Impact on Student Achievement of Teacher Participation in K-8 Mathematics Professional Development.

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Abstract
The purpose of this study is to determine the impact on student achievement of elementary school teachers who participated in professional development in the content area of mathematics. Teachers participated in professional development courses and have accumulated a range from three to eighteen total credits from the summers of 1998 through 2007. The impact is measured by student achievement data collected on standardized tests.

Introduction
Beginning in the summer of 1998 regional teachers were invited to the campus of Bemidji State University (BSU), a small regional university in northern Minnesota, to participate in professional development in the content area of mathematics. The initial "math camp" was funded by federal money from the US Department of Education through the Minnesota Higher Education Services office. These funds have continued to support professional development of teachers in northern Minnesota through the summer of 2009. Teachers from many districts participated in the professional development; however, this study examines student achievement data from only one district.

Professional Development of US Mathematics Teachers in Grades K-5
The statement: "mathematics education in the United States needs some work" is putative! The mathematics education faculty at BSU sought to develop a professional development program in 1998 for elementary mathematics teachers in grades kindergarten through eight to address this national need on a regional level. Elementary school teachers generally are responsible for teaching several content areas; however, the focus of this program is exclusively mathematics. A professional development program at BSU was designed with these goals in mind: challenge teachers' traditional beliefs on teaching mathematics, be long term in nature, and fit the demographics of our region. One of the most influential groups in the U.S. calling for changes in mathematics teaching is the National Council of Teachers of Mathematics (NCTM) with their *Standards* documents (NCTM, 2000; NCTM, 1995; NCTM, 1991; NCTM, 1989). The professional development program at BSU was designed to follow the vision promoted in the NCTM standards documents and implement many of the lesson activities from the NCTM's *Navigations* series and National Science Foundation funded reform curricula (Hirsch, 2007).
Loucks-Horsley, *et. al.* (2003, p. 35) indentify the following features of professional development based on what researchers know of learning. They are:

- make useful connections between teachers' existing ideas and new ones;
- provide opportunity for active engagement, discussion, and reflection to challenge existing ideas and construct new ones;
- situate the learning in contexts teachers find familiar;
- challenge current thinking by producing and helping to resolve dissonance between new ideas and existing ones;
- support teachers to develop a range of strategies that address learning for all students.

In addition to challenging ideas about teaching, and how to teach mathematics, the program was designed to help teachers develop the specialized mathematical knowledge (Ball, Hill, & Bass, 2005) necessary to teach mathematics well. The professional development program addressed this need by using the following pedagogical model multiple times in each course: engage teachers in a mathematical activity, then follow it through to its conclusion, which involved multiple solution methods being described, explained, and examined, then analyze where the teachers struggled and where students would stumble in elementary and middle school classrooms.
To maintain engagement in one particular course, participants played games where keeping score looked surprisingly like addition. After several of these activities, participants no longer saw a set of rules or steps for the addition algorithm but rather a concrete understanding of place value and the concept of addition. Also, professional discussions took place where the university instructors discuss

current research findings and policy issues relevant to mathematics education in the state and nation, including international comparisons.

A Long-term Professional Development Program in Mathematics

The program was designed to encourage K-8 teachers to pursue further study in mathematics. The overwhelming impression of the program designers was that having a series of professional development courses culminate in a master's degree would be necessary to encourage participants to persevere through the professional development series. The program was designed to have coursework on the following topics:

- algebra (patterns and functions)
- number sense
- assessment
- educational psychology.
- geometry
- probability and data
- discrete mathematics

The five process standards (problem solving, reasoning and proof, communication, connections, and representation (NCTM, 2000)) are addressed in each mathematics course by the manner in which the course is taught and instruction modeled. As an external program reviewer observed: "I was constantly struck by the parallels of the content of these courses with recommendations of the standards documents" (Martin, 2005, pg. 3). Each course was team taught by two instructors in a three week block on-campus with a face-to-face delivery method. Classes met five days each week for approximately three hours each day. One focus in the program was to have teachers actively engaged in doing mathematics and making sense of the solutions (Timmerman, 2003); hence, the three hours each day were filled with activities appropriate for the K-8 mathematics classrooms to which the teachers would be returning in the fall.

Loucks-Horsley *et. al.* (2003) make it clear that excellent professional development takes time; hence, the designed program would optimally occur over several years of the teachers' careers. Teachers begin with a wide variety of mathematical backgrounds and experiences, then study mathematical content and processes relevant to the K-8 mathematics classrooms. The program aligns well with both state and national content standards (Martin, 2005) while also addressing the process standards from the NCTM.

Professional Development in a Rural Setting

Any pragmatic professional development program must consider the geography of the participants. This program was designed for a small state university in rural northern Minnesota. The Minnesota Office of Higher Education (2008), using census data, identified the eighteen neediest school districts in the state of Minnesota and sixteen of them reside in the service region of BSU. In addition to high rates of poverty, the challenge of covering a large geographic region of the state also exists. Many of the teacher participants in the professional development program need to either drive long distances daily or reside in residence halls during the professional development coursework.

While on-campus teachers work collaboratively to develop a mathematical community with the goal of improving student learning (Timmerman, 2003). When they return to their classrooms in the fall, the teachers are often isolated from the professional community which the mathematics program attempts to promote. The professional development program may provide the only source of professional connections to our teachers and thus the cooperativeness of our program receives even more attention. Most teachers in BSU's service region are financially limited and thus the professional development program needs to be financially accessible to teachers. To address this financial concern, grant funding for the coursework was sought and obtained. The "math camps" were funded by federal money from the US Department of Education through the Minnesota Higher Education Services office. Courses were taught during the summer when teachers were able to be out of their classrooms and, if necessary, away from home. Timmerman (2003) noticed that elementary school teachers frequently lack confidence in their mathematical abilities, possess a procedural knowledge of the subject, and may have negative attitudes or even anxiety toward mathematics; hence, the courses were designed, and taught, in an intentionally welcoming and relaxed atmosphere to actively engage teachers in a long-term professional development program.

Purpose of this Study

The purpose of this paper is to describe the impact on student achievement of teacher participation in professional development in the content area of mathematics. The degree program was approved during the 2005-2006 academic year but participants began taking coursework in 1998. The courses

evolved over the first several offerings but have now been sufficiently revised to represent a "final form" even though small improvements continue to be made with each offering. At this point, no teachers from the studied district have completed the requirements for the K-8 mathematics master's degree program, so this study focuses on the student achievement of teachers who have participated in some of the available coursework.

Research Methodology

This study utilizes Measures of Academic Progress (MAP) test data from the Northwest Evaluation Association. The MAP test data are norm referenced and this study analyzes data from the fall and spring testing sessions. The student achievement data that are available at this time are only grades K-5. Data from academic years 2000-2001 through 2006-2007 were obtained from one school district where teachers earned between zero and eighteen credits of the mathematics course offerings. The district averages *n*=73.3 elementary teachers and *n*=1686.6 elementary students each year (see Table 1).

Year	1st	2nd	3rd	4th	5th	Total	# of Teachers
'00-1	328.4	344.6	342.7	376.1	424.6	1816.4	97.50
'01-2	331.8	327.8	318.6	336.7	373.1	1688.0	76.00
'02-3	310.0	325.1	325.1	322.5	356.2	1638.9	64.00
'03-4	324.0	303.1	335.6	325.6	319.4	1607.7	64.34
'04-5	338.0	337.8	307.7	339.0	329.3	1651.8	68.27
'05-6	335.6	330.0	329.1	311.8	335.0	1641.5	70.00
'06-7	339.4	343.5	355.4	340.8	325.3	1704.4	71.00
'07-8	335.0	348.0	347.0	360.0	354.0	1744.0	75.00

Table 1: School District K-5 Attendance

The K-12 student population in the 2007-2008 academic year reported 19.6% minority students and 48% students of poverty and 14.8% of students qualifying for special education services. This study is looking for a relationship between teacher participation in the summer mathematics program and their students' achievement in mathematics.

Teachers were coded as 0 for having not participated in the mathematics professional development offerings, 1 for having participated in the past, and 2 if they participated in the future. For instance, a teacher who participated in 2004 would be coded 2 for the years 2000-2004 then coded 1 from 2004-2007 upon completion of their first credits from BSU. Teacher and student data are presented in Table 2.

Year	0 – No Math PD				1 – Past Math PD				2 – Future Math PD			
	#Teachers		#Students		#Teachers		#Students		#Teachers		#Students	
	Fall	Spr	Fall	Spr	Fall	Spr	Fall	Spr	Fall	Spr	Fall	Spr
2000-1	0	0	0	0	0	0	0	0	0	0	0	0
2001-2	0	0	1163	1178	0	0	0	0	0	0	0	0
2002-3	46	0	1240	1141	4	1	0	25	4	5	0	135
2003-4	31	44	1093	1085	5	4	97	100	3	4	105	106
2004-5	47	46	777	1107	5	5	125	127	2	3	73	79
2005-6	46	47	1121	1121	4	5	131	126	3	2	51	50
2006-7	51	47	1158	1173	7	5	109	131	0	2	75	52

Table 2 – Teacher and Student Participation in Mathematics Professional Development (PD)

Results

The computer program SPSS, version 16.0, was used to analyze the data. Student achievement data was a composite mathematics score which is an aggregate of number sense, algebra, geometry, measurement, and data sub scores. Initially the question "is there a difference between participation and no participation?" was examined. The group coded 0 (no participation in math program, mean = 199.50, N=14,803) was run against the group coded 1 (participants, mean = 211.97, N=1,149) using a two-sample unequal variances *t* test. The test was very significant (P-value = 0.000). These data clearly indicate that student mathematics achievement is different in the group whose teachers participated in the professional development when compared to the students whose teachers did not participate. Next, the question "is there a difference between no participation and future participation?" was examined. The group coded 0 (no participation in math program, mean = 199.50, N=14,803) was run against the group coded 2 (future participation, mean = 208.31, N=726) using a two-sample unequal variances *t* test. The test was significant (P-value = 0.000). These data clearly indicate that student

mathematics achievement is different in the group whose teachers did not participate in the professional development when compared to the students whose teachers would be future participants. Finally, the question "is there a difference between past participation and future participation?" was examined. The group coded 1 (participants, mean = 211.97, N=1,149) was run against the group coded 2 (future participants, mean = 208.31, N=726) using a two-sample unequal variances *t* test. The test was very significant (P-value = 0.000). These data clearly indicate that student mathematics achievement is different in the group whose teachers had participated in the professional development when compared to the students whose teachers would be future participants.

Conclusions

The data indicate that students whose teacher participated in the summer mathematics institutes achieved significantly higher when their teacher had participated in professional development than students whose teacher had not participated in professional development. This result does not explore the relationship between the number of credits of professional development taken by a teacher and achievement by students; however, there exists an opportunity for future research in this area.

Next, we compared the teachers who did not participate in any professional development (0) with the teachers before they did participate in professional development (2). Here again the data indicated differences in achievement between students of the two groups of teachers. We hypothesize that the teachers who participated in the professional development sessions were more highly motivated people, or had fewer personal distractions, enhanced general teaching skills from the beginning, or other desirable characteristics. These attributes would be independent and unrelated to the professional development.

The next hypothesis examined compared students of teachers before the teachers participated in professional development and after the teachers participated in professional development. The students will have matriculated to different grades, so the student-teacher association will change through time; however, the teacher's professional development is the variable of interest. Here again the data indicate student achievement increased with teacher participation in professional development. The teachers in these two groups should be, on average, equivalent on many confounding variables such as teacher motivation and other general teaching skills.

Limitations

The authors realize that the variability of number of credits taken ranges from zero to eighteen and is a large range. It is difficult to expect a small number of credits to have the same impact as a large number of credits on teacher performance and further study needs to be done in this area. This study did not have access to data indicating teacher experience. This variable may prove illuminating in future studies.

Additionally, it will be interesting to explore if the positive impact of the professional development fades as time passes. Perhaps it is a treatment that "wears off" over time and teachers need to revisit their professional development.

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