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ABSTRACT

Researchers investigated the relationship between the American Federation of Teachers' Thinking Math (TM) professional development program and mathematics achievement of 5th grade students in an urban school district in the northeast. Four schools were studied; 3 had TM trained 5th grade math teachers. Questionnaires gathered demographic data and teacher self-evaluation of the influence, efficacy, and implementation of 7 TM principles. Student achievement was measured by Stanford Achievement Tests and the Pennsylvania State System of Assessment. Findings are based on 37 questionnaires from TM trained teachers and 203 student records. The TM program and, specifically, having a 5th~grade TM math teacher, had positive effects on mathematics and reading achievement scores. TM training's effect on teacher confidence and implementation varied across the principles. (Author)

THINKING MATHEMATICS AS PROFESSIONAL DEVELOPMENT

Thinking Mathematics as Professional Development: Teacher Perceptions and Student Achievement

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Abstract

Researchers investigated the relationship between the American Federation of Teachers *Thinking Math* (*TM*) professional development program and mathematics achievement of 5th grade students in an urban school district in the northeast. Four schools were studied; 3 had *TM* trained 5^{th}-grade math teachers. Questionnaires gathered demographic data and teacher self-evaluation of the influence, efficacy, and implementation of 7 *TM* principles. Student achievement was measured by Stanford Achievement Tests and the Pennsylvania State System of Assessment. Findings are based on 37 questionnaires from *TM* trained teachers and 203 student records. The *TM* program and, specifically, having a 5^{th}-grade *TM* math teacher, had positive effects on mathematics and reading achievement scores. *TM* training's effect on teacher confidence and implementation varied across the principles.

Thinking Mathematics as Professional Development:

Teacher Perceptions and Student Achievement

The research study was designed and conducted by educators from the Scranton, Pennsylvania School District and Marywood University. The Scranton School District, whose urban student population exceeds 8000, includes 18 schools (13 elementary) and over 700 teachers. Fifty-four percent of its students are designated as economically disadvantaged, contrasting with Pennsylvania's mean of 31%. Nearly one fourth of elementary-age students residing in Scranton attend private schools.

The Scranton Federation of Teachers, Local #1147 of the American Federation of Teachers (AFT), had collaborated with the Scranton School District for 15 years in the sponsorship of site-based professional development programs for educators. Among several of the Educational Research and Dissemination (ER & D) initiatives, AFT's *Thinking Mathematics (TM)* programs had been nationally recognized and positively received by Scranton teachers since its 1995 introduction. Given this local history, the state and national interest in identifying factors that relate to mathematics performance, and Pennsylvania's introduction of high stakes elementary math testing in the mid 1990s, an assessment of the *TM* program was timely.

The primary purpose of this research project was to determine the effect of the AFT's *Thinking Mathematics* professional development program on the mathematics achievement of 5^{th}-grade students and on teacher efficacy and implementation in mathematics instruction. Student achievement in mathematics was measured by the corresponding Stanford Achievement Test *(SAT9)* and Pennsylvania System of School Assessment (PSSA) scores, while teachers' self-report measured efficacy and classroom practices.

Literature Review

Because of the particular interest in student mathematics performance on the PSSA as it relates to the AFT's *Thinking Mathematics* training, we examined representative research literature on mathematics achievement, professional development, and *Thinking Mathematics* itself.

Mathematical Achievement

Concern about the mathematical achievement of United States students has been persistent, widespread and serious over the past two decades. *A Nation at Risk*, released in 1983, made clear the anxiety of a prestigious panel that schools were failing to hold American students, especially adolescents, to standards of performance that would enable them to compete internationally. From a similarly competitive stance, the National Education Goals, formulated by U.S. governors in 1989, committed the nation to raise achievement in science and mathematics substantially, so that American youngsters would be recognized as first in the world in these subjects. But, as if anticipating the struggle to effect such goals, the 1989 National Research Council's *Everybody Counts* contended that "Evidence from many sources shows that the least effective mode for mathematics learning is the one that prevails in most of America's classrooms: lecturing and listening." (Summary, p. 12)

In the same year, the National Council of Teachers of Mathematics (NCTM) published curriculum and evaluation standards; it released teaching standards in 1991. In a revision, some 11 years later, NCTM tied "the future well-being of our nation and people" not only to "how well we educate our children generally", but also to "how well we educate them in mathematics and science specifically". (2000, p. 4) Particularly significant for teachers and students in Pennsylvania was the Commonwealth's concurrent development of math standards tied closely to the content emphases of NCTM. As an accountability indicator, the state designed a standards based, criterion-referenced assessment system, the Pennsylvania System of School Assessment (PSSA), which was initially administered to all 5th, 8th and 11th-grade students in the mid-1990s.

The mathematics education policy publications already mentioned were not the only ones to distinguish the closing years of the 20th Century. Findings from the *Third International Mathematics and Science Study* (TIMSS) were released by the National Center for Educational Statistics (NCES) in 1997, following examination of 1995 assessment data from over one half million students in more than 40 countries. Mathematics scores for U.S. 4th-graders were above the international average, but comparative results for 8th and 12th-graders were much weaker, with U.S. high school scores among the lowest. The announcement was heard by many as an alarm echoing *A Nation at Risk*, almost 15 years before. Indeed, the National Commission on Mathematics and Science Teaching for the 21st Century (commonly known as the Glenn Commission), entitled its 2000 report *Before It's Too Late.*

Formation of the Glenn Commission had been announced on the 30th anniversary of the first moon landing, with the charge of "setting the stage for advancement in mathematics and science for the next thirty years". (p. 2) Its findings affirmed the significance of math and science, deplored students' accomplishment in those fields, and cited the crucial role of effective teachers, whose ability depends on "sustained, high-quality professional development". (p. 5)

Mathematical proficiency was again targeted in the 2001 report, *Adding it Up.* This National Academy publication defined central strands of proficiency to include "conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition". (p.5) In a sweeping statement, the 2002 report of the RAND Mathematics Study Panel asserted that "the mathematics performance of U.S. citizens has never been seen as satisfactory." (p. *xi*) Without doubt, professional concern about how to enhance mathematics achievement continues. So, too, does interest in sustaining, across their career span, teachers' competence in promoting student learning.

Professional Development

Recent academic publications have viewed effective professional development as critical to the existence of self-renewing, learning institutions such as schools. For example, in its 2000 report on science and math, the Glenn Commission asserted the direct link between effective teaching and accomplished learning, concluding that, "A focused professional development experience led by qualified teachers, mentors, and colleagues is the indispensable foundation for competence and high-quality teaching." (p. 18) With similarly high expectations for mathematical proficiency, *Adding it Up* (2001) contended that "preparing to teach is a career-long activity…that needs to be generative…Studies of teacher change indicate that short-term, fragmented professional development is ineffective for developing teaching proficiency." (p. 430)

Several reports on ongoing teacher learning, while not examining ER&D or *TM* formats specifically, nevertheless are quite relevant to those modes of training. A 1995 claim by Deborah Loewenberg Ball, crediting Suzanne Wilson, warned against undue confidence: "The work of professional development is as uncertain as practice itself…our understanding of professional development that can support teachers' learning is a mix of myth, belief, and conjecture." (p. 42) Corcoran (1995, p. 4) agreed that no consensus exists, but he did establish some guiding principles and pointed out common failings, including lack of focus, intensity, follow-up and continuity. Ball later collaborated with Linda Darling-Hammond to offer several premises for improving teacher learning. Noting that their tenets are not usually characteristic of professional development opportunities, the authors contended that, "A great deal of what teachers encounter as professional development does not consider them as learners, is not designed to help them develop over time, does not focus on the content or students whom they teach, and does not offer opportunity for focused analysis and reflection. Moreover, most professional development is conducted at a distance from the materials and problems of teachers' work." (p. 16)

Contrasting with that ineffective format of professional development is the list of quality indicators recently endorsed by James Stigler in an interview with Scott Willis: "Today, people believe that professional development should be targeted and directly related to teachers' practice. It should be site-based and long-term. It should be ongoing-part of a teacher's workweek, not something that's tacked on. And it should be curriculum-based, to the extent possible, so that it helps teachers help their students master the curriculum at a higher level." (2002, p. 6) Elmore, writing for an Albert Shanker Institute publication, also in 2002, developed many of the same beliefs, and cited the research-based principles identified by the National Partnership for Excellence and Accountability in Teaching (Lewis, 2000).

Harold Wenglinsky's two reports (2000 & 2002) examined the impact of both teaching and schools on student academic performance. His analysis in both cases included professional development factors. In the first report he looked especially at two aspects of professional development, while his later study expanded that to include 10 measures. The greatest positive impacts on student achievement were associated with professional development in higher order thinking skills and in strategies for working with special populations.

As we consider the imperative for improving mathematics achievement, examine the principles of good practice by which that might happen, and reflect on effective formats of professional development, the authors note the paucity of research on the actual effectiveness of implementing *Thinking Mathematics* principles in the curriculum.

Thinking Mathematics Knowledge Base

The American Federation of Teachers conducts *Thinking Mathematics* training using its own Educational Research and Dissemination (ER&D) protocol. ER&D employs a trainer of trainers, site-based, professional development model which recommends released time for teachers to engage in consideration of research implications under the leadership of colleagues. This network approach, designed to provide teachers a collaborative opportunity to interact with research findings, predated *Thinking Mathematics* by a decade. Its design rested on a conviction wherein "teacher change—and teacher conviction in the changes being advocated—was viewed to be critical for successful student learning outcomes". (Hojnacki & Grover, 1992, p. 1)

TM, the first instance of subject-specific ER&D, is not a mathematics curriculum for students, but a teacher development program which targets the improvement of children's mathematics learning. An internal communication (2001) to ER & D participants illustrated many parallels between the *TM* principles and recommendations from the National Research Council's *Adding it Up*- a consistency probably due to the strong research base which guided the formulation of *TM* over the years from 1987 to 1992. *Thinking Mathematics* resulted from a proposal sponsored by the National Science Foundation as a joint undertaking of the Learning Research and Development Center of the University of Pittsburgh and the AFT. The initiative sought to disseminate new knowledge about mathematics instruction and learning; its charge included examination of both pedagogical and learning research. The first publication, in 1992, was *Analysis of Arithmetic for Mathematics Teaching*, edited by Leinhardt, Putnam, & Hattrup. This reference is a compilation of writings forming a knowledge base for much of elementary school math. Shortly thereafter, the collaboration produced several volumes of research interpretations intended specifically for use in the teacher training workshops. It is worthy of note that the texts were written by a team of five practicing teachers whose work was then submitted to the collaborating researchers. In the first volume, Bodenhausen et al (1993) cited references to approximately 70 foundational works used in formulating the ten principles representing *TM's* central core. Our researchers were especially interested in seven of the ten principles. In the summary that follows, we note representative citations from Bodenhausen et al for each of those selected.

The directive to build from *children's intuitive knowledge* drew from the findings of Cobb, Yackel, & Wood (1988), Carpenter, Hiebert, & Moser (1981), and Carpenter & Fennema (1988). They made the case that children do not enter into instructional situations as the proverbial blank tablets. Consequently, resourceful teachers harness foundational intuition to extend youngsters' mathematical power. Similarly, because prior experience and intuition are powerful enablers of mathematical understanding, invented algorithms can have advantages over standard forms.

Thinking Math encourages teachers to establish a *strong number sense* through counting, estimation, use of benchmarks, mental computation skills, and understanding the effects of operations. Counting and estimation are fundamental to children's mathematical ease. Hence, teachers should expand what NCTM referred to as their "intuition about numbers" to include, for example, a sense of magnitude and equivalence for whole numbers as well as fractions. Several publications from Sowder, both individually and with other researchers, including Schappelle (1989), established the role of number sense.

When teachers base instruction on *situational story problems*, (as NCTM standards emphasize,) they promote the relationship of mathematics to children's lived reality. *TM* cited Fuson, (1992) and Resnick (1987), among others, to document the value of helping children establish bonds between the formality of some school math and their own intuition. Aware of problem solving's complexity, the *TM* resource volume stipulated the varying degrees of difficulty experienced by students according to the syntax and structure of scenarios.

The exhortation to provide *manipulatives* for student use and teacher demonstration rested on several claims related to multiple modes of learning, progression from concrete to symbolic representations, and the value of concrete materials in facilitating discourse. Resnick & Omanson, (1987) and Fuson, (1992) were among the authorities cited on this point. Emphatic among the recommendations was the need for teachers to explicitly construct links between the concrete and symbolic forms, and not to leave this association to chance.

To require students to describe and *justify their mathematical thinking* is to take seriously an earlier NCTM (1989) standard promoting increased discourse in mathematics classrooms. The *TM* foundational publication emphasized written and oral sense-making for mathematics learners when it cited personal communication with both Leinhardt and Resnick (1990.)

Once quality discourse becomes the norm, it is reasonable to expect facilitators of learning to *accept multiple correct solutions* and, in some cases, more than one correct answer. Lampert (1986) offered justification for this mathematical open-mindedness, as did Resnick, Bill, & Lesgold (1994.) And, of course, the very nature of algorithms, as socio-conventional constructions, lends credence to a principle of multiple representations.

Teachers find a challenge when they try to *balance procedural and conceptual learning*. As *TM* literature employed the terms, procedural learning emphasizes the algorithmic or "how to" skills of routine operations, contrasting with the higher level comprehension and representation required by the more conceptual mode. Acknowledging diverse opinion about whether one should precede the other, the resource authored by Bodenhausen et al (1993) endorsed their integration. In formulating this stance, *TM* developers cited the works of Porter (1989), Schliemann & Magalhaes (1990).

Researchers in the present study excluded three principles: *using a variety of teaching strategies* as supported by Shulman, (1989); using ongoing and *new types of assessment* to guide instruction (Stenmark, 1989); and *adjusting the curriculum timeline,* which had been researched by Carpenter & Fennema (1988), Fuson, Stigler, & Bartsch (1988).

Thinking Mathematics' Effectiveness

Although *TM* is not well represented in the literature, three studies were found to be relevant to our present research. Rauth and Billups (1992) offered qualitative insights into the benefits of the collaborative writing which evolved into the training model. Particularly, they focused on the intellectual and social advantages that classroom teachers reported as arising from their close interaction with the research community during the writing process.

Hojnacki & Grover's interest in *TM*'s cognitive and affective effects on students motivated their 1992 quantitative study of its 1990-91 pilot implementation. Disclaiming interest in formal program evaluation, they gathered data from 65 classes, mostly grades k-5, taught by volunteer teachers at five sites. Their measures included results of mid-year and end-of-year teacher surveys, measures of student attitude, student problem solving assessment, and student standardized test scores. Forty-nine teachers, across five sites, volunteered to complete evaluations. In their report to the American Educational Research Association, Hojnacki & Grover concluded that participating teachers perceived improvement in their own confidence, and that students seemed to benefit both cognitively and affectively. Cognitive benefits included increased number sense; one of the affective benefits cited was greater respect for the opinion of others.

Recognizing the concern that *TM* students might be disadvantaged on standardized tests relative to those not in a pilot program, Hojnacki & Grover collected scores from 51 pilot classes and from 36 classes which were not involved in *TM*. Specifically, they examined mathematics portions of the California Achievement Test, the Indiana State Test of Educational Progress, and the Comprehensive Test of Basic Skills, and compared the computational and the concepts and applications indicators for *TM* and non-*TM* classes. Their conclusion was that the measured achievement of the pilot study students was largely comparable to that of the non-*TM* group across 1^{st} through 5^{th}-grades.

Hojnacki & Grover studied student attitude by developing a 24 item survey administered to more than 500 pilot students in grades two and higher. The researchers offered detailed commentary on the varied interpretations that might be drawn from the responses, but they emphasized the lack of a control group or of norms with which student responses might be compared.

Finally, these researchers administered, to pilot students only, pretest and posttest forms of a problem solving instrument authored by Wood and Cobb. They concluded that there was marked improvement in accuracy of responses for all grades studied, and decrease in idiosyncratic errors. The types of errors varied by grade level. Computational errors were more frequent at grades one and two, and conceptual/procedural mistakes more common for 3^{rd}-grade. While several indicators suggest that *TM* had a positive impact on its students, the authors caution against generalizing the findings due to the "completely voluntary, non-threatening, and non-judgmental nature of the instructional program". (p. 23)

Both of these studies were conducted during the formative years of *TM*, when factors related to student mathematics achievement and teacher implementation of program principles may have been affected by the high degree of voluntary participation. The research literature indicates that the next reported study occurred five years later, in 1997, when Buck reported on her investigation designed to compare mathematical achievement of students taught by *TM* trained teachers with those whose teachers had not been *TM* participants. Additionally she studied teacher perceptions of the effectiveness of two formats of training workshops: five sessions over five weeks versus six sessions over 10 months.

Data were drawn from more than 1000 1st through 6th-grade students and 48 teachers in one Florida county. Measures included pre and post forms of a teacher survey regarding implementation of eight instructional techniques espoused by *TM* and student grade equivalent scores on four subscales of the Comprehensive Test of Basic Skills (mathematics computation, mathematics concepts and applications, mathematics total, and reading comprehension). The research indicated that students of the *TM* teachers earned significantly higher scores on all measures studied, and that, while all teachers self-reported higher implementation scores following their training, the improvement was greater for those participants in the 10 month format. Additionally, Buck's data indicate that the amount of increase in teacher implementation differed across strategies. She found significant differences in the implementation frequency reported by 10 month participants for estimating, recording, justifying strategy, and using a situational story base for problems. No such significant difference in implementation frequency between the five week and 10 month training participants was reported for other *TM* principles, including use of manipulatives and accepting multiple solutions.

Relationship to Present Study

While the very timing of the Rauth and Billups study makes it unique, our work does share some characteristics with the later two investigations. As with Buck and with Hojnacki & Grover, we were interested in student achievement measured on standardized tests. We, also, sought to probe teacher perceptions about the efficacy of *Thinking Mathematics*. However, our *ex post facto* research, conducted in an era of standards-driven curriculum, is distinctive from the prior research in several ways. We investigated a *TM* format which had been in place for several years; we investigated relationships between *TM* teacher implementation and efficacy; we limited our study to performance of urban 5th-grade students (the first grade level to face Pennsylvania's state achievement tests); and, recognizing the interrelationship between performance in reading and math problem solving, we examined achievement scores in both mathematics and reading for all 5th-grade students enrolled in the selected schools, regardless of whether they had studied with educators trained in *Thinking Mathematics*.

Methodology

Presuppositions and Questions

A research presupposition was that professional development affects teacher efficacy in teaching mathematics. Several aspects of the Scranton *TM* training reflect best practice for professional development. Specifically, it occurs on-site; it is offered to teachers across the eighteen district schools, and substitute coverage is provided to enable teachers to attend eight full day sessions distributed throughout the year. This sustained format resembles that favored in Buck's 1997 research. Scranton sessions are facilitated by district teachers trained by the AFT

Educational Issues Department at a nine day summer institute followed by a three day winter institute. To link the training to classroom practice, at each session teachers develop action plans for applying the research concepts with their students. They also regularly review resulting student work samples.

The specific research questions addressed in this study were: What is the level of and relationship between teacher confidence in and implementation of mathematics education practices emphasized in the *TM* program? Does greater confidence in and implementation of these practices result in higher student achievement? Do 5^{th}-grade students who have a *TM* trained teacher achieve at a higher level in mathematics than those who do not have such a teacher?

Design and Sample

Researchers invited a group of *TM* trained Scranton School District teachers to Marywood University in May, 2001 to explain the research project and to elicit their perceptions of *TM* professional development. Teachers reported their perceptions in a questionnaire. While most participants did so on site, a follow-up distribution was provided for teachers unable to be present.

Three elementary schools were selected for study, because of their representative student population, the extensive *TM* preparation of their staff, and the fact that the 5^{th}-grade teachers of math were *TM* trained. Researchers chose the 5^{th}-grade level for study because it represents the students' first experience with PSSA evaluation. A fourth school, which had several *TM* prepared faculty, but none teaching at the 5^{th}-grade level, served as a control. *TM* teachers in the four schools were surveyed. More than 90% responded.

Researchers investigated the relation between *TM* teacher professional development and student math achievement by conducting an *ex-post facto* study to investigate variables known to influence mathematics achievement. Comparisons between the three schools and the control school were examined to determine the effect, on student mathematics achievement, of having a 5th-grade *TM* trained teacher.

Student scores and other records of all students in the three schools who were enrolled in classes of *TM* teachers and who were completing 5th-grade in June 2001 were examined, as were records and scores of all 5th-grade students in the control group. Findings are based on thirty-seven questionnaires returned by teachers, and on the records of 169 students from the three schools and 34 from the control group, for a total of 203.

Instruments

During Spring, 2001, the researchers designed a teacher questionnaire, which included demographic questions as well as self-reports of their confidence in and practice of the seven *TM* principles of interest to the research study. The principles selected were: building on students' intuitive knowledge, establishing number sense, using manipulatives, having students describe and justify their thinking, accepting multiple correct solutions, using situational story problems, and balancing procedural and conceptual learning. The confidence questions were rated on a 10-point scale from 1(not confident) to 10 (very confident), while the questions about implementation ranged from 1 (not at all) to 10 (to a great extent). The survey also queried perceptions of the influence of *TM* on a similar scale.

Content validity of the questionnaire was determined by having three *TM* trainers examine the questions on confidence, implementation, and influence. Reliability is evident in Cronbach's alphas of .87, .82, and .67 for the three scales, respectively.

Student achievement in mathematics was measured by scores on two test batteries which had been administered throughout the district in Spring, 2001. To acknowledge teachers' conviction that complex constructed response items on PSSA math tests involved considerable verbal skill, researchers included 5th-grade scaled scores on Mathematics Problem Solving, Mathematics Procedures, and Reading Comprehension from the *Stanford Achievement Test (SAT9)* scores. Similarly, we collected both Math and Reading scores from the Pennsylvania System of School Assessment (PSSA).

Results

Teacher Data

Teachers reported descriptive information on the survey, including gender, teaching experience, grade level, *TM* experience, and professional development activities. In the same survey, they completed scales rating their self-perceptions of the influence of *TM*, confidence in the ability to use *TM* principles, and the degree of implementation of those principles in the classroom.

Descriptives

The teachers represented every grade level from pre-K through 5 and included Title 1 and Learning Support specialists. They worked in four schools having as few as seven *TM* teachers to as many as 12. The 37 *TM* trained teachers, 33 of whom are female, represent a considerable resource of teaching experience. Only one had been employed in the district for as few as five years, while10% had less than 10 years of experience, and 70% had taught for 20 or more years.

Their self-reports indicated extensive math preparation, with nearly two thirds of the respondents reporting more than three college math courses. (Researchers, however, speculate that these responses were given in terms of credits rather than courses.) More than 75% of these educators completed *Volume One* of *Thinking Mathematics*, on the additive structure, over half had worked through the multiplicative structure of *Volume Two,* and one individual had progressed through the third, on rational numbers.

Scales

In addition to the descriptive data, teachers rated themselves on 34 scaled items reflecting *TM* confidence, implementation, and importance. For each item, they rated their confidence in a given strategy higher than its implementation. Table 1 shows that, while confidence in all principles is strong, the highest ratings were given for accepting multiple correct responses and in providing opportunity for students to describe and justify their mathematical thinking. The lowest degrees of confidence were expressed for teacher ability to use students' intuitive knowledge and to balance conceptual and procedural knowledge.

Paralleling their confidence ratings, teachers reported most implementation for accepting multiple correct solutions and for requiring students to explain/justify solutions. Using situational story problems, building on students' intuitive knowledge, employing manipulatives, and balancing teaching for procedural and conceptual knowledge were reported as being less fully implemented. Again the relationship between confidence and implementation emerged, as two of the least fully implemented principles were among those with the lowest confidence rating.

Table 1

Teacher Perceptions of Confidence in and Implementation of TM Principles

Principle	Means	
	Confidence	Implementation
Develop number sense	8.58	8.09
Use situational story problems	8.66	7.69
Use manipulatives	8.62	8.01
Require justification & explanation	8.68	8.47
Encourage multiple solutions	8.95	8.64
Build on intuitive math knowledge	8.12	7.93
Balance conceptual & procedural knowledge	8.43	8.04
Teach for procedural knowledge[a]	8.65	8.31
Teach for conceptual knowledge[a]	8.46	8.07

[a]Constructed by the researchers, these are not *TM* principles.

Overall, the influence of *TM* training is considerable in the perception of the teachers surveyed. They indicate that they teach math content at a deeper level as a result of the training. Consistent with the objectives of *TM* training, the teachers did not feel as strongly that they increased their mathematical knowledge as they did about the depth of knowledge and change in methods of teaching. Nevertheless, teachers across all elementary grades and teaching roles indicated that a considerable amount of math knowledge is needed for effective teaching.

Table 2 displays the correlations between such varied factors as teacher experience, confidence, and support.

Table 2

Correlation among Teacher Survey Item Responses

	Years of teaching	*TM* influence	*TM* implementation	Peer support	Administrative support
Confidence	.097	.395*	.877**	.427**	.366*
Years of teaching		.210	.117	.015	.213
TM influence			.429**	.277	.215
TM implementation				.478**	.326
Peer support					.700**

Note. $N = 37$. * $p < .05$. ** $p < .01$.

Acknowledging the relationship between confidence and performance, it was not surprising to researchers that confidence correlated with implementation and with support by administrators and peers. The correlation of confidence with peer support was stronger than the correlation with administrative support. While the correlation of peer support to implementation was significant, administrative support was not.

The researchers could not help notice the many years of teaching experience that characterized the teachers in the study. Hence, we queried the extent to which more and less senior teachers implemented *TM* principles. Table 3 shows that more experienced teachers with extensive *TM* training surpassed their more junior colleagues in reporting greater implementation of and confidence in its principles, a finding that does not support the stereotypical burn-out among older teachers. Indeed, for these professionals, the mean rating of enjoyment of math teaching was high, (9.12), clustering very close to scores for both confidence in the ability to teach math, (9.24), and the understanding of concepts taught (9.26). In light of these three strengths, researchers were not surprised that, although they acknowledge the influence of PSSA and the textbook on what they teach, these teachers are sufficiently independent to strongly disagree that it is necessary to teach each page of the text.

Table 3

Confidence and Implementation Means by Years of Teacher Experience

Teacher experience	*N*	Confidence in *TM* principles	Implementation of *TM* principles
Less than 20 years	11	8.35	7.75
20 years or more	26	8.95	8.32

Student Data

Information on students consists of both descriptive data and test performance. Individual student descriptives include gender, school attended, years in the Scranton School District, years of *TM* teachers, Individualized Education Program (IEP) status, and whether or not the 5th-grade teacher had *TM* training. In addition, researchers collected information descriptive of the four schools in which students were enrolled, including 5th-grade class size, total enrollment, number of k-5 faculty, percentage of low SES, attendance, transiency, Title 1 program availability, and class organization for math instruction. Performance data were drawn from two standardized tests. For the *SAT9*, researchers used school and district mean scaled scores for the two math test sections and for reading comprehension. We also used school, district and Commonwealth mean PSSA scaled scores for total math and total reading. Additionally, we studied the 4-tier PSSA performance bands for state and district comparisons

Descriptives.

The student sample consisted of 203 5^{th}-graders enrolled in the four selected schools in Spring, 2001. Gender distribution was similar in most schools and across the sample, where males constituted 56% of the total. Students in the three treatment groups, accounting for 83% of those studied, were enrolled in 5^{th}-grade math classes taught by *TM* trained teachers. Most students (89%) had been in district schools for six years. Over three fourths were grouped heterogeneously for math instruction, and two thirds were in non-departmentalized settings. Twelve percent of the student group had been identified as being eligible for special services. Related to these student descriptors are the school characteristics summarized in Table 4.

Table 4

School Demographics

Variable	School A	School B	School C	School D (control)
Enrollment[a]	537	422	434	190
# Faculty in grades 1-5	17	13	13	8
# 5th-graders studied	44	55	70	34
5th-grade class size mean	22	18	23	17
% Low income[a]	46.4%	36.3%	28.1%	76.5%
Title 1 reading[a]	yes	yes	yes	yes
Title 1 mathematics[a]	yes	no	no	yes
Attendance rate[a]	94.5%	94.6%	95.2%	93.3%
% *TM* faculty	50%	58%	37%	60%

[a]Reported in *PA Profiles 1999-2000.*

Many characteristics, such as attendance rates, class size, and presence of Title 1 reading programs, are similar across the several schools, although other differences are evident in Table 4. Each of the schools is essentially a neighborhood school, but Schools A and D draw learning support students from a broader area. Student turnover is remarkable at school D; according to PA Profiles for 1999-2000, 86 students enrolled after the academic year began, and 55 withdrew before it was complete. This school, which has the greatest percentage of *TM* trained faculty, also is distinguished by its proportion of low income students, which notably exceeds the district mean of 54%.

Scaled Scores

Although our primary interest was in students' math performance, the expectation of verbal proficiency, both in *TM* Principles and in the constructed response format of PSSA math assessments, suggested the value of studying reading performance as well. Similarly, examining both the state-specific PSSA measures and those of the nationally published *SAT9* offered the possibility to examine student performance more comprehensively. Our research established high correlation between math components of the *SAT9* and PSSA tests, and between the math and reading measures within each test, as shown in Table 5.

Table 5

Correlations between SAT9 and PSSA measures

	SAT9 Math Procedures	*SAT9* Reading	PSSA Math	PSSA Reading
SAT9 Math Prob. Solving	.798***	.694***	.819***	.648***
SAT9 Math Procedures		.626***	.777***	.620***
SAT9 Reading			.692***	.765***
PSSA Math				.693***

Note. N=167. *** $p<.001$.

Researchers had access to different data when examining student achievement on the measures, and consequently, interpretations are not parallel. Differences in mean scaled scores on the *SAT9* and PSSA by treatment and control groups are reported for both math and reading in Table 6; comparisons with the school district constitute Table 7.

Table 6

Comparison of Treatment and Control groups on SAT9 and PSSA Scaled Scores

Test	Treatment group (N =168)		Control group (N = 34)		
	M	*SD*	*M*	*SD*	*t*
SAT9					
Math Problem Solving	665	35.87	631	46.18	4.009**
Math Procedures	672	42.92	644	65.83	2.418*
Reading Comprehension	670	31.38	639	43.57	3.907**
PSSA					
Math	1307	164.16	1216	178.67	2.588*
Reading	1342	168.75	1265	176.34	2.217*

* $p < .05$. ** $p < .01$.

Table 6 indicates significant differences between the two groups in all areas. The control group had a greater proportion of low income subjects (77%) than the other three schools, which average 36%. Since this variable may contribute to the difference, researchers also compared the treatment groups with the district, (wherein low income students constitute 54% of the population). See Table 7.

Table 7

Comparison of Treatment Group Mean on SAT9 and PSSA Scaled Scores with District Mean

Test	Treatment mean	District mean	*SE*	*df*	*t*
SAT9					
Math Prob. Solving	665	609	2.77	167	20.159***
Math Procedures	672	594	3.31	167	23.587***
Read. Comprehension	670	610	2.42	167	24.594***
PSSA					
Math	1307	1270	12.74	166	2.907**
Reading	1342	1310	13.06	167	2.436*

* $p < .05$. ** $p < .01$. *** $p < .001$.

In all five measures of reading and math performance, the mean scaled score of students in the treatment group exceeded that of their district peers by a statistically significant difference. For PSSA measures, although the difference is statistically significant, it is less than the 50 points established by the Commonwealth as educationally meaningful.

PSSA state norms are, of course, critical; hence it is important to note that the treatment mean in math is three points less than the state mean, (where the median proportion of low income students is 31%). In reading, the treatment group mean exceeds the Pennsylvania average by 31 points.

Performance Levels

Beyond examining the scaled score data in Tables 6 & 7, researchers analyzed PSSA results in terms of the performance levels established by the Commonwealth. Chi-square tests indicated a significant difference on math performance levels between treatment and control groups, ($\chi^2 = 9.501$, $df = 3$, $p<.05$), as well between treatment groups and the district ($\chi^2 = 9.69$, $df = 3$, $p<.05$), and, also between treatment groups and the state. ($\chi^2 = 12.99$, $df = 3$, $p<.01$.) Looked at from another perspective, the percentage of students in our treatment group who ranked at the below basic level was lower than levels for both the state and the district (18%, 22%, and 28% respectively).

The reading performance level of students studied in the three treatment schools was higher than both district and the state mean. A greater percentage of students studied in the three schools read at the proficient or advanced levels than was the case for the state and district. The respective percentages are 60%, 56%, and 51%. The percent reading at the below basic level in the three treatment schools was 15%, considerably less than that of the district (22%) or the state (23%).

Student Performance Related to Teacher Characteristics

Table 8 summarizes the multiple regression studies that were run, using three predictor variables (years of teaching experience at grade level, professional development apart from *TM* training, and the scale score on implementation of *TM* principles) with the criterion variables being *SAT9* reading comprehension and both of the *SAT9* math measures.

Table 8

Teacher Experience, Professional Development, and TM Implementation as Predictors of SAT9 Scores

Variable	Standardized coefficients	*t*
SAT9 Math Procedure		
Implementation	.497	3.52***
Experience	-.158	NS
Professional development	-.191	NS
SAT9 Math Problem Solving		
Implementation	.451	3.18*
Experience	-.130	NS
Professional development	-.151	NS
SAT9 Reading Comprehension		
Implementation	.549	3.88***
Experience	.077	NS
Professional development	-.311	-2.30*

$^{*}p<.05.$ $^{***}p<.001.$

The implementation of *TM* principles was a significant predictor in all three cases. In contrast, experience was significant only in math problem solving achievement, and professional development beyond *TM* emerged as significant only in reading comprehension.

Since 5th-grade performance on PSSA was of particular interest, researchers specifically analyzed the achievement of students according to whether they had a *TM* trained teacher for their 5th-grade year. We found that those with a 5th-grade *TM* trained teacher performed significantly better on PSSA math than did the control group and the district, as indicated by Table 6. The notably lower SES of the control group may well account for the difference, however.

Conclusion

The student subjects, hailing from urban elementary schools of varied size, SES ratings, transiency, and class organization, formed a reasonably diverse basis for study. Based on our findings, *TM* training of teachers is associated with positive 5th-grade student performance on PSSA assessments of total mathematics and total reading. The sample teachers and schools did quite well at getting their student achievement to the basic or better level in mathematics on this measure.

TM training of teachers is also associated with strong *SAT9* reading, math problem solving, and math procedures performance. Specifically, having a *TM* trained 5th-grade teacher is a predictor of student achievement in mathematics, especially problem solving.

Teacher confidence in *TM* principles and teacher perception of the influence of *TM* are both related to implementation of the principles. Implementation is, in turn, a predictor of student achievement in math problem solving and math procedures.

Implications for *TM* Training

The ER&D trainers, the teacher participants, and the Scranton School District administrators can take justifiable satisfaction from the fact that *TM* training is perceived as a strong professional development tool. Experienced and relatively new faculty value this professional development experience and report perceptions consistent with its purpose of improving their ability to promote students' effective learning of mathematics. Student test results also support the perception of effectiveness.

With these strong indications of effectiveness for *TM* overall, and for so many of its principles, it is reasonable to consider the areas in which teachers report relative weakness of confidence or implementation. Developing conceptual knowledge, and its balance with procedural knowledge, is one such area. Procedural knowledge is more closely associated with traditional practice and with teachers' own lived experience. It can be routinized in classroom settings; it is expected by parents; it is less demanding of materials and real-world applications. In contrast, conceptual activities and knowledge building are more suited to constructivist settings; they thrive in situations which promote high level discourse; they are well served by multiple representations and models. Consequently, effecting a balance is a genuine challenge.

Teachers also reported relatively weak confidence in using students' intuitive knowledge. This may also relate to their perceived ability to develop conceptual knowledge, since student intuition more closely approximates concept than procedure, and intuitive understanding is nonalgorithmic. It seems plausible that if teachers' own math experience has been heavily computational in nature, their sense of efficacy in building from the intuitive base of immature learners may be slow to develop.

Using situational story problems is another area of weaker confidence. The most valuable situational scenarios emerge from genuine, mathematically rich experiences of the students. Recognizing the ingredients in the shared classroom culture that may be effectively combined into a provocative problem (eg. realistically representing division of a common fraction by a common fraction) requires ingenuity as well as mathematical knowledge. Overall instructional and mathematical confidence seems a prerequisite to such teacher creativity in a standards-driven culture. Another consideration is the range of reading ability in a typical classroom, which challenges mathematical problem solving instruction, even acknowledging that not all situational problems require written format.

The final item in our list of those rated lower than others in the confidence survey is use of manipulatives. We suggest several possible explanations for this variance. Manipulative use is somewhat counter-cultural and hence may not be modeled by peers; its success demands strong classroom management; it can be time-consuming; and, of course, access to adequate supplies of appropriate manipulatives cannot be assumed. Given its physical nature, effective manipulative use also involves skilled performance more than is the case with some other principles, such as accepting multiple correct responses. In order to promote confidence in manipulatives, *TM* trainers may reconsider such diverse factors as whether there is adequate opportunity for teachers to rehearse their physical modeling of the materials and whether willing teachers actually have the manipulative resources at hand.

Suggestions for Further Research

While investigators were especially interested in math outcomes, the notably strong reading performance suggests that further research might examine the efficacy of *TM* training in developing language skills, perhaps interpretative reading comprehension in particular.

Additional research to isolate elements among the *TM* principles to determine whether some are more efficacious than others would seem especially helpful to *TM* trainers.

Since the *TM* teachers seemed to have success with keeping their students out of the lowest of performance bands on PSSA, research might look especially at correlating teacher implementation with achievement of the mathematically weakest students.

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