The P-5 Mathematics Endorsement: Impacts and Lessons Learned

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The Context of K-5 Mathematics Education in Georgia

Teacher Preparation

Convinced of a causal relationship between teacher content knowledge and student achievement, the University System of Georgia changed a certification requirement for Early Childhood Education majors in 2002. Since then, pre-service P-5 teachers are required to complete four prescribed, rigorous mathematics courses. However, prior to 2002, P-5 teachers were able to earn certification having completed as few as one college-level mathematics course.

In-Service Teachers

Georgia education leaders recognized the importance of increasing in-service P-5 teachers' mathematics content knowledge in the work to improve student achievement and reduce achievement gaps in mathematics. As a result, faculty from the mathematics and mathematics education departments of University System of Georgia institutions of higher education (IHEs) joined members of the Georgia Department of Education and the Professional Standards Commission (PSC) to form the Georgia Mathematics Consortium in February 2003.

The Consortium developed a four-course, 12-credit hour sequence to provide in-service P-5 teachers with the knowledge and skills needed to competently teach the new Georgia Performance Standards (GPS) in mathematics. The four courses are *Understanding Numbers and Operations*, *Understanding Geometry*, *Understanding Algebra*, and *Understanding Data Analysis and Probability*.

Georgia IHEs that prepare teachers and Regional Education Service Agencies (RESAs) were invited to submit applications to the PSC to offer the P-5 mathematics endorsement. IHEs were also permitted to develop and apply for approval of their own endorsement programs. The University of Georgia (UGA) developed and received PSC approval for its endorsement program in 2004.

Partnership for Reform in Science and Mathematics

As stated on its website,

> the Georgia Partnership for Reform in Science and Mathematics (PRISM) is an initiative of the University System of Georgia designed to increase science and mathematics achievement for all P-12 students in order to improve their readiness for post-secondary education and careers by enhancing teacher quality, raising expectations for all stakeholders, and closing achievement gaps. Awarded to the University System of Georgia in 2003, the initiative is funded by a five-year, $34.6 million grant from the National Science Foundation (NSF) and is scheduled to be funded through the school year of 2008. (http://www.gaprism.org)

In 2003-04, 2004-05, and 2005-06 one PRISM strategy to increase student achievement and reduce achievement gaps focused on encouraging elementary teachers to earn the P-5 mathematics endorsement. For 2006-07 and 2007-08 that strategy has been rolled into the strategy to provide high quality professional development to P-12 mathematics and science teachers.

PRISM functions in four Georgia regions. One region, Northeast Georgia, achieved greater success than other regions in recruiting and retaining teachers in its endorsement program.

The Northeast Georgia PRISM P-5 Mathematics Endorsement

The P-5 Mathematics Endorsement courses offered through Northeast Georgia PRISM are keyed to Professional Standards Commission standards. The course descriptions include purpose statements, learning outcomes, course objectives (both mathematical content and pedagogy), as well as resources and instructional details. In the descriptions below, we focus on the learning outcomes and a few key objectives from the purpose statement. Numbers and Operations serves as a pre-requisite for the other courses, which can be taken in any order after satisfying the pre-requisite.

It is worth noting that although the content focus varies by course, several high-level goals remain consistent throughout the sequence. Those goals are as follows:

- Solve problems using multiple strategies, manipulatives, and technological tools; interpret solutions; and determine reasonableness of answers and efficiency of methods.
- Nurture collaboration, critical thinking, hands-on exploration, manipulative use, problem-based inquiry, technology utilization, and activity implementation addressing various learning styles and multiple intelligences.
- Select and use a variety of formative and summative assessment techniques to monitor student progress, gauge students' mathematical understanding, and interpret school-based progress.

Numbers and Operations

Learning outcomes are that all students learn to: (1) understand numbers, ways of representing numbers, relationships among numbers, and number systems; (2) understand meanings of operations and how they relate to one another; (3) compute fluently and make reasonable estimates; (4) demonstrate a deep understanding of how P-5 students learn mathematics and of the pedagogical content knowledge appropriate to P-5 mathematics teaching. Goals address major concepts in numbers and operations for P-5 mathematics, using multiple strategies for solving problems, a variety of critical thinking and collaboration skills, and using a variety of formative and summative assessment techniques.

Understanding Geometry

Learning outcomes are that all students learn to: (1) analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; (2) specify locations and describe spatial relationships using coordinate geometry and other representational systems; (3) apply transformations and use symmetry to analyze mathematical situations; (4) use visualization, spatial reasoning, and geometric modeling to solve problems; (5) understand measurable attributes of objects and the units, systems, and processes of measurement; (6) apply appropriate techniques, tools, and formulas to determine measurements; and (7) demonstrate a deep understanding of how P-5 students learn mathematics and of the pedagogical content knowledge appropriate to P-5 mathematics teaching. Nurturing collaboration and critical thinking and assessment remain in the goal statements, as well as broadening understanding of fundamental concepts of geometry and constructing and justifying arguments as well as interpreting solutions.

Understanding Algebra

Learning outcomes are that all students learn to: (1) understand patterns, relations, and functions; (2) represent and analyze mathematical situations and structures using algebraic symbols; (3) use mathematical models to represent and understand quantitative relationships; (4) analyze change in various contexts; (5) demonstrate a deep understanding of how P-5 students learn mathematics and of the pedagogical content knowledge appropriate to P-5 mathematics teaching. Goals address algebraic concepts, as well as solving problems with multiple strategies, collaboration and critical thinking, and using a variety of assessments.

Data Analysis and Probability

Learning outcomes are that all students learn to: (1) formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; (2) select and use appropriate statistical methods to analyze data; (3) develop and evaluate inferences and predictions that are based on data; (4) understand and apply basic concepts of probability; (5) demonstrate a deep understanding of how P-5 students learn mathematics and of the pedagogical content knowledge appropriate to P-5 mathematics teaching. Goals include "making decisions and predictions through collecting, representing, processing, analyzing and transforming data taken from real-world scenarios," as well as using multiple problem-solving strategies, nurturing critical thinking, and using a variety of assessments.

The Georgia Performance Standards: K-5 Mathematics

From the 1980s to the early 2000s, K12 education in Georgia was governed by the curricula that resulted from the Quality Basic Education (QBE) Act of 1985. By the late 1990s, the QBE curricula were widely seen as too broad and too shallow to allow for the effective education of students in the 21st century. Reflecting national trends, the Georgia Department of Education (GDOE) began developing the Georgia Performance Standards (GPS) in 2002.

As stated on the GDOE website (http://public.doe.k12.ga.us), the GPS are based on best practices that have proven effective in high-performing states and nations, and they will place Georgia schools and students at the top of the Southeast & the nation. The web brochure for the fifth grade (http://www.georgiastandards.org) states that by the end of fifth grade, students will be able to:

- Classify counting numbers by distinguishing characteristics (prime or composite, odd or even), find multiples and factors, and use divisibility rules
- Find equivalent fractions and add and subtract common fractions and mixed numbers
- Use <, >, or = to compare fractions
- Understand decimals as part of the base-ten number system and multiply and divide decimals
- Understand the meaning of percent and use percentages and circle graphs to represent and interpret statistical data Compute area and volume of simple geometric figures and measure capacity
- Understand congruence of geometric figures, and the relationship of circumference to diameter of a circle
- Represent and investigate mathematical expressions algebraically by using variables
- Compare and contrast multiple graphic representations of statistical data
- Use different strategies to solve problems, including he strategy of solving a simpler problem

Teachers began participating in professional learning to support implementation of the K-5 mathematics GPS in 2005-06. They will begin teaching those GPS in 2006-07.

Purpose

This study, a component of the evaluation of PRISM, had three purposes.

- First, test the hypothesis that elementary-school teachers who earn the P-5 mathematics endorsement (a) increase their knowledge and understanding of important mathematics required to effectively teach the K-5 mathematics GPS, and (b) change their teaching practices in ways that make those practices more reflective of the standards-based approach implicit in the GPS.
- Second, identify other impacts of earning the endorsement.

- Third, explain the greater success achieved Northeast Georgia PRISM compared other PRISM regions recruiting and retaining participants in the endorsement program.

Method

The study was conducted by two members of the PRISM evaluation team; one an internal evaluator, the other a regional evaluation liaison. Data, both quantitative and qualitative, were collected from course instructors and course takers using multiple methods, as follows.

- Pre-and post content assessments completed by members of cohorts one and two
- Group interviews with course instructors and teachers in cohorts one and two
- Questionnaire completed by teachers in cohorts one and two
- Observations in the classrooms of five teachers in cohorts one and two

Pre and Post Content Assessments

As a component of the evaluation of the effectiveness of the endorsement courses in contributing to the course-takers mathematics content knowledge, PRISM contracted with a mathematics-education professor at Emory University to develop assessments for each mathematics course. The assessments use items released from the Trends in Mathematics and Science Studies (TIMSS) and National Assessment of Educational Progress (NAEP) assessments. The TIMSS items were selected from those released from the 1994, 1995, and 1999 administrations. Some items had been administered to the eighth-grade student population and others to the 12^{th}-grade population. The NAEP items were also from eighth- and 12^{th}-grade student administrations and were chosen from released items from 1990, 1992, 1996, and 2003. The assessments included multiple-choice items, constructed-response items (one correct response), and extended constructed-response items (explanations, discussions, or other “no-one-correct-answer” tasks).

The professor who developed the mathematics assessments reported the criteria used for selection of specific items were first, to obtain an even distribution of items across the content areas of Numbers and Operations, Geometry, Algebra, and Data Analysis, and second, when a choice between closely related items was available, to select the item that had proven to be the most difficult for students. The rationale was that teachers should be proficient with the basic content and have sufficient pedagogical content knowledge of the typical difficulties their students experience to avoid those mistakes themselves. The assessments were not constructed to explicitly assess the content of the learning outcomes specified for the Northeast Georgia PRISM endorsement courses.

The pre- and post-assessments were administered by the regional evaluation liaison. They were scored, using the appropriate TIMMS or NAEP scoring guidelines, by the internal PRISM evaluator. A paired-sample t-test was used to test whether there was a significant difference ($p<0.05$) between the mean scores on each assessment.

Group Interviews

The authors conducted a group interview with three of the five course instructors shortly before the last meeting of the last course of the first cohort. The interview was conducted at a coffee shop outside of class time.

The authors also conducted group interviews with 10 of the 15 members of the first cohort and nine of the 12 members of the second cohort. At each interview, some participants joined the conversation after it had begun. Also, with the authors’ permission, two instructors “sat in on” the first cohort interview, and one instructor did so for the second. Each interview was conducted at the beginning of class time of the last meeting of the last course in the sequence.

The group interviews were loosely structured. The authors described their purpose as seeking to understand the impacts of the endorsement and invited the participants to describe and discuss those impacts. Follow up questions were posed as appropriate or when clarification was needed.

The interviews were not recorded. Each interviewer took notes, and the regional evaluation liaison gave copies of her notes to the internal evaluator. One author used thematic coding to identify key areas of change reported by the interview participants and wrote a draft of the impacts reported by the interviewees. The other author reviewed and revised that draft.

Questionnaire

Following the cohort interviews, the interviewees completed a short questionnaire based on an analysis of the data from the interview with the course instructors. The survey asked participants to use a four-point scale (1=little/no, 2=modest, 3=moderate, and 4=considerable) to indicate extent. For several items, participants were asked to provide the ratings for “before the courses,” and “now, after the courses.” The questionnaire encouraged respondents to use the back of the page to explain or elaborate on their answers, to make comments, and/or to offer suggestions.
The mean score and standard deviation were calculated for each item, and the written comments, of which there were few, were incorporated into the write up of the interviews.

Classroom Observations

After the other data were analyzed, the authors emailed the members of cohorts one and two. The authors stated they were to present a paper on the impacts of the endorsement and asked permission to observe the recipients during mathematics instruction. The authors explained, “We would love to see first-hand some of your new strategies in practice.” On very short notice, arrangements were made to observe five teachers who had earned the endorsement and participated in one of the group interviews. In addition, one teacher gave the authors permission to view the videotape of his teaching submitted as a requirement of the endorsement program.

Three of the observees teach lower elementary students (K-2) and three teach upper elementary students (3-5). Two observes teach in a small urban district, two in a suburban district, and two in a rural district.

Results

Analysis of the data indicated the course takers developed new content knowledge and changed their teaching practice. That analysis also suggested the course takers increased the level of student engagement in their mathematics lessons, changed their beliefs about the capabilities of students, and became mathematics leaders in their schools.

Content Knowledge

Pre- and Post-Assessments

The mean 100-point post-assessment scores were significantly higher than mean 100-point pre-assessment scores for each course at the $p=0.05$ level for paired sample t-tests. Means, standard deviations, change scores, and p values are presented in Table 1.

Table 1. *Pre- and Post-Assessments: Mean Scores*

Course	N	Mean 100-Point Score			Standard Deviation		Statistically Significant Difference in Means?	p
		Pre	Post	Change	Pre	Post		
Numbers and Operations	26	72.6	81.1	8.5	17.0	14.9	Yes	0.000
Algebra	25	52.0	64.8	12.8	18.7	16.2	Yes	0.000
Geometry	24	64.5	73.4	8.9	21.4	17.2	Yes	0.000
Data Analysis	21	77.0	83.9	6.9	13.9	11.9	Yes	0.009

Interviews

The instructors reported the sequence of courses contributed to the course takers mathematics content knowledge. They provided the following examples of weaknesses in content knowledge corrected in the class.

- One teacher was convinced that the ratio of the area of quadrilateral to its perimeter is a constant.
- There was general confusion about the classification of quadrilaterals; for example, the belief that a square is not a rectangle.
- Several teachers were unable to use protractors and even rulers correctly; for example, one teacher reported a reading of 4 and 3/16 of an inch as 4.3 inches.
- Several teachers had difficulty with the concept of three-dimensional (cubic) units; for example, asked to create one-, two-, and three-dimensional models of a given unit, one teacher did not maintain the length of the unit in the three-dimensional model. Also, teachers initially had difficulty understanding the number of cubic feet in a cubic yard.
- There were misconceptions about the meaning of the equal sign (=) in an equation. Teachers tended to interpret the sign as meaning “the answer is to the right” rather than “is the same as,” which leads to less confusion for students when called on to tackle concepts in algebra.

The teachers were asked if they had developed new mathematics content knowledge or had misconceptions clarified in the courses. There was general agreement that the *Numbers and Operations* course had been of great value in fostering the teachers’ fundamental understanding. Another said she had learned much in the *Data Analysis* course that, though not applicable to her students, would be of great help to her in analyzing test data. The *Algebra* course was excellent, said another. Although few specific examples of new content knowledge were given, teachers did mention partial products and a deeper understanding of the equals (=) sign.

There was some criticism of the geometry course from members of the first cohort. One of those teachers said it was a long time since she “had the basics,” and the course did not always provide a bridge to the new content. The course instructor had stated during the instructors’ interview that she was aware of the criticism of the course, and revisions would be made for the second cohort. No criticisms of the geometry course were made during the second-cohort interview.

Referring to all the courses, there was agreement that some of the content was too difficult, “too far above our heads,” and not specifically relevant to P-5 mathematics. One interviewee in the first cohort suggested the courses might focus on content at the middle-school level rather than the high-school level. A member of the second cohort gave a written comment with the wish that content presented be specific to elementary math. Another wrote, “I would like to have had more specific grade-level materials for elementary school students.”

Questionnaire

Three items on the questionnaire related to content knowledge. The responses to each item indicate that completing the courses increased the teachers' content knowledge.

First, participants were asked to rate "the extent to which you increased your math content knowledge by taking each of the following courses." As shown in the Table 2. below, the *Numbers and Operations* course was credited with making the greatest contribution (mean = 3.74, standard deviation = 0.56), followed by *Algebra* (3.63, 0.60), *Data Analysis* (3.42, 0.77), and *Geometry* (3.00, 0.88). The table also shows that 78.9 percent of respondents chose "considerable" to rate the extent to which they increased their content knowledge by taking *Numbers and Operations*. The corresponding percentages for *Algebra, Data Analysis, and Geometry* were 68.4%, 57.9%, and 36.8%, respectively.

Table 2. *Questionnaire Data: Content Knowledge*
To what extent did you increase your math content knowledge by taking each of the following courses?

Course	Mean Score	Standard Deviation	Increased Content Knowledge to a Considerable Extent
Numbers and Operations	3.74	0.56	78.9%
Algebra	3.63	0.60	68.4%
Data Analysis	3.42	0.77	57.9%
Geometry	3.00	0.88	36.8%

N=19, 1=little/no 2=modest 3=moderate 4=considerable

Because of criticism of the geometry course during the first cohort interview, the questionnaire data for this item were disaggregated by cohort. That analysis showed the second cohort rated the geometry course more favorably than did the first. For the second cohort, the mean score on the four-point scale was 3.22 (S.D. = 0.97) with 55.6% of the respondents saying the geometry course increased their math content knowledge to a "considerable" extent. The corresponding data for the first cohort were 2.80 (0.80) and 20.0%.

Second, the 19 participants rated their after-the-courses mathematics content knowledge 1.21 points higher than their before-the-course content knowledge. (Before: mean (standard deviation) 2.42 (0.51); After: 3.63 (0.5)) No teacher rated his/her math content knowledge as "considerable" either before or after the course sequence. However, the percentage of respondents rating that knowledge as "moderate" increased by 21.1%, from 42.1% before to 63.2% after the courses.

Finally, the respondents were asked the extent to which they believed completing the course contributed to their ability to effectively help all their students master the math GPS. Eighteen of the 19 respondents checked "considerable." The 19th said the courses had little or no impact.

Changes in Teaching Practice

Interviews

By reflecting on class discussions, submitted work products (units, videos, and journals), and conversations overheard between teachers, the instructors identified changes in the teachers' classroom practices. Those changes were as follows.

- Journaling
- Assignments made
- Reactions to wrong answers

- Questions asked and classroom dialog
- Acceptance of multiple ways to solve problems

Teachers in both cohorts spoke enthusiastically and at length about the impact of the courses on their teaching practices. Participants agreed all students, from special education to gifted, benefited from the new pedagogies implemented as a result of completing the courses. "I can reach the low achievers and challenge the high," said one teacher. "I teach special education, and my kids are enjoying math more," said another. To a great extent, the changes in practice described by the teachers mirrored those identified by the instructors.

In addition to those discussed below, the teachers made several comments that suggested their practice had changed to better reflect implementation of standards-based learning environments. Those comments included the following.

- I was able to let go of the book.
- I learned new ways to reach kids.
- The textbook has become one resource.
- I am so much more familiar with the GPS.
- I am more aware of correct terms and procedures.
- Sometimes I think I owe my former students an apology.
- I don't teach isolated math. I make everyday connections, and I make them early.
- I am a lot more confident in teaching the standards rather than just going by the book.
- I posted the standards…. I found kids discussing them, looking to see what they had done.

Journaling

The teachers' use of journaling as a learning opportunity had clearly increased. One interviewee said her math teaching now involved "a lot more writing." In response to a follow-up question about the use of student journals in mathematics, every interviewee in the first cohort joined in the enthusiastic group answer that, yes, they now used journals. Teachers in both cohorts gave examples of the value of student journals, including the following.

- Students use journals (a) to explain their mathematical reasoning, (b) to ask questions they did not want to pose in public, and (c) as references; they go back to their journals to look up things forgotten.
- Teachers use journals to understand student mathematical reasoning and misconceptions and to provide private feedback to students.

One teacher said some students who were unwilling to demonstrate their mathematics knowledge and skills publicly welcomed the opportunity to do so in the privacy of their journals. Another noted some students were better at explaining themselves in writing than verbally. A third reported she now emphasized rather than skipped the "Write About It" assignment in the text. That, she said, reflected her focus on problem solving and comprehension and de-emphasis of memorization and computation.

On the questionnaire's four-point scale (1=little/no, 2=modest, 3=moderate, and 4=considerable), the mean score for use of journals in mathematics classes "before the courses" was 1.84 with a standard deviation of 0.90. The mean for "now, after the courses" was 3.58 (SD = 0.61), a gain of 1.74 points. From another perspective, there was a 57.9% increase (from 5.3% to 63.2%) in the teachers reporting they used journals to a considerable extent. There were 19 responses.

Assignments

The interviewees identified a number of ways the kinds of assignments they used in math had changed. The interviewees gave the following examples of the characteristics of their new assignments.

- Puzzles rather than problems
- Real-world connections
- Problem-based
- Math talk
- Hands-on
- Writing
- Fun

The questionnaire included an item that asked the teachers to rate the extent to which they used/use projects in math that "involve the collection and analysis of data before the courses and now, after the courses." With 19 responses, the "before" and "after" means were 2.26 (SD = 0.99) and 3.32 (SD = 0.82) for a gain of 1.06 on the four-point scale. The number of respondents who said they used such project to considerable extent increased from 5.3% to 68.4%, an increase of 63.1%.

Wrong Answers

The interviewees confirmed their responses to wrong answers had changed. For example, one teacher said she now used wrong answers as a "platform to go forward." Her students now knew to examine incorrect work to understand where "it had gone wrong." Another stated her new approach allowed students to say, "I got it wrong, but I know why." That, she said, allowed students to take ownership of their own learning. A third teacher reported she now looked for more than correct answers when grading papers, she wanted to know how her students got their answers, right or wrong. The questionnaire did not address teachers' responses to wrong answers.

Questions and Dialog

The questions and teacher-student, student-teacher, and student-student dialog in the interviewees' classrooms had changed. One interviewee said she now focused more on "the big questions" than she had in the past. She explained she now knew how to frame questions to get "richer answers." Another teacher reported becoming "a facilitator, a listener, a learner, not a dominator." That, she stated, helped her students to be more comfortable and to take ownership of the classroom. The students no longer saw themselves as the audience, she said.

Words such as "feel," "believe," and "conjecture" had become part of mathematics, according to one interviewee. Another said she now saw math as talk. "Kids are excited, talking, explaining," said another. One teacher expressed her new conviction that students must be able to articulate their math learning if they were to own, rather than rent, that learning.

Several teachers stated the kinds of the questions they asked had expanded. One stated, "[M]y goal to write and use questions that needed more knowledge and deeper thinking was met with these classes." Others provided the following in examples of the types of questions they now posed.

- How do you know?
- Why do you think that?
- What's another way to do that?
- Can you show me what you did?

One teacher stated she was greeted with "blank stares" when she first posed such questions. Students expected them now, she said.

Several teachers in the second cohort described initial resistance by gifted students to the new emphasis on “math talk” in their classes. One teacher suggested gifted students were “good memorizers” who wanted to be held accountable only for their answers, not their thought processes. She said those students were becoming more comfortable talking about math.

The questionnaire included an item that asked, “To what extent did/do your questions in math focus on conjectures and explanations before the courses and now, after the courses?” The difference between the means was +1.78 points on the four point scale. (N=19; pre mean (SD) = 1.84 (0.90); post mean (SD) = 3.63 (0.50)). There was a 63.1% increase in the percentage of respondents who said their questions focused on conjectures and explanations to a “considerable” extent, from 5.3% to 68.4%.

Multiple Ways

Several interviewees provided evidence their acceptance of multiple ways to solve problems had increased. Those included the report that the question “What’s another way to do that?” was now frequently heard. Another noted students now understood there is often more than one way to “get at the answer.”

In rating the extent to which they encouraged and accepted different ways to solve math problems, the teachers’ “before” mean was 2.47 (SD = 0.77) and their “after” mean was 3.89 (SD = 0.32), a gain of 1.42 points on the four-point scale for the 19 responses. There was an 84.2% increase, from 5.3% to 89.5%, in the respondents who assigned the rating of “considerable” in their responses to this item.

<u>Classroom Observations</u>

The observed teachers demonstrated the teaching practices described to the authors by the instructors and the interviewed members of cohorts one and two. Thus, the data, summarized in Table 3 below, validated the conclusion that the cohort members’ teaching practice had changed to better reflect the standards-based approach implicit in the K-5 mathematics GPS.

Table 3. *Summary of Observational Data*

	Teaching Practice				
Observee	Journaling	Assignments	Wrong Answers	Questions & Dialog	Multiple Ways
1		Yes	Yes	Yes	
2		Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes	Yes
4		Yes	Yes	Yes	Yes
5	Yes	Yes		Yes	Yes
6 [1]	Yes	Yes	Yes	Yes	Yes

[1] Based on analysis of videotape submitted as a requirement of the endorsement program

Journaling

Journaling was evident during three of the six observations, by children ranging from kindergarteners to upper elementary students. One group of early elementary students who were working on addition were directed to “take out your math journals and draw a math sentence that shows two sets that come together to equal six.” An upper elementary teacher drew a triangle on the electronic board, and said, “I want you to write some conjectures about triangles. Things you know, things you don't understand that you'd like answered."

Assignments

Students were not observed engaged in mathematics projects. However, in each observed classes students did engage in other types of assignments reported by the interviewees. For example, each teacher used hands-on assignments that required problem solving. Those assignments ranged from collecting data by drawing colored chips from bags in an exploration of probability to the manipulation of Cuisenaire rods in a lesson in which kindergarten students were assigning number values to the rods.

Students were observed working on a rather traditional worksheet in one of the six observed lessons. That worksheet was a component of the preparation for a mathematics competition, but it was the focus of only a part of the observed lesson. For the bulk of the lesson, the students worked in pairs to solve a series of sophisticated problems.

Wrong Answers

There were zero incidents in the observed lessons where a student gave an incorrect answer and the teacher simply identified that answer as wrong and then either gave the correct answer or asked another student to respond. A variety of responses to incorrect answers were observed. Those included the following.

- Providing a hint. "Look around the room. Do you see anything that might help?"
- Asking the student to reconsider. "Think about that. I'm coming back to you on that in a minute."
- Asking the class to signal whether or not they agreed with the answer, and then asking one student who did not agree to explain why not.
- Asking follow-up questions to guide the student's thinking. For example, asked to explain the term addends, an early elementary student responded, "Five plus five is ten, ten is the addends." The teacher responded, "What do we call the answer to an addition?" The student said, "The sum." The teacher asked, "In five plus five equals ten, what is the ten?" The student identified it as the sum, not an addend. He still could not explain the term, but he did know an addend was not the sum.

Questions and Dialog

In each observed class, there were multiple examples of students asked to explain the reasoning behind their answers, and the students appeared to be very accustomed to such questions. Examples included.

- Why did you say to count by 10s?
- What would happen if we…?
- Why did you do that?
- How did you know that?
- Show us how you got that.

Students in each observed class were encouraged to work together, to talk each other. For example, students in one upper elementary class were journaling and the teacher said, “When you get finished, share with your partner what you wrote.” As he walked around, the teacher observed two students discussing their entries and said, “I hear good conversation over here.” In another upper elementary class, the students worked in pairs to solve problems and there was constant student-student talk. In that case, the teacher had not encouraged or given permission for such talk, it was simply the norm. In a lower elementary class, students were grouped in fours to tackle a problem using manipulatives. Their teacher repeatedly encouraged them to share ideas with each other.

Multiple Ways

It was evident during five observations that multiple approaches to solving problems were valued. For example, in an early-elementary class, students were asked to make two groups of six tiles. At one table, one student lined up two rows of six tiles and other made two two-by-three blocks of tiles. The teacher said, “I see people finding lots of ways to make six” In another early-elementary class where students were working on probability, the teacher said, “Now, A..., you said you figured out a different way to do it. Show us.” In an upper-elementary class, students first found common denominators using matrices and then using an algorithm. Students were solving problems using fractions in a second upper-elementary class. That teacher said, “I want to see different ways. Write down how you worked them.”

Other Impacts

In was the specific intent of the study to identify and describe the impact of the endorsement on teachers’ practice and content knowledge. However, the study also sought to identify other impacts, and the data suggested student engagement in the participants’ math classes increased, their beliefs about student capabilities changed, and they took on leadership roles within their schools.

Student Engagement

The course instructors identified increased K-5 student engagement in mathematics lessons as one impact of the courses. There were no specific references to student engagement during the interview with the first cohort. However, the second cohort did discuss and provide evidence of increased engagement. For example, one interviewee referred to the partnership for learning she had established with her students. Another spoke of her students becoming comfortable with writing and talking more about math; with struggling with math.

The questionnaire included the item: “To what extent were/are your students actively engaged in their math lessons before the courses and now, after the courses?” That item produced a gain in the means of 1.21 points, from 2.68 (SD=0.82) to 3.89 (SD=0.46). There was an increase from 15.8% to 94.7%, or 78.9%, in the percentage of “considerable” responses on the four-point scale described for other items. There were 19 responses to this item.

Student engagement was high in each observed class, and that engagement was not the result of close monitoring or rigid discipline. To the contrary, teacher attention was often focused on individual or small groups of students. During such times, the norm was for the other students to continue work on the task at hand.

Belief About Student Capability

The instructors reported teachers had developed new appreciation of the ability of students to learn complex mathematics. That contention was supported by one teacher who said she learned "elementary students can handle a lot more than I thought." Her statement produced general agreement but also the caveat that students "knew a lot less than we thought." Discussion of that comment revealed the teacher had been surprised, once she began to probe understanding, how often students could apply algorithms with no understanding of the underlying mathematics. It was evident in the observed classes that teachers expected students to develop ways to solve problems, not just apply memorized algorithms.

The questionnaire included the following item. "To what extent did/do you believe your students can learn and understand sophisticated, but grade-appropriate, mathematics?" With 19 respondents, the "before" mean was 2.84 with a standard deviation of 0.77. The "after" mean was 3.95 with a standard deviation of 0.23, for again of 1.11 points in the mean on the four point scale (1=little/no, 2=modest, 3=moderate, and 4=considerable). There was a 73.6% increase (from 21.1% to 94.7%) in the number of responses that indicated belief to a "considerable" extent that students can learn and understand such math.

<u>Leadership</u>

Several teachers described leadership roles they assumed in the mathematics programs at their schools as a result of the courses. Examples given included the following.

- Other teachers who checked to see if new approaches they were considering "fit with what you're learning in class"
- A teacher saying she had become a "resource teacher," because "kids go back (to their other classes) and talk."
- A request to "talk with" teachers at same the grade level and those one grade above and below
- Another teacher duplicating the learning centers used by the participant
- A request to present a model lesson
- Leadership in writing GPS units

At one school where he was conducting a classroom observation, the author was met by an instructional lead teacher. That ILT stated the whole faculty greatly appreciated the lessons learned the observee had brought back from the endorsement program.

Additional Observations, Limitations, and Future Research

Though the data strongly indicate these classes did indeed increase content knowledge and result in changed pedagogical practices, some critical contextual factors require noting. The classes were offered in all four PRISM regions, but only one region was able to successfully recruit and retain participants. That region departed from the planned model in ways that seem to have affected participation in the classes. Variants included (1) offering the programs through a RESA (Regional Education Service Agency) rather than the local university and (2) choosing high school mathematics teachers with advanced degrees as instructors, rather than university mathematics or mathematics education faculty. The first decision reduced enrollment barriers: had the classes been offered through the university, the teachers would first have had to be enrolled in a graduate program with stringent admission requirements.

The second decision affected participants' perceptions of the relevance of the courses. In the group interview, participants emphatically stated they would not have enrolled in courses taught by higher education faculty. When pressed, they said "possibly" the right College of Education faculty, but "definitely not" a faculty member from the Mathematics Department. While intimidation about the content might seem an obvious reason, their rationale was very different. In their view, pedagogy – how to teach the material – was a critically important part of the courses, an element they felt could be better addressed by another P-12 teacher, even one at a different school level.

Pay raises were projected for in-service teacher who completed the endorsement sequence when PRISM first designed this strategy. Those raises did not materialize. Difficulty recruiting and retaining teachers in the endorsement program in other PRISM regions can in part be attributed to the lack of incentives to complete such a demanding and time-consuming course sequence. Northeast Georgia PRISM, the region successful with respect to this strategy, offered significant stipends for teachers to take these courses. More research is needed on the extent to which the changes implemented in Northeast PRISM affect recruitment and retention.

In addition, examining other contextual or structural components of the course may be useful. For example, it would be interesting to compare and contrast outcomes documented for the Northeast Georgia PRISM with those resulting from the program offered by North Georgia College and State University (NGC&SU), the only other successful program know to the authors. In the NGC&SU program, the endorsement is imbedded in advanced degree programs and taught through condensed, intensive summer courses.

In considering the question "why did these courses succeed where others didn't," the authors looked at Appreciative Inquiry (AI), which focuses on examining areas of success (Preskill, 2004; Christie, 2006). Beyond using AI as a philosophical underpinning for questions, the specific protocol for an Appreciative Inquiry could prove beneficial in research on future cohorts or in looking at comparisons with other programs.

Summary

This study suggests that completing the P-5 Mathematics Endorsement resulted in the following impacts.

- The teachers' mathematics content knowledge increased.
- The teachers' practices changed to better reflect the standards-based instructional model explicit in the K-5 mathematics GPS.
- The teachers developed higher expectations for students' ability to learn sophisticated grade-level appropriate mathematics.
- Many of the teachers assumed new leadership roles in their schools' mathematics programs.
- Student engagement in mathematics learning increased through increased thinking, talking, and writing about mathematics.

References

Christie, C. A. (2006). Appreciative inquiry as a method for evaluation: An interview with Hallie Preskill. *American Journal of Evaluation*, *27*(4), 466-474.

Preskill, H. (2004). The transformational power of evaluation: Passion, purpose, and practice. In M. Alkin (Ed.), *Evaluation Roots* (pp. 343-355). Thousand Oaks: Sage.