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Teacher Professional Development in Mathematics and Student Achievement:

A NAEP 2005 Analysis

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Abstract

This paper reports on a study conducted on the National Assessment of Educational Progress (NAEP) 2005 database. The purpose of the study was to examine predictors of student achievement using middle school mathematics teacher professional development items as criterion variables, such as the number of mathematics courses taken, the number of mathematics education courses taken and professional development in various pedagogical strategies. A multiple regression analysis was conducted on the eighth grade database. The results indicated that a statistically significant association was found between the number of mathematics courses taken and student achievement, and that the number of mathematics education courses was not associated with student achievement. Moreover, a statistically significant association was found for the amount of professional development where students of teachers who reported receiving a small amount of professional development tended to have higher achievement. The relationships for other professional development activities are also reported. Recommendations include that middle school mathematics teachers should receive a small extent to a moderate extent of professional development with the areas of mathematical theory and applications of mathematics, content standards, the use of curriculum materials, the use of calculators for developing mathematical concepts and strategies for assessing student learning.

In the era of the No Child Left Behind [NCLB], a focus has been placed on teacher quality. For in-service teachers, the law allows states flexibility in setting standards that define what it means to be highly qualified. These teachers may pass a certification test, have a college major or states may use some other mechanism, whereby the High Objective Uniform State Standard of Evaluation provision permits states to allow their teachers to demonstrate content knowledge through experience, college coursework, or professional development (NCLB, 2001). The intent is that these mechanisms will provide effective and knowledgeable teachers. There has long been a debate as to what constitutes effective teaching. One measure is look at student performance. This paper presents findings related to middle school mathematics teachers' professional development and student achievement.

Knowledge for Effective Teaching

What knowledge is necessary for effective teaching? According to Darling-Hammond, (2001), teachers need knowledge in specific domains, an understanding of general human development and learning, knowledge of the effects of curricular approaches and teaching strategies for special instances and circumstances, and knowledge of assessment resulting in insight into students' understanding. This knowledge is echoed by 10 principles established by the Interstate Teacher Support and Assessment Consortium [INTASC] (1992) for beginning teachers. They include understandings related to how children learn, how children differ in their approaches to learning, using various instructional strategies that foster critical thinking, and problem solving, and understanding how to use formal and informal assessment strategies.

As NCLB implies, content knowledge is a necessary component of effective teaching. Reform efforts in mathematics teaching have been encouraged since the National Council of Teachers of Mathematics [NCTM] (1989) published, "Principles and Standards for School Mathematics." Hence, content knowledge plays an important role in how reform efforts are implemented. Ball, Lubienski, Spangler-Newborn, (2001) contend that the degree to which mathematics instruction is effective through the use of reform ideas, using new curriculum and strategies, and new content, depends on the teachers' knowledge of mathematics.

NCLB calls for middle and secondary teachers to pass rigorous State certification tests in mathematics and/or have a major in mathematics. Yet, in a review of 57 studies conducted by Wilson, Floden, and Ferrini-Mundy (2002) which focused on research in teacher preparation, there were no reports identified by the group that directly related prospective teachers' subject matter knowledge with student achievement. Four of seven studies were identified relating to mathematics teacher subject matter knowledge. Wilson, Floden and Ferrini-Mundy summarized that a positive relationship existed between teachers' subject matter knowledge and higher student achievement. The authors further noted that certification test scores and grade point averages only contributed to a very small amount of the variance associated with teacher performance of prospective secondary teachers, whereas, education course work account for a much a larger percentage of the variance, ranging between 39% to 48%. They concluded that education coursework is an essential ingredient in teacher performance. Regarding subject matter course work, there is little effect on student achievement when teachers report having more than four to six courses. An apparent landmark study conducted by

Monk (1994) found a threshold effect where there was a little improvement in student achievement when teachers took more than 5 undergraduate mathematics courses and that mathematics education courses contributed more to student achievement gains than undergraduate mathematics courses. These findings suggest that both undergraduate mathematics content and mathematics education courses are necessary to positively affect student achievement with mathematics education courses having a greater impact.

Early studies related to teacher preparedness and effectiveness have found that teachers who are more fully prepared through teacher education and licensing were more effective in their fields than those teachers who did not have as much professional education from elementary school level to secondary mathematics and science (e.g., Ashton & Crocker, 1986, 1987, Begle, 1979; Darling-Hammond, 2001). In contrast, Wilson, Floden, and Ferrini-Mundy (2002) revealed that research on pedagogical preparation is very scarce, with little or no studies having been conducted on the relationship between pedagogical preparation and student learning or teacher behavior. They concluded that because of inadequate measurements, it is unclear as to the degree of this association, showing some benefit for pedagogical preparation. Pedagogical preparation includes instructional methods, learning theories, educational measurement and testing, and educational psychology.

Overall effects of pedagogical preparation may be measured by comparing certified to non-certified teachers (Wilson, Flodden, Ferrini-Mundy, 2002). There are very few studies that examine this issue. However, Wilson, Flodden, and Ferrini-Mundy reported that one study found that students of certified mathematics teachers scored higher on certified tests than those of uncertified teachers, another study found that the

higher the percentage of teachers in a school with emergency certificates was associated with lower mathematics student achievement. Yet Wilson, Flodden, and Ferrini-Mundy reviewed another study which found that the higher percentage of fully certified teachers in a state was associated with higher student achievement in mathematics and reading. In contrast, another study found no difference in student achievement of students who had teachers with certification and those who held temporary or emergency certificates. The important influence of pedagogical preparation was identified in an interpretive study where secondary teachers with no pedagogical preparation were limited in their ability to engage students in instruction (Darling-Hammond, 2000; Felter, 1999; Goldhaber & Brewer, 2000; Grossman, 1989; Hawk, Coble, & Swanson., 1985). What role does teacher education courses play? Kagan (1992) surveyed veteran teachers and found that teacher education courses experienced by those teachers were thought to be of little or inconsequential use to them in practice. Many teachers viewed them as irrelevant and had to learn how to teach on their own in their school (Zeichner, 1988).

The value of the impact of teacher education coursework is reported to be inconclusive due to research methods used, small sample sizes in interpretive studies (Wilson, Floden, Ferrini-Mundy, 2002). However, as a predictor, education coursework was better in predicting teacher success than subject matter coursework (Wilson, Floden, Ferrini-Mundy). Hence, the research on the effect of teacher education courses and teacher performance appears to be scarce in quality.

Professional Development

Staff development in education is often viewed as being fragmented, on a need basis, and relatively superficial. Professional development for inservice teachers is an expensive endeavor, and teachers may experience workshops that do not directly address their needs, making them a waste of time and money (Cohen & Hill, 2000; Heaton, 1992; Wilson, Lubienski, & Mattson, 1996). Professional development is rarely considered developmental because there is no curriculum that addresses teachers' learning and the practices they are to enact, and associated mathematical practices (Heaton, 2000). Although professional development is an expensive endeavor, professional development is a critical aspect of teachers' professional life.

The National Council of Teachers of Mathematics [NCTM] established standards for the professional development of mathematics teachers (1991) and revised in a recent publication (NCTM, 2007). The council contends that professional development should focus on five standards: (1) Teachers' mathematical learning experiences, (2) Knowledge of mathematical content, (3) Knowledge of students as learners of mathematics, (4) Knowledge of mathematical pedagogy, and (5) Participation in career-long professional development (p. 109). This last standard that focuses on professional development encourages mathematics teachers to examine and revise their assumptions about the nature of mathematics, how it should be taught, and how students learn mathematics, to observe and analyze various approaches to mathematics teaching and learning related pedagogical strategies such as selecting tasks, classroom discourse, environment, and assessment, to work with a diverse range of student abilities and backgrounds, and analyze and evaluate the appropriateness and effectiveness of their

teaching (NCTM, 2007). Smith, Desimone, and Ueno (2005) conducted a study using the 2000 National Assessment of Educational Progress data set. The researchers examined the relationship between teacher quality and the use of reform-oriented instructional strategies. They found that teachers holding a regular or temporary certificate is not associated with an increase emphasis on conceptual teaching goals and that teachers who participate in content related professional development activity are more likely to emphasize conceptual learning goals and conceptual learning strategies. The current study differs from Smith, Desimone, and Ueno's study in that these researchers used professional development as a whole, examining the relationship between the number of workshops and professional development hours with other teacher credential variables while this study examined the relationship of the extent of different professional development activities with student achievement. Hence, the purposes of this study were to determine, which is a better predictor of student achievement, content knowledge,or mathematics education knowledge, and to determine the relationships between various standards-based oriented professional development activities and student achievement.

Research Questions

1. What is the relationship between student achievement and the degree of teacher mathematics content knowledge?
2. What is the relationship between student achievement and the degree of teacher mathematics education course work?

3. Which variable contributes most in a multiple regression analysis teacher mathematics content knowledge as measured by the number of courses, or teacher mathematics education course work?
4. What is the impact of professional development activities related to standards-based instructional methods on student achievement?

Method

Data

To examine the relationship between teacher quality indicators and professional development opportunities correlated with student achievement, data were complied using the 2005 National Assessment of Educational Progress database. The analysis was conducted during a training workshop sponsored by the National Center of Educational Statistics. The NAEP database contains data on student achievement for fourth, eighth, and twelfth grades national samples. This study used the eighth grade data set (U.S. Department of Education, 2000, 2006). A stratified national probability sample of over 100,000 eighth grade students, and their teachers are included in the sample. The teachers of the students are administered a survey that asks about their educational background. For this study, aspects of teacher preparation in mathematics content and in mathematics education, along with participation in professional development activities were examined to determine relationships between specific teacher background and professional development activities on student achievement. The data for this study included responses from teachers whose students were selected to be tested. This allows

researchers to examine relationships between teacher background characteristics and their students' achievement.

Sample

NAEP uses a complex sampling design. In this design, schools are sampled from each geographic region, students are selected from each selected school. Oversampling is used to make sure that there is a sufficient number of schools that are small in number like private schools, rural schools and those with high concentrations of Black or Hispanic students (U.S. Department of Education, 2001). To adjust for oversampling, sampling weights are used in order to generalize to the population of eighth grade teachers.

Measures

Multiple regression analyses were conducted using variables such as the number of mathematics courses and mathematics education courses controlling for Gender and Ethnicity to the Composite Mathematics Plausible Value. For this report, only the Composite Plausible Value will be presented as the criterion variable. Also, the survey addresses various professional development topics that teachers reported attending such as, training in how students learn, learning about mathematics theory, training in the use of curriculum materials, training related to instructional strategies, use of manipulatives, using calculators, training in assessment, training in how to teach diverse students, training on state mathematics assessment. The NAEP survey asks teachers about the extent that they spend in professional development workshops or seminars during the prior year, Not at All, Small Extent, Moderate Extent or Large Extent. Note, the author

could not determine the specifics related to each category. The NAEP teacher survey included only those categories without an explanation as to the number of hours within each category.

Results

Both multiple regressions and t-tests, with Bonferroni adjustments, were conducted. T-tests were conducted to determine differences in mean performance for students whose teachers experienced various professional activities. Table 1 presents results for the multiple regression with type of course and the composite mathematics score as variables, controlling for Gender and Ethnicity. Females student performance was negatively associated with achievement when compared to males. Hispanic, Black, and American Indian students' performance was negatively associated with achievement when compared to White students, while Asian/Pacific Islander students' performance was positively associated with achievement. Students whose teachers reported taking mathematics courses was associated with higher achievement, with teachers reporting taking five or more mathematics classes having a larger impact on the model. The number of mathematics education courses had a slightly negative or no impact on the model.

Insert Table 1

about here.

Table 2 presents regression results for teachers reported professional development hours and Composite Plausible Value. Students whose teachers reported receiving a large extent of professional development training were associated with lower achievement scores. While those students whose teachers reported experiencing a Small to Moderate Extent had little to no effect on the relationship to achievement.

Insert Table 2

about here.

Table 3 presents results for t-tests comparing Composite mean scores of students whose teachers reported no professional development, in various categories, to those students' Composite mean scores whose teachers' reported attending professional development in a Small Extent, Moderate Extent, Large Extent.

The results indicated that students of teachers reporting a Small Extent of training in how students learn mathematics scored higher than those students whose teachers reported receiving professional development at a Moderate or Large Extent. Similarly, students whose teachers reported receiving a Small Extent of Professional Development in Mathematics Theory and Applications scored higher than those students whose teachers attended professional development at a Moderate or Large Extent. Regarding professional development in mathematics content standards, the mean score were higher for students whose teachers attended workshops on content standards at each level when compared to those students' teachers who received not training in content standards. The

means for students whose teachers reported a Small Extent of training in content standards was 281.9, a Moderate Extent was 279.0 and a Large Extent 280.0.

A small extent of training in curriculum materials produced greater achievement than teachers who received no training in curriculum materials. The differences were not statistically significant for a Moderate Extent or Large Extent. The means were 281, 280, and 280, respectively. Students of teachers who reported a small extent of professional development in the use of curriculum materials, with mean of 281, scored higher than those who received no training. The students' performance tended to decrease as the extent increased with means for a Moderate Extent was 280, and a Large Extent was 279.

Students of teachers who reported a Small Extent of professional development in the use of manipulatives performed at the same level as those not receiving professional development in manipulatives. Those students whose teachers reported a Moderate, with a mean of 279, and a Large Extent, with a mean of 278, of professional development performed at a lower level than those who teachers received no professional development in manipulative use with means of 282.Students of teachers who reported a no professional development in the use of calculators did worse, with a mean of 278, than those students whose teachers reported a Small Extent, Moderate Extent, or a Large Extent of professional development with means of 280, 281, and 281, respectively.

Students of teachers who reported a Small Extent of professional development in assessment of students in mathematics, with a mean of 281 performed at the same level as those teachers who did not receive professional development in assessment, with a mean of 281. The students whose teachers who received either a Moderate Extent, with a

or a Large Extent of professional development performed lower than those whose teachers did not receive training with a means of 279 and 278 respectively.

Finally, students of teachers, regardless of the extent of professional development performed worse than those students whose teachers received no training in teaching diverse students. The mean for students whose teachers did not receive the professional development was 284, while the means for those students whose teachers reported a Small Extent, Moderate Extent and a Large Extent were 281, 276, 271.

Discussion and Conclusion

The results showed that mathematics teacher content knowledge had a greater impact on student achievement than mathematics education course work. This finding corroborates early research (e.g. Darling-Hammond, 2001). There is a strong association between teachers' content knowledge and student achievement. Future studies should address this relationship through the use of quasi-experimental or casual comparative methods.

Although professional development may be conducted in a variety of ways such as, study groups, curriculum development, mentoring (Loucks-Horsley, et al., 1998) but commonly it is in a form of workshops, seminars, college course work (Garet, Birman, Porter, Yoo, & Desimone, 2001). The variables selected for this study were chosen because they represent aspects or categories of activities for professional development that are thought to improve teacher performance as reflected by student achievement.

The findings of this study, regarding middle school mathematics teacher preparation, are surprising. It appears that, overall, middle school students whose

mathematics teachers receive only some extent of professional development performed better on the NAEP than those who had received moderate to large extent of training. This brings to light the question, how much professional development is enough and what should be the focus of the professional development? The findings suggest that, overall, too much professional development may reduce student achievement.

The study reveals that perhaps some professional development topics need more time spent on training than others. The findings show that although content knowledge is important for teachers to possess, any more than a small extent of professional development in this area is associated with lower achievement when compared to teachers not receiving any training. Similarly, professional development in how students learn tends to adversely affect student achievement beyond a small extent of training as compared to no training at all.

Professional development topics that include training in content standards, the available curriculum materials, instructional methods for teaching mathematics, and effective use of calculators in mathematics instruction where found to be positively related to student achievement when compared to no professional development as long as teachers received a small extent of professional development in these areas. A surprising result is students of teachers who received a small extent of professional development in methods for assessing students performed at the same level as teachers receiving no training at all, while students whose teachers received more than a small extent of training were found to have lower achievement. This may imply professional development in methods of assessment may be ineffective. Likewise, another surprising result was professional development in strategies for teaching mathematics to students

from diverse backgrounds, including English Language Learners, produced student achievement levels lower than if teachers received no training at all in this area regardless of the extent of the training they received.

In summary, the findings suggest that teachers should receive a small extent of training in order to produce student achievement levels at a higher level than not receiving training at all. It appears that going to a moderate level can have the potential to lower student achievement. These results seem to answer the question, How much professional development is enough? And yet, it raises more questions. Why did students of teachers who reported receiving professional development in dealing with diverse students score worse than those who did not receive this training? Perhaps those teachers were teaching that particular group and they are low performing students. It would be advantageous to conduct a follow-up study to examine once the training is receive how is it implemented and what are the effects on student achievement. Another question raised is why did students of teachers who received professional development in methods for assessing students beyond a small extent have lower achievement levels? The answer is not clear. Further research is needed to tease out the nuances of this finding.

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Table 1

Overall Score (Composite Value) Regression Estimates

Parameter Name (R-square = 0.18)	Estimate	Standard Error	z-Score	$p > \|z\|$
Constant	281.99	0.89	315.98	0.00
Gender (Males)	-1.88	0.26	-7.31	0.00
Ethnicity (White)				
Black	-34.23	0.53	-64.86	0.00
Hispanic	-24.90	0.36	-68.88	0.00
Asian/Pacific Islander	3.29	0.20	3.59	0.00
American Indian/ Alaskan Native	-25.3	1.00	-25.35	0.00
1 or 2 Mathematics Courses	4.44	0.78	5.69	0.00
3 or 4 Mathematics Courses	4.89	0.73	12.12	0.00
5 Mathematics Courses or more	13.07	0.66	19.93	0.00
1 or 2 Mathematics Education Courses	-0.67	0.77	-0.88	0.38
3 or 4 Mathematics Education Courses	-0.14	0.80	-0.17	0.87
5 Mathematics Education Courses or more.	0.49	0.78	-0.64	0.53

Table 2

Regression Results of Overall Professional Development and Achievement

Parameter Name	**Estimate**	**Standard Error**	**z-Score**	**p >** $\lvert z \rvert$
Constant	280.733	0.749	374.801	0.000
Amount of Professional Development (Not at all)				
Small Extent	0.479	0.887	0.540	0.589
Moderate Extent	-1.243	0.829	-1.499	0.134
Large Extent	-2.107	1.00	-2.106	0.035

Table 3

T-test Results for the Extent of Professional Development and Students' Composite Score.

Parameter 1	**Parameter 2**	**Mean 1**	**Mean 2**	**Standard Error\difference**	**df**	**T-statistic**	**p > t**
How students learn math							
Small Extent	Moderate Extent	281.212	279.490	0.543	123	3.169	0.002
	Large Extent	281.212	278.626	0.738	121	3.502	0.001
Professional Development in Mathematics Theory or Applications							
Not at all	Small Extent	280.974	281.093	0.59	122	-0.200	0.841
	Moderate Extent	280.974	278.93	0.699	119	2.924	0.001
	Large Extent	280.974	277.995	0.916	110	3.251	0.001
Professional Development in Content Standards							
Not at all	Small Extent	277.608	281.875	1.300	108	-3.283	0.001
	Moderate Extent	277.608	279.737	1.176	120	-1.810	0.073
	Large Extent	277.608	279.975	1.190	123	-1.989	0.049
Professional Development in Curriculum Materials							
Not at all	Small Extent	278.718	281.159	0.941	119	-2.593	0.011
	Moderate Extent	278.718	279.528	0.973	123	-0.832	0.407
	Large Extent	278.718	279.974	0.896	119	-1.400	0.164
Professional Development in Instructional Methods							
Not at all	Small Extent	279.513	281.142	0.873	114	-1.866	0.065

	Moderate Extent	279.513	280.329	0.917	122	-0.889	0.38
	Large Extent	279.513	278.632	1.010	116	0.873	0.384
Professional Development in the use of manipulatives							
Not at all	Small Extent	282.022	281.336	0.806	121	0.850	0.415
	Moderate Extent	282.022	278.492	0.909	120	3.882	0.001
	Large Extent	282.022	278.248	0.953	110	3.960	0.001
Professional Development in the use of calculators							
Not at all	Small Extent	278.195	280.421	0.603	121	-3.693	0.001
	Moderate Extent	278.195	281.840	0.725	117	-3.648	0.001
	Large Extent	278.195	280.548	0.929	117	-2.532	0.013

Professional Development in assessment of students in math							
Not at all	Small Extent	280.798	281.801	0.755	122	-1.329	0.187
	Moderate Extent	280.798	279.038	0.781	121	2.255	0.026
	Large Extent	280.798	277.328	0.929	107	3.735	0.000
Professional Development in teaching students from diverse backgrounds							
Not at all	Small Extent	283.646	280.656	0.561	121	5.333	0.000
	Moderate Extent	283.646	275.732	0.612	121	12.93	0.000
	Large Extent	283.646	272.114	1.077	121	1.68	0.000