard (Shephard and Smith 1989). Rarely is measurement integrated into the curriculum in a meaningful way that is sufficient for facilitating children’s acquisition of the knowledge they needed to build more logical measurement constructs in future lessons. To facilitate teachers’ understanding and implementation of appropriate content and pedagogy for teaching measurement at the second and third grade levels, we focused again on research-based recommendations endorsed by NCTM and NAEYC. The scope and sequence of measurement activities included measurement in context of real-life experiences, enabling teachers to describe measurable attributes, measurement processes, number systems, length, volume, telling time, and using values of coins at both grade levels. At the second grade level additional concepts of focus were weight; at the third grade level, we placed additional emphasis on area and temperature (Guillaume 2005). After teachers demonstrated their proficiency at designing effective measurement, we focused on threading the standards, i.e., addressing multiple standards in a single mathematics lesson.

Geometry

To sufficiently impact teaching and learning in measurement as well as geometry, teachers must be immersed in professional learning that emphasizes developmentally appropriate content and pedagogical knowledge (Guillaume 2005; NCTM 2000). Teachers must gain sufficient content knowledge about geometry, and be able to use appropriate pedagogy already proven to impact children’s construction of knowledge they will need to solve complex geometry problems. They must also be able to equip their students with the knowledge they will need to connect what they learn to more complex notions about geometry. Therefore, professional learning exercises for this session included two and three dimensional shapes and relationships at both the second and third grade levels. Location and spatial relationships, applying transformations, using symmetry, using visualizations, spatial reasoning and geometric modeling were concepts introduced to both teacher groups (Guillaume 2005). This session was intense and included ample number of small group activities so that teachers would have the opportunity to have rich, meaningful and even argumentative dialogue about the standard and corresponding principles.

Data Analysis and Probability

Because data analysis and probability concepts require the construction of knowledge about multiple concepts, including skills needed to make decisions regarding how to gather and using data to solve problems, we delved deeply into the study of daily routines proven to facilitate children’s acquisition of such knowledge. An emphasis was on constructing and solving problems based on children’s interests, and incorporating scenarios related to real-life contexts (NCTM 2000). In order to solve such rich problems, it was critical that teachers understood appropriate pedagogical strategies for teaching possibility, probability,
data collection and data analysis methods. Therefore, we focused on activities that incorporated the examination of “features of data sets,” reading and interpreting graphs, designing investigations and representing data graphically during the second and third grade teacher training. Finally, we included a study of predictability and probability relative to data sets second and third grade teachers developed (Guillaume 2005).

Despite the fact that an ample amount of time was devoted to the immersion of teachers in the study of each standard individually, more emphasis was placed on equipping them to apply their knowledge in meaningful ways, such as designing developmentally appropriate lessons that facilitated the study of multiple mathematics standards.

Methods

Subjects

Teacher participants were randomly selected from a group of prequalified prospective participants from nine experimental school sites ($n = 30$). Descriptive statistics for the participants included the following: 29 females (12 Caucasian and 17 African–Americans), and one male (African–American). The sample included 13 participants who participated in each of the 3 years of professional learning. Data were collected on all participants but analyzed and reported for the 13 participants with sustained participation for the sake of this study. For comparison purposes, a future study will include data from participants who were involved in the study for either 1 or 2 years. Teachers taught at the second and third grade level and were evenly distributed between both grades. Sites were selected based on the school’s average percentage of impoverished students. Poverty was defined using the definition established by the United States Department of Agriculture, which is based on family size and annual income (USDA 2004). This criterion is the same used by schools to determine family eligibility for free and reduced-priced lunches. Qualified school sites were those with poverty levels of at least 60%. Because most schools within this school district met this criterion, the nine schools with the highest poverty levels were selected; those with poverty levels exceeding 80%.

Students Impacted by Teacher Participants

Approximately 260 students were impacted by the 13 teacher participants from the sample group each project year (1–3). According to state demographics for the population of third graders at one school within the school district participating in the study in 2002 (pre-project data), there were 351 students who took the state’s mathematics assessment. Of those third grade students, 34.3% scored below basic (failed to meet standard); 43.1% scored at basic (meets standard); 13.6% scored at proficient (above standard); 9.1% scored at advanced. Altogether 65.8% met or exceeded standard during the 2002 academic year, the year immediately prior to the beginning of the project. Of the 351 students 88.8% receive subsidized meals and 11.2% pay full price (see Table 1).

Phase 1: Workshop Development

The first phase of the project involved garnering the support of a university Arts and Sciences mathematics faculty; collaborating with the school district’s interim superintendent, district mathematics coordinators, school principals, second and third grade mathematics teachers, second and third grade parents, and homework help-line assistants. During this phase the team members completed a plethora of project development tasks. The research team (a) reexamined and selected research-based strategies proven to impact teachers’ content and pedagogy knowledge; (b) collaborated with the school district, school administrators to identify and select schools that met all criteria, which included a minimum of at least 80% poverty level and third grade student populations where at least 35% of the children scored below basic on the state’s mathematics assessment; (c) garnered matching funds from the school district; (d) identified a training site; and (e) gained access to state mathematics scores for students taught by teacher participants.

Phase 2: Workshop Implementation

Initially, the project was scheduled to be implemented over the course of 5 years; however, the project lasted 3 years due to the relocation of a key program researcher. Each teacher agreed to (a) participate in the project over the course of 5 years; (b) attend a mandatory 3–5 day summer professional learning seminar; (c) collaborate with the research team and peer teacher participants during the academic school year. Collaborations included participating in focus group sessions, submitting sample lessons plans and interactive homework assignments, incorporating standards-based strategies into their math curriculum.

Table 1 Pre-project data, 2002 SC state mathematics assessment

<table>
<thead>
<tr>
<th>SC mathematics assessment criterion</th>
<th>Below basic</th>
<th>Proficient</th>
<th>Advanced</th>
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<tr>
<td>34.3%</td>
<td>43.1%</td>
<td>9.1</td>
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Procedures

This study is quasi-experimental by design. Both quantitative and qualitative data were collected. Data were analyzed by the research team and evaluators external to the project to increase the likelihood of an unbiased and professional data analyses. Descriptive statistics were gathered to determine frequency, means, and distribution of all data. Qualitative and quantitative data included teachers’ survey data to determine their current standards-based mathematics content knowledge; teachers’ survey data to compare their pre-post methods for instructing second and third graders. A repeated measures t-test was run on data collected from the surveys. Qualitative data also includes teacher focus group session to detect changes in teachers’ pedagogy and content knowledge.

Instrumentation

A South Carolina improving teacher quality survey was used, as required by the South Carolina Commission on Higher Education (SCCHE), as well as a researcher designed Improving Teacher Quality survey to gather data not requested on the SCCHE instrument. This tool was submitted to a panel of experts in early childhood education to evaluate its validity and reliability. After receiving feedback from the panel, the research team revised the survey and deemed it valid and reliable for collecting pertinent teacher content and pedagogy knowledge data. Possible responses on both teacher quality content knowledge surveys ranged from 1 to 5, one indicating “strong perceived ability” to prepare high quality instruction, assessments and homework for second and third grade students; five indicating the “weakest perceived ability” to prepare high quality mathematics instruction, assessments and interactive homework.

Results

Improving Teacher Quality survey data were coded and analyzed to uncover changes in teachers’ content and pedagogical knowledge. Pre- and posttest data results were aggregated and analyzed to determine if there was significant change in teachers’ beliefs about their ability to impact student learning. Pre- and posttest teacher content knowledge scored are presented in Table 2 in the form of means, standard deviation and n (see Table 2).

A repeated measures analysis of variance with one within-group factor (pre- and posttest) and one between group factor (pre- and posttest content knowledge test) was used to analyze the data. The analysis yielded a statistically significant difference in pre- and posttest content knowledge test scores, $F(1, 12) = 11.636, p < .005$. It can be seen from Table 1 that the mean scores for teacher participants decreased from the pretest to the posttest. Scores on the content knowledge test ranged from 1 to 5, 1 being the strongest and five being the weakest.

Project impact was demonstrated by examining significant changes in the participants’ content knowledge and pedagogical practices, which should result in increases in teachers’ ability to understand and use standards-based methods proven to impact student learning. All participants completed two pretest and two posttest improving teacher quality surveys. The scores from the sample group (13 teachers who participated in the project throughout its duration) for both tests were aggregated and analyzed. Five items on the formal, SCCHE instrument and five on the researcher developed survey tool examined teachers’ perceived ability to prepare and use standards-based instruction, assessments and homework. Posttest results indicated teachers perceived their ability to prepare instruction, assessment and homework to impact student learning was significantly better than their perceived abilities reported for the pretest. In fact, only 31% of teachers indicated that their ability to prepare interactive homework assignments, design assessments and engage students in instruction was effective on the pretest, while 78% deemed their ability to complete these same tasks “highly effective” on the posttest. No significant difference was found between the pre- and posttest results for selecting and using appropriate resources.

The multivariate test analysis revealed that there was a strong effect size of .492 (Pillai’s Trace).

Discussion

Involving teachers in sustained standards-based professional development aimed at increasing their content and pedagogical knowledge improves their ability to prepare and use effective instruction over the course of 3 years, thus enabling teachers to impact the learning of second and third grade students in their classes. Although there was not a statistical difference between teachers’ pre- and posttest

<table>
<thead>
<tr>
<th>Teacher content knowledge criterion</th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
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<tbody>
<tr>
<td>Pretest: content knowledge results: understands and uses effective approaches for increasing student learning</td>
<td>2.54</td>
<td>.660</td>
<td>13</td>
</tr>
<tr>
<td>Posttest: content knowledge results: understands and uses effective approaches for increasing student learning</td>
<td>1.9231</td>
<td>.27735</td>
<td>13</td>
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Table 2 Pre- and posttest teacher content knowledge, means SD and n
results reported for their perceived ability to select and use appropriate mathematics material, there was a significant difference between teachers’ pre- and posttest scores on the same test that reported their ability to design and use effective instruction, assessments and interactive homework. This may be the function of teachers’ eagerness to better understand methods they preconceived to be important for impacting student learning, such as instruction and assessment. It could be that teachers perceived that the ability to select and use appropriate resources was slightly less important than being able to design instruction and assess student learning, and thus there was no change in pre- and posttest results for this category. However, these findings provide sufficient evidence to (a) support professional development that immerses teachers in the study of children’s problem solving; (b) equip teachers to understand and use NCTM principles and standards to design instruction; (c) engage teachers in activities that result their understanding and use of NAEYC standards and pedagogy proven to impact teaching and learning, and (d) train them to design and use authentic assessments.

Equally important is the need to involve teachers who are not deemed highly-qualified in their field in intense, research-based, interactive mathematics teacher training. Teachers answered questions on the both content and pedagogy knowledge surveys related to professional development instruction they deemed most effective for improving their ability to design effective instruction. They indicated that becoming actively involved in the production of teaching material and engaging in rich peer-to-peer and peer-to-researcher dialogue was important. Viewing videotaped lessons and watching their peers teach was also deemed effective. These findings are supported by researchers’ conclusions (Cobb and Wheatley 1988; Hill et al. 2004) that teachers’ content and pedagogy knowledge can be affected by effectively designed, and ongoing instructional intervention. Teachers reported that engaging in peer-to-peer and peer-to-researcher dialogue following peer teaching and video-based demonstrations of appropriate teaching impacted their understanding of early childhood mathematics content and pedagogy.

One limitation is that the study was not a true experimental design; however, participants were randomly selected to participate in the study from a group of second and third grade teachers already pre-qualified for the program, and deemed suitable by the researcher and school district for engaging in project activities.

Implications

The implications for use of this research, which focused on improving teachers’ content and pedagogy knowledge are vast. Researchers, teacher educators and school administrators must consider working collaboratively to develop high-quality, standards-based professional development programs to be implemented over a sustained amount of time. Based on the results of this study, the components of the training should include ample focus in the following areas of study: (a) teachers’ cognition, understanding and use of effective strategies for facilitating children’s problem solving; (b) teachers’ knowledge about NCTM standards, NAEYC standards, and state mathematics standards; (c) teachers’ understanding and use of NCTM principles relevant for developing an appropriate math curriculum (i.e., technology, equity and etc.); and (d) mathematics content proven to impact teachers’ ability to design and use authentic assessments.

An overarching theme for all components of teacher professional development activities must be peer-to-peer interactions, peer-researcher interactions and teacher immersion in the development of standards-based instruction, assessments, and homework.

References


