Evaluation of the Singapore Math Pilot Program: Year 1 Report of Findings

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Table of Contents

Overview of the Study 1
Context 1
Purpose of the Pilot 1
A Model of Instructional Change 1
The Evaluation Study Design 5
Pilot and Control Schools 5
Instruments and Methodology 5
Evaluation Questions 6
Evaluation Findings 8
Implementation Issues 8
Late Notification 8
Participation of Control A Schools 8
Communication with Control A Schools 8
Lessons Learned 9
Inputs 9
The Curriculum 9
Instructional Materials 12
Teacher Training 13
The Assessment Model 17
Processes 18
A Combination of Factors Produced Change 19
Contextual Conditions 19
Teachers' Perceptions of Principals' Support 21
Processes Related to the Curriculum 22
Processes Related to Instructional Materials 33
Processes Related to Teacher Training 36
Processes Related to Assessment 44
Outcomes 45
Accelerated Student Progress Through the Mathematics Curriculum and Students' Deepened Understanding of Mathematics Concepts 45
Students' Mathematics Achievement 47
Students' Attitudes About Mathematics 51
Parents' Satisfaction 52
Summary and Recommendations 54
Summary 54
Recommendations 56

Evaluation of the Singapore Math Pilot Program:
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Overview of the Study

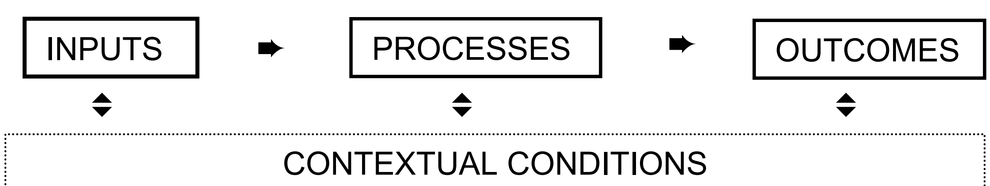
Context

Purpose of the Pilot

In spring 2000, Superintendent Jerry D. Weast announced his intent to pilot the Singapore Math program in several Montgomery County Public Schools (MCPS) elementary schools in an effort to improve and accelerate mathematics instruction.[1] Results of international studies of mathematics achievement consistently showed Singapore students to be at or near the top in mathematics performance.[2] Comparison of Singapore Math curriculum materials to the list of student objectives assessed by MCPS's Instructional System in Mathematics (ISM) assessments showed that students who participated in Singapore Math were exposed to mathematics topics earlier than was typical in MCPS. In many cases, Singapore Math presented the topics as much as a year or two before they were assessed in ISM. The purpose of the pilot was to determine whether, and to what degree, implementation of the Singapore Math program in Grades 1-5 in selected schools could 1) alter how mathematics concepts were presented by teachers, and 2) elevate and accelerate the mathematics performance of MCPS elementary school students. This report presents the results of an evaluation of the first year of the Singapore Math pilot. The evaluation study was conducted by staff in MCPS's Office of Shared Accountability (OSA).

A Model of Instructional Change

In framing a context for evaluation of the Singapore Math pilot, the OSA evaluation team adapted a model from economics:



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[1] MCPS. *Investing in the Call to Action: Highlights from the New Educational Initiatives for Fiscal Year 2001*, p. 5.
[2] Mullis, Ina V. S., et al. *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study (TIMSS).* Boston, MA: TIMSS International Study Center, Boston College, June 1997, p. 24-25.

In the economics model, inputs include the human and capital resources that exist; pro??cesses refer to what is done with the inputs; and outcomes might be the profit margin, quality of the product, or consumer satisfaction. Contextual conditions would be existing factors that serve to enhance or inhibit progress toward satisfactory outcomes. One might think of this model more concretely in the context of manufacturing a brand of soup. Inputs might be the quality of the raw materials used to make the soup – the vegetables, meats, and spices. Processes might include how much liquid is added to the raw materials, how large or small the pieces of vegetables and meats are, or the ratio of meats to vegetables. Outcomes would be the taste of the soup, its heartiness, etc. Contextual conditions might include the age and physical condition of the machinery used to manufacture the soup, or the quality control methods in place to ensure that each batch of soup met industry standards. Evaluation findings from the first year of the Singapore Math pilot are structured around an adaptation of this model (see Figure 1). In Figure 2 we elaborate on this structure by presenting a logic model that illustrates how the various components of the model fit together.

Figure 1

Adapted Model Used to Describe Changes That Might Arise from the Singapore Math Pilot Efforts

Inputs

- curriculum
- appropriate instructional materials
- teacher training
- assessment model

Processes

- improved classroom instruction
- effective use of instructional strategies and materials
- shift in beliefs about how and what children can learn
- teachers' deepened understanding of mathematical concepts
- improved assessment of students' understanding and retention of math concepts

Outcomes

- improved student achievement
- improved student attitudes about learning
- accelerated student progress through the mathematics curriculum
- parent satisfaction

Contextual Conditions

- communication between Central Office and schools
- MCPS mathematics curriculum framework
- State of Maryland learner outcomes (MLOs)
- principal support
- school-based decisions on use of resources
- schools' interactions with parents
- school-wide focus on achievement
- school-wide environment of collaboration and support

Figure 2

Logic Model for Evaluation of the Singapore Math Pilot

Inputs	Processes	Outcomes
(I1) Curriculum *Data sources: curriculum materials received by Singapore and control schools; teacher survey*	**(P1a)** Coherent presentation and in-depth exploration of topics building on prior understanding; **(P1b)** Shift in beliefs about how/what children can learn **(P1c)** Teachers' adoption of the Singapore curriculum *Data sources: classroom observations; teacher survey; principal interviews*	**(O1)** Improved student mathematics achievement
(I2) Appropriate instructional materials *Data sources: instructional materials received by Singapore and control schools; teacher survey*	**(P2a)** Appropriate instructional materials in use (e.g., texts and workbooks, manipulatives, pictorial representations, graphs, data charts) *Data sources: classroom observations, teacher survey*	**(O2)** Improved student attitudes about math **(O3)** Students' deepened understanding of mathematics concepts
(I3) Teacher training *Data sources: analysis of training content and frequency; dosage by school*	**(P3a)** Improved quality of classroom instruction (e.g., effective questioning strategies, alternative solutions encouraged, student involvement in decision making, hands-on minds-on activities) **(P3b)** Teachers' deepened understanding of mathematical concepts *Data sources: classroom observations; teacher survey; principal interviews*	**(O4)** Improved parent satisfaction **(O5)** Accelerated student progress through the mathematics curriculum *Data sources: Singapore quarterly assessments; CRTs; CTBS; student and parent focus groups; teacher survey; report card files*
(I4) Assessment model *Data sources: summary of Singapore quarterly assessments; comparison with ISM assessments; principal interviews*	**(P4)** Improved assessment of students' understanding and retention of math concepts *Data sources: principal interviews; analysis of quarterly assessment results*	

(Continued on next page)

Figure 2 (continued)

Logic Model for Evaluation of the Singapore Math Pilot

Contextual Conditions

- **(C1)** Communication between Central Office staff and schools *(Data sources: principal interviews; evaluators' observations of interactions between Central Office staff and teachers/principals;)*
- **(C2)** MCPS mathematics curriculum framework and State of Maryland learner outcomes (MLOs) *(Data sources: Montgomery County and Maryland documents)*
- **(C3)** School-based decisions on use of resources (e.g., SDT) *(Data sources: principal interviews; teacher survey)*
- **(C4)** Schools' interactions with parents; parental reactions *(Data sources: parent focus groups; principal interviews; teacher survey)*
- **(C5)** School-wide focus on achievement *(Data sources: principal interviews; teacher survey)*
- **(C6)** School-wide environment of collaboration, support, sharing, use of planning time *(Data sources: principal interviews, teacher survey)*
- **(C7)** Principal support *(Data sources: principal interviews, teacher survey)*

The Evaluation Study Design

Pilot and Control Schools

We formulated an evaluation design that incorporated three types of schools: the Singapore Math pilot schools, and two types of control schools which we called Control A and Control B. This design allowed for a comparison of three combinations of inputs:

- full dosage - all inputs provided (Singapore schools);
- partial dosage - some inputs provided (Control A schools); and
- no dosage - no new inputs provided (Control B schools).

Table 1 presents the schools that were selected to participate in the first year as Singapore pilot, Control A, and Control B schools. Figure 3 illustrates how these schools were defined by input dosage and the anticipated processes and outcomes we might observe. Due to implementation problems at the outset of the pilot, the evaluation findings focus primarily on the effect of the curriculum and training on the four Singapore pilot schools.

Instruments and Methodology

We used a variety of evaluation instruments and procedures to gather data for this study. We observed in-service training sessions provided to teachers; talked with teachers, principals and Central Office staff to gather perceptions regarding implementation of the pilot and its effects on classroom instruction and student learning; observed classroom instruction; conducted focus groups with parents and students; and analyzed system-wide mathematics assessments and quarterly assessments developed for the pilot program. Additionally, for students who participated in Singapore Math as 5^{th} graders, we examined the mathematics courses in which they were enrolled in middle school as 6^{th} graders, and compared their pattern of course enrollment to that of the prior year's 6^{th} graders. Use of these multiple data sources allowed us to provide a qualitative assessment of the effectiveness of the first year pilot activities and a quantitative assessment of classroom instruction and student achievement.

Table 1

Elementary Schools Selected for the Evaluation of the Singapore Math Pilot

Singapore Pilot Schools	Control A Schools	Control B Schools
College Gardens	Brookhaven	Bells Mill
Drew	Candlewood	Darnestown
Highland View	Carderock Springs	Georgian Forest
Woodfield	Twinbrook	Maryvale

Figure 3

Illustration of Inputs, Processes and Outcomes for Three Types of Schools in the Singapore Math Pilot

	Singapore Pilot Schools	Control A Schools	Control B Schools
Inputs	curriculum and materials	na *	na *
	teacher training	teacher training	na
	curriculum	na	na
	effective practices	effective practices	na
	special topics	special topics	na
	quarterly assessments	quarterly assessments	na
	no ISM assessments	no ISM assessments	ISM assessments
Anticipated processes	increased school-wide focus on achievement	increased school-wide focus on achievement	na
	greater shared vision of effective instruction	greater shared vision of effective instruction	na
	shift in beliefs about how students learn	shifts in beliefs about how students learn	na
	time available for planning/ sharing	na	na
	improved instruction	improved instruction	na
	effective instructional strategies	effective instructional strategies	na
Anticipated outcomes	improved student achievement	na	na
	deepened understanding of math concepts	na	na
	accelerated progress	accelerated progress	na
	improved student attitudes	na	na
	parent satisfaction	parent satisfaction	na

* na = not applicable; no change anticipated

Evaluation Questions

Data collection activities were structured around the following evaluation questions:

1. What is the effect of the new curriculum (Singapore Math) on classroom instruction and student achievement?

2. What is the effect of teacher training on classroom instruction and student achievement?

3. What effect does the model of student assessment have on classroom instruction and student achievement?

4. If we wanted to expand the pilot to other MCPS schools, which aspects of the Singapore pilot would best lend themselves to other school contexts within MCPS?

Table 2 displays the types of data that were collected and the number of participants who were included for each data type. The next sections of this document present the evaluation findings related to inputs, pro??cesses, and outcomes.

Table 2

Data Activities and Respondent Groups for the Evaluation Study

Data Activity	**Singapore Pilot Schools**	**Control A Schools**	**Control B Schools**
Classroom observations	62	32 *	0 **
Teacher surveys	63	37 *	0 **
Principal interviews	4	2 *	0 **
Student focus groups (# groups)	4	0 *	0 **
Student focus groups (# students)	84	0 *	0 **
Parent focus groups (# groups)	4	0 *	0 **
Parent focus groups (# parents)	34	0 *	0 **
Quarterly assessments	1,660	1,447 ***	0 **
Analysis of report cards, CTBS, CRTs, MSPAP, and prior ISM performance	1,593	1,413	1,491

* Of the four Control A schools that agreed to participate in the study, two were only interested in using the proposed quarterly assessments in place of ISM assessments. These schools were not interested in participating in any teacher training, thus they were not included in some aspects of data collection for the evaluation study.

** Since the Control B schools did not actively participate in the evaluation study, they were included in only the analysis of report card and mathematics assessment data.

*** None of the Control A schools participated in the first quarterly assessment; 3 participated during 2nd quarter, and all 4 participated in quarters 3 and 4.

Evaluation Findings

Implementation Issues

It is necessary to preface the discussion of findings with a short description of implementation of the pilot components and an assessment of how some implementation problems adversely affected uniform adoption of the pilot. These concerns impacted not only what happened in the schools involved in the pilot, but also created some limitations regarding what we are able to conclude after the first year's evaluation of the pilot through comparisons of the Singapore pilot and control schools.

<u>Late Notification</u>

Implementation of the pilot program in the Singapore Math and Control A schools got off to a rocky start because decisions about the pilot were made very late in the 1999-2000 school year, with little input from principals or teachers. Principals of the four Singapore pilot and two Control A schools that actively participated in the evaluation study felt they were told to participate without the option to decline (see discussion below regarding Control A school participation). Also, the principals of the four Singapore pilot schools were informed of their selection just before the July 2000 training session was to begin, and they had to contact teachers at the last minute to ask that they attend the training. For these reasons, principals expressed that many teachers at first were resistant to participating in the pilot.

<u>Participation of Control A Schools</u>

The Control A schools were not officially named until October because it was difficult to get schools to agree to sign on as control schools despite promises of staff training and release from the ISM assessments. Two of the four schools were allowed to participate in only the assessment component of the study, thereby limiting their potential usefulness as control schools. Because of this limitation and the overall lateness in identifying the Control A schools, the proposed teacher training component for Control A teachers was not implemented as intended.

<u>Communication with Control A Schools</u>

According to the principals of the Control A schools, they and their teachers received incomplete communication regarding why they were participating in the pilot, what they would get out of it, and what the expectations would be for student achievement in their schools. As a result of this apparent lapse in communication, several of the program inputs and pro??cesses were not implemented uniformly between the Singapore pilot and Control A schools.

Lessons Learned

Despite these implementation problems, some lessons were learned regarding effective implementation of pilot programs. Training was restructured for the second year of the pilot to better meet the specific needs of each Singapore pilot and Control A school; Control A teachers were invited to attend the 2001 summer training institute with the Singapore pilot teachers; and Singapore pilot and Control A schools were given clearer guidance at the beginning of the second year regarding how to handle the quarterly assessments.

Two of the Singapore pilot principals used the initial pilot year to provide a school-wide focus on mathematics, and one of these two principals used the initial pilot year to restructure the delivery of mathematics instruction throughout the school. One of the Control A principals also tried to use the initial pilot year to develop a school-wide focus on mathematics; however, these efforts were severely hampered by lack of appropriate curriculum and insufficient training opportunities for the teachers. Nonetheless, in this Control A school, processes were put in place for continuing to focus on mathematics during the second pilot year. These schools provide interesting illustrations of what can be accomplished within a school building, on the one hand, with assistance from outside the school, and on the other hand, as a grass roots effort within the school with very limited outside assistance.

Inputs

The Curriculum

The Singapore curriculum is structured around a set of textbooks, workbooks, and spiral-bound teacher guides that are based on how mathematics instruction is provided in Singapore.[3] The books are structured in semester-long instructional blocks. First grade students would be expected to complete Primary Mathematics 1A in the first semester and 1B in the second semester, second grade students would complete books 2A and 2B, etc. Singapore Math pilot schools were provided with books for Grades 1-5.

Initial examination of the Singapore Math books suggested that there was not much substance in them. Examples and illustrations appeared to be rudimentary and based on rote learning, and the page layouts and presentation suggested that students would find the materials not very stimulating. However, this initial assessment of the quality of the instructional materials was premature and not supported by the evaluation findings. In fact, commentary received from principals, teachers, parents and students throughout the evaluation study indicated that the Singapore Math books provided an in-depth presentation of important mathematics content, and the scope and sequence provided a scaffolding of key knowledge upon which more complex topics could be developed.

[3] *Primary Mathematics, Third Edition*. Singapore: Curriculum Planning & Development Division, Ministry of Education, 1999

The Singapore curriculum is based on three overriding strategies for teaching mathematics:

1. concrete – working with manipulatives to express mathematical concepts;
2. pictorial – using pictures of objects to illustrate mathematical concepts (e.g., showing fractions as parts of a geometric figure such as a rectangle or circle); and
3. abstract – use of algorithms, for example, to solidify students' understanding of mathematical concepts such as division.

The Singapore Math curriculum's stress on depth rather than breadth of content was a paradigm shift for MCPS teachers who were used to having to cover a variety of mathematics content areas in one class period or unit. It is common for a mathematics lesson in Singapore to focus on one topic, e.g., an entire class period could be spent exploring the number 8. In the training sessions provided to Singapore pilot teachers, the Office of Instruction and Program Development (OIPD) mathematics specialists modeled strategies for focusing on content depth rather than breadth.

One of the major reasons the Singapore Math curriculum was selected for piloting by MCPS was its emphasis on mathematics concepts in earlier grades than they had been traditionally introduced in ISM. Since MCPS initiated the Singapore curriculum in Grades 1-5 simultaneously, many teachers, especially those of Grades 3-5 classes, were concerned about the potential disparity or gaps in students' prior mathematics instruction and the rigor that would be expected in the grade-level Singapore texts. Despite these concerns, teachers were advised by the mathematics curriculum staff to place students in the Singapore Math books designated for their grade levels (e.g., 3rd grade students would use Singapore Math texts 3A and 3B, 4th grade students would use texts 4A and 4B, etc.). Those teachers who felt that many of their students were not working on grade level as determined by the prior year's ISM results feared that the students would not be able to cope with the accelerated Singapore texts.

Implementation of Singapore Math began in September 2000 with teachers using the Singapore Math texts assigned to their grade levels. Concerns about gaps in students' knowledge continued to be an issue throughout the first pilot year. Many teachers found the need to reach back into earlier years of the Singapore Math curriculum to fill in mathematics content that their students had not yet mastered or been exposed to. When asked to describe any difficulties in implementing the Singapore curriculum, 26 percent of the teachers reported that gaps in students' prior knowledge presented major problems (see Table 3). Backtracking was done frequently in 4th and 5th grades, and somewhat less so in 3rd grade. For the most part, 1st and 2nd grade students were able to handle the Singapore materials designed for their grade level.

Despite the concerns regarding students' instructional gaps, teachers and principals reported that the Singapore materials offered a more challenging curriculum to students in a way that promoted problem solving and critical thinking skills. Seventy-five percent of the Singapore pilot teachers felt that MCPS was moving in the right direction with its math curriculum changes, but only 24 percent felt that MCPS was moving in the right direction in how it was implementing the curriculum changes. Eighty-two percent of the teachers found the transition to the Singapore Math curriculum to be very challenging.

Table 3

Singapore Pilot Teachers' Perceptions of the New Curriculum and its Implementation

Perception Area	% Agreement
Gaps in students' prior knowledge present a major problem.	26 *
MCPS is moving in the right direction with its math curriculum changes.	75
MCPS is moving in the right direction in how it is implementing curriculum changes.	24
The transition to the Singapore Math curriculum has been very challenging.	82

* This item came from responses to an open-ended question on the teacher survey: what problems have you encountered in implementing the Singapore Math program? The remaining items represent percentages of teachers who indicated agreement with statements on a 5-point scale from strongly agree to strongly disagree.

Control A and Control B schools received no new curriculum materials. Rather, they were expected to continue using whatever mathematics instructional materials they had been using in the past. Control A principals and teachers expressed frustration at not receiving the Singapore books. Principals wanted the students to have the benefits of the Singapore books, and Control A teachers reported that they had difficulty preparing students for quarterly mathematics assessments without these books. It appears that use of the Singapore Math curriculum materials in the pilot schools brought to a head many of the frustrations that teachers had been feeling about the old MCPS mathematics curriculum materials. Many teachers in the Control A schools expressed concerns regarding the effectiveness of the old mathematics curriculum, the lack of appropriate instructional materials, and the instability of the mathematics curriculum over time. Only 32 percent of the Control A teachers felt that the ISM objectives provided a good way of capturing each student's mathematics prog??ress, only 6 percent felt that MCPS was right where it should be with its math curriculum, and 67 percent found working with the math curriculum to be very challenging (see Table 4). Additionally, about 40 percent of the teachers chose to comment about problems in the organization of the mathematics curriculum available to them and the fact that it is continually undergoing change. The following teacher comment is illustrative of challenges encountered by Control A teachers.

> "I'm not clear on how each objective should be taught. Because there is no text to guide teachers' instruction, I find that strategies for the objectives differ from class to class on my grade level."

Table 4

Control A Teachers' Perceptions of the Mathematics Curriculum and its Implementation

Perception Area	% Agreement
The ISM objectives provide a good way of tracking students' math progress.	32
MCPS is right where it should be with its math curriculum.	6
Working with the MCPS math curriculum is very challenging.	67
There is no clear organizational structure for the math curriculum.	42 *
We are constantly changing the mathematics curriculum.	39 *

* These items came from responses to an open-ended question: what problems have you encountered in implementing the MCPS mathematics program? The remaining items represent percentages of teachers who indicated agreement with statements on a 5-point scale from strongly agree to strongly disagree.

In hindsight, the concerns expressed by the teachers could have been predicted. The Phi Delta Kappa audit of the MCPS mathematics curriculum[4] spoke to the fragmentation of the elementary school mathematics curriculum, the great variation in textbooks used, and the lack of system-wide guidance and direction regarding important mathematics concepts for each grade level. The principal of one of the Control A schools learned from this experience and used FY 2002 instructional materials money to purchase new mathematics textbooks.

Instructional Materials

The issue of appropriate instructional materials to support the Singapore pilot was not well thought out in advance of the pilot's implementation. Initially, teachers in the Singapore pilot schools were told that they could only use the Singapore materials for mathematics instruction and they should not supplement mathematics instruction with any other materials they had used in the past. The rationale behind this decision was that, for evaluation purposes, MCPS wanted to have a "pure" assessment of the Singapore curriculum. Later on in the school year as other implementation issues arose, this restriction was eased and teachers were able to use materials such as digi-blocks to teach the Singapore curriculum concepts.

A second, related topic concerned the Singapore materials themselves. Since the Singapore books were written for students and teachers in Singapore, they contained some vocabulary/spelling and referred to some manipulative materials that were not familiar to MCPS teachers and students. Teachers were told that they could substitute their own vocabulary/spelling and manipulative materials for those referred to in the Singapore books,

[4] Poston, W. K., Jr., et. al. *A Curriculum Management Audit of Mathematics Education in the Montgomery County Public Schools*. Bloomington, IN: Phi Delta Kappa, September 2000.

which created confusion in the minds of teachers because they had been instructed to teach “pure” Singapore math.

In hindsight, it probably would have been productive to address the vocabulary and manipulatives concerns head-on in the initial summer training provided to Singapore pilot teachers. The mathematics curriculum specialists provided several after-school follow-up training sessions during the school year that specifically addressed how manipulatives could be used effectively. However, few teachers attended the follow-up training sessions (see next section), and observations of classroom instruction by the evaluation team in Singapore pilot schools yielded several instances in which manipulatives were not used or were used ineffectively in instruction.

Teacher Training

Teacher training was provided in three ways:

1. summer in-service training in the use of the curriculum materials;
2. monthly after-school follow-up training sessions on how to use effective instructional strategies and supporting materials to teach mathematics; and
3. school-based mini-training sessions during regular school hours on topics of specific interest to grade level teams.

All training sessions were designed and provided by the mathematics specialists. Teachers in the Singapore pilot schools received all three types of training; teachers in the Control A schools received limited school-based training but not the curriculum training; and teachers in the Control B schools were not provided with any training through the pilot. The training sessions provided to the Singapore pilot teachers were well designed and implemented by the mathematics specialists. They modeled effective instructional strategies and provided conceptual and content information that had the potential to enhance implementation of quality mathematics instruction.

Teachers in the Singapore schools also received a copy of a newly-published book comparing instruction in China and the United States.[5] This book was not utilized in the training sessions, but Singapore teachers had the opportunity to hear a presentation by the author in November 2000 at the National Science Foundation. Singapore teachers and principals reported that they found this research to be important and relevant to mathematics instruction in their schools.

The potential effectiveness of teacher training was impeded somewhat by problems in implementation and differences in participation rates across schools. As the following discussion illustrates, these circumstances limit somewhat what we can say about the effect of teacher training on improved classroom instruction and use of effective teaching strategies.

[5] Ma, Liping. *Knowing and Teaching Elementary Mathematics*. NJ: Lawrence Erlbaum Associates, 1999.

Summer Training

The mathematics curriculum staff had an abbreviated timeframe in which to organize the summer training program for teachers. While some aspects of the first training session did not appear as smoothly organized as typical MCPS training sessions usually are, the mathematics staff managed to pull together a worthwhile and engaging workshop in short order. The training session provided teachers with the opportunity to become acquainted with the Singapore Math books and plan mathematics lessons for the beginning of the school year.

Due to the late decision regarding which schools would pilot the Singapore curriculum, many teachers had prior commitments that precluded them from attending the three-day July training session. A two-day make-up session was offered at the end of August to accommodate teachers who could not attend in July. Principals were informed that as pilot schools, the Singapore curriculum had to be taught in each of the grade levels 1-5, and in order to be able to teach the Singapore curriculum, the teachers were required to attend one of the summer sessions. Many teachers were reluctant participants in the summer sessions.

After-school Training Sessions

Follow-up training sessions in effective strategies for teaching mathematics were provided to Singapore pilot teachers from 4:00 to 7:00 p.m. four times during the school year. All training sessions were developed and facilitated by the mathematics curriculum staff. The mathematics specialists modeled effective strategies for using manipulatives; presented content lessons on key topics such as fractions; and provided the teachers with a framework for teaching students how to approach word problems. The evaluation staff attended all sessions provided by the mathematics specialists, and found them to be well designed and implemented. The fifth after-school training session was the presentation of research findings by Liping Ma at the National Science Foundation.

Teachers in the Control A schools were supposed to receive after-school training that would be similar to the training provided to the Singapore pilot teachers, but these training sessions were not provided.

Participation of Singapore Pilot Teachers in Summer and After-school Training Sessions

Table 5 illustrates the amount of training in which Singapore pilot teachers participated. The maximum training dosage that teachers could acquire in the Singapore Math curriculum and effective mathematics strategies was:

- 18 hours for the July 2000 training or 12 hours for the August 2000 training; plus
- 15 hours for the four after-school sessions on effective mathematics strategies and the visit to NSF.

Most of the Singapore pilot teachers attended either the July or August summer training. However, 10 percent of the teachers did not attend any summer training, and seven percent attended for only one day. Attendance at the after-school training sessions during the school year was much more spotty. Eight percent of the teachers attended none of the after-school sessions, and another 57 percent attended only one after-school session. Attendance varied by school, with teachers in Schools 1 and 2 attending the greatest amount of training overall.[6] Reasons provided by teachers for not attending the school year training sessions primarily centered around time constraints, conflicts with other classes they were taking, other competing obligations, or inconvenience of the location of the training.

Table 5

Participation in Training by Singapore Pilot Teachers

Training Dosage	School 1	School 2	School 3	School 4	All Schools
Summer 2000					
0 hours	6%	0%	21%	13%	10%
6 hours	6	13	0	6	7
12 hours	56	56	64	56	58
18 hours	31	31	14	25	26
After-school training					
0 hours	0	19	14	0	8
3 hours	19	56	64	88	57
6 hours	63	13	21	13	27
9 hours	6	6	0	0	3
12 hours	6	0	0	0	2
15 hours	6	6	0	0	3
Total					
0 hours	0	0	7	0	2
3 hours	0	0	7	6	3
6 hours	0	0	7	6	3
9-12 hours	13	25	7	6	13
15-21 hours	50	56	62	81	65
24 hours or more	38	19	0	0	13
# of teachers	16	16	14	16	62

School-based Training

The school-based training component was provided by the OIPD mathematics specialists during the regular school day. All four of the Singapore pilot schools received this train-

[6] To preserve confidentiality, the Singapore pilot schools are referred to as Schools 1, 2, 3, and 4.

ing. Each of the Singapore pilot schools had a mathematics specialist assigned to the school, and the specialists visited the schools once a week. During these visits the specialists modeled mathematics lessons for the teachers and assisted with grade-level team planning of mathematics instruction. Two of the Control A schools received limited school-based training from the mathematics specialists,[7] but the remaining two control schools were not interested in school-based training.

Table 6 contains the ratings of the school-based training sessions that were provided by teachers on their surveys. The ratings show that almost 60 percent of the Singapore pilot teachers and 45 percent of the Control A teachers felt the training was very good or good.

Table 6

Teachers' Ratings of School-based Training

Rating	Singapore Pilot	Control A
Very good/good	59%	45%
Fair	29	45
Poor/very poor	12	10
Number of teachers	63	37

Principals' Perceptions of the Training Provided to Their Teachers

Principals of the Singapore pilot schools were pleased, overall, with the training their teachers received. Additionally, they felt that the mathematics specialists were attentive to their teachers' needs. In contrast, principals of the two Control A schools were disappointed that their teachers did not receive all of the promised training.

Lessons Learned from Year 1 Training

The second year training offerings were modified based on lessons learned in the first year. The second year began with a four-day summer institute for Singapore pilot and Control A teachers. Many Singapore pilot and several Control A teachers availed themselves of this training opportunity. The after-school follow-up sessions were eliminated in the second year of the pilot. Instead, the schools were allowed to request that the mathematics specialists assigned to their schools provide school-based training to meet the spe-

[7] In one of these Control A schools, the mathematics specialist was asked by the principal to provide school-based training in the use of manipulatives. This training was provided and the evaluation team observed manipulatives in use in mathematics lessons.

cific needs of their students and teachers. Two of the Singapore pilot schools and one Control A school made requests for and received these training services in year 2.

The Assessment Model

Prior to the implementation of the Singapore Math pilot, elementary school teachers used the ISM assessments to monitor student progress through the MCPS mathematics curriculum. These assessments tested student learning on many domains of mathematics content and discrete skills. The assessments, which were innovative for their time (they were first implemented in 1976), were viewed by many teachers and principals as outdated, based on too many small components of instruction and assessment, and not at the level of coverage to foster deep understanding of major mathematics concepts. To support the Singapore Math pilot, the mathematics specialists prepared a set of quarterly assessments aligned with the scope and sequence of the Singapore Math curriculum. These assessments were designed to place greater emphasis on depth of understanding and problem solving in context. Singapore pilot and Control A schools were to use these new quarterly assessments in place of the ISM assessments. Control B schools were to continue using the ISM assessments.

The quarterly assessments were developed for each grade level with items that were linked to the Singapore Math curriculum for that grade. Singapore pilot students took these assessments in place of the ISM assessments in all four quarters of the 2000-01 school year. Since Control A schools were not identified until late October, their students took the ISM assessments for the first quarter, and began taking the new quarterly assessments in the second quarter of the 2000-01 school year. Some teachers in the Control A schools continued to base their instruction in part on the ISM assessments throughout the school year.

Because of their continuing concerns regarding gaps in students' mathematics knowledge, teachers in both the Singapore pilot and Control A schools often deleted items from the quarterly assessments that they felt their students had not yet learned, and in some cases the assessments were not given at all. Research on systemic reform of curriculum and instruction[8] indicates that reform works most effectively when there is alignment throughout the instructional system, e.g., when curriculum, teacher training, and assessment are based on the same vision and framework for instruction. In the case of the Singapore pilot schools, some teachers felt the quarterly assessments assumed prior knowledge that their students had not had the opportunity to learn. In the case of the Control A schools, principals and teachers expressed that they were given the new assessments, but not the new curriculum with which they were aligned. As one teacher reported:

> "The assessments we receive from the county do not match the strategies I use in my classroom, so it's almost like setting up children for failure."

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[8] O' Day, J. A. and Smith, M. S. "Systemic Reform and Educational Opportunity." In S. Fuhrman (ed.), *Designing Coherent Policy: Improving the System*. San Francisco: Jossey-Bass, 1993.

It is anticipated that the assessment component will be implemented more uniformly in the second year of the Singapore pilot program.

Processes

Earlier we identified some implementation problems associated with the key pilot components: the curriculum, instructional materials, training, and assessments. The implementation problems affected how the project was rolled out, and had subsequent effects on what changes could be expected regarding teachers' content or pedagogical knowledge, quality of classroom instruction, and beliefs about how and what students could learn. This section of the report addresses what we learned about these topics in the first year of the evaluation study.

Findings in this section on processes are based on what we learned from multiple data sources:

- what we learned from principals and teachers in the interviews and surveys;
- what we learned from students and parents in the focus group discussions;
- and what we observed in the classrooms.

The several tables in this section reflect responses by Singapore pilot teachers to specific teacher survey questions and findings from the classroom observations of Singapore pilot and Control A classes. The principal interviews and the parent and student focus group discussions were structured around open-ended questions on major topics and do not lend themselves readily to summary tables. Illustrations of principals', parents' and students' comments are inserted in the text as appropriate.

Based on the extent to which we observed Singapore Math materials and strategies in use in classroom instruction in the pilot schools, the evaluation team concluded that:

- 18 percent of the pilot teachers were not using the Singapore Math curriculum or instructional strategies emphasized in the training sessions;

- 38 percent were attempting to use the curriculum and strategies but were struggling with them;

- 29 percent were experiencing moderate success implementing the curriculum and strategies; and

- 16 percent were highly successful in implementing the curriculum and strategies (see Table 7).

The observation data also showed that in two Singapore pilot schools – Schools 1 and 2 – where the teachers and principals actively participated in training activities, the teachers were significantly more successful in implementing the curriculum and strategies than were teachers in Schools 3 and 4. Also, the Singapore curriculum and instructional strategies were implemented more consistently and pervasively in Schools 1 and 2 than they were in Schools 3 and 4.

Additionally, the data suggest that teachers in Schools 1 and 2 modified instruction and changed their opinions and beliefs about mathematics instruction in meaningful ways and in greater numbers than was true for the other two schools. Much of this change was facilitated by the steps the principals in these two schools took to lay the groundwork for a school-wide focus on effective instruction, but the hard work and commitment to change on the part of the teachers in these schools should not be underestimated. Specific illustrations of these findings are provided in the following discussion.

Table 7

Extent of Implementation of Singapore Math Curriculum and Effective Instructional Strategies in Singapore Pilot Schools

Extent of Implementation	Schools 1 & 2	Schools 3 & 4	All Pilot Schools
None observed	6%	33%	18%
Struggling with implementation	41	37	38
Moderately successful	31	23	29
Highly successful	22	7	16

A Combination of Factors Produced Change

When we began this evaluation study a year ago, we were interested in whether there would be meaningful changes in instruction that could be attributed to the Singapore curriculum or to the training that was provided to the teachers. The data and discussion that follow suggest that both the curriculum and training contributed meaningfully to changes within the schools. The curriculum provided a structure and coherence to the Grades 1-5 mathematics program, and the training provided teachers with instructional strategies and deeper understanding of how students learn that were essential to effective implementation of the curriculum.

Another important factor was the leadership that principals gave to pilot activities and the degree to which they provided supports within the school to facilitate effective implementation of the curriculum and instructional strategies.

Contextual Conditions

The principal's leadership is key to shaping the context of any major reform effort in a school building. The principals of Schools 1 and 2 showed their endorsement of the Singapore pilot by attending the training sessions with their teachers. This conveyed a message to teachers in these two schools that the administrator viewed the training as important, and suggests to the evaluation team that the two principals felt that attending the training sessions with their teachers would enhance their ability to be effective instructional leaders. In each of the sections that follow, there are examples of how various types of principal support played out in enabling the teachers in Schools 1 and 2 to form a common vision for mathematics instruction and become more effective in teaching mathematics.

A special note must be inserted here regarding how the principal of School 1 used her leadership ability to completely restructure how the school would be organized to deliver mathematics instruction and how teachers would be supported to teach mathematics. This restructuring included:

- abandoning homogeneous (ability) grouping in mathematics, in favor of heterogeneous grouping – no longer was there a "low" class and a "high" class in mathematics; rather, each class in a grade level had students with a diverse range of abilities in mathematics.

- slightly increasing class size to free up a full-time teaching position which was divided between a half-time teacher to support reading instruction and a half-time teacher to support math.

- emphasizing staff development – nearly all of the school's staff development money was devoted to supporting Singapore Math, and nearly all the school's instructional supplies money was used to purchase materials to support the Singapore curriculum.

- physically locating teachers within grade levels in adjacent classrooms – this enabled teachers to debrief in the hallway following math class, check students' progress in the math curriculum on a daily basis, and, as a team, make adjustments to the next day's lesson.

- providing common planning time for teachers within a grade level.

These factors, combined, enabled the teachers in School 1 to pull together as a professional learning community in which they worked together to plan for and implement effective mathematics instruction. This is most notable in the perceptual shift expressed by teachers in School 1 regarding the relative benefits of homogeneous vs. heterogeneous grouping for mathematics instruction. When the principal reorganized mathematics classes to make them heterogeneously grouped for instruction, the teachers vocally opposed this move. By the end of the school year the teachers had changed their minds. Across all four Singapore pilot schools, 60 percent of the teachers reported that they felt that students generally learned mathematics best in classes with students of similar abilities and 35 percent reported disagreement with this concept. In School 1, however, 86 percent of the teachers strongly disagreed with the concept. Thus, in the first year of the

Singapore pilot, teachers in School 1 had moved as a group from the position of strongly endorsing homogenous grouping to strongly opposing it.

Teachers' Perceptions of Principals' Support

Singapore pilot teachers were asked some specific survey questions regarding the level of support they received from their principals in facilitating mathematics instruction. Teachers in all four Singapore pilot schools were positive about this support. Most teachers felt that their principals provided needed instructional materials, encouraged implementation of current national standards in mathematics instruction, and encouraged teachers to select mathematics content and strategies to meet individual students' learning needs (see Table 8). However, while over half of the Singapore pilot teachers agreed that their principals provided time for them to meet and share ideas with colleagues regarding mathematics instruction, most felt that this time did not allow them to jointly plan curriculum or lessons.

The teachers also felt that their principals encouraged innovative instructional practices in mathematics and acted as a buffer between teachers and external pressures. Teachers in Schools 1 and 2 felt significantly more positively about these areas of support than did teachers in Schools 3 and 4.

Table 8

Singapore Pilot Teachers' Responses Regarding Supports Provided to Them for Mathematics Instruction

Supports Provided by Principals	Strongly Agree/Agree	No Opinion	Disagree/ Strongly Disagree
Teachers are well supplied with materials for mathematics instruction.	59%	3%	38%
My principal enhances the mathematics program by providing teachers with needed materials.	70	10	21
My principal encourages the implementation of current national standards in mathematics instruction.	89	10	2
My principal encourages teachers to select math content and strategies to meet individual students' learning needs.	89	6	5
My principal provides time for teachers to meet and share ideas about mathematics instruction.	57	8	35
I have time during the week to work/plan with peers on mathematics curriculum and lessons.	21	5	74
My principal encourages innovative instructional practices in mathematics.	89	7	5
My principal acts as a buffer between teachers and external pressures.	61	18	21

Processes Related to the Curriculum

The multiple data sources available to us suggest that effective implementation of the Singapore Math curriculum can lead to a more coherent presentation of mathematics topics that builds on prior understanding. In the context of this study, coherence may be operationally defined by the presence of several attributes:

- the depth and thoroughness with which key topics are covered;
- the extent to which topics build on prior knowledge; and
- the extent to which a precise vocabulary or mathematical language is used.

Depth and Thoroughness

When principals were asked to compare mathematics instruction in the Singapore curriculum to how it was in the past using ISM, they used phrases such as "more in-depth," "scaffolding," and "sequential" to describe the Singapore curriculum. Teachers' responses to the survey questions were consistent with principals' perceptions. Sixty-six percent of the teachers reported that they had made many changes to their mathematics instruction as a result of the Singapore Math pilot, and another 25 percent indicated that they had made some changes (see Table 9). Nine percent of the teachers reported that they had changed their classroom practice little or not at all. Teachers in Schools 1 and 2 reported significantly greater changes than did teachers in Schools 3 and 4, and teachers in School 1 reported the greatest change of any of the groups.

Table 9

Singapore Pilot Teachers' Reports Regarding How Much They Had Changed Their Math Instruction This Year: (n=56) *

Amount of Change	Schools 1 & 2	Schools 3 & 4	All Pilot Schools
Little or none	4%	14%	9%
Some	18	32	25
A great deal	79	54	66

* There were 56 Singapore Pilot teachers who responded to this question. The remaining 7 teachers were new to teaching and had no prior basis for change.

Overall, 84 percent of the Singapore pilot teachers reported that they focused on topics in greater depth now than they did in the past, and 73 percent indicated that they spent more time on each topic (see Table 10). Seventy-three percent of the pilot teachers reported that they had increased both the depth and time they devoted to mathematics topics. The majority of the teachers reported that these changes resulted from the Singapore curriculum. There was little difference across the four Singapore pilot schools in how teachers responded to these items.

Table 10

Singapore Pilot Teachers' Reports of Changes in Depth and Thoroughness of Coverage of Mathematics Topics and What Caused The Change

Area of Change	No change in this area	Change due to training	Change due to curriculum	Change due to training and curriculum
I focus on topics in greater depth.	16%	9%	61%	14%
I focus longer on one topic.	27	2	57	14

Students and parents corroborated the information provided by principals and teachers. In comparing instruction in Singapore Math to instruction they received in the past, students noted that the Singapore curriculum is "...more organized and topics are covered in greater depth." Parents reported that "...Singapore math is more creative, takes more time, and focuses more on an understanding of the concepts rather than on memorization**.**"

These reflections on the part of principals, teachers, students, and parents get at the heart of the paradigm shift regarding effective mathematics instruction that the Singapore Math curriculum has helped to bring about. One of the major findings of the Third International Math and Science Study (TIMSS) [9] was that mathematics curriculum in the United States tends to be a "mile wide and an inch deep." That is, school systems in the United States tend to cover many topics in mathematics each year at a surface level, and keep revisiting the same topics year after year. This is how instruction was organized in the past in ISM. In the Asian countries, however, fewer topics are covered each year and the focus of instruction is on in-depth understanding of these topics.

The following comments illustrate how some teachers are struggling with the paradigm shift.

> "One of the principles I like about Singapore Math is the idea of teaching to mastery. Mastery seems to be emphasized. That is really important, especially early on to develop a good number sense. That seems to be better than my understanding of ISM: teach it, and if they don't get it they will get a chance at it again next year. In principle you teach to mastery in Singapore, but I am still feeling pressure to move at a faster pace and not get the mastery Singapore requires before moving on."

[9] Schmidt, William H., et al. *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education.* Boston, MA: Kluwer Academic Publishers, September 1996.

> "I have difficulty knowing when to move on. For example, how long do I stay on addition before I move onto subtraction? I am feeling guilty about not completing the workbook. I can't wait for all students to catch up."

Our classroom observation data suggest that these teachers are not alone in their struggle (see Table 8). The following vignettes, taken directly from the classroom observations, illustrate various levels of implementation.

In-depth focus on one topic:

> "The teacher spent the entire class period with her 5th grade students exploring the problem ½ of 3/8 using illustrations and shading parts of the whole on graph paper. After students grasped this concept, the teacher had them repeat the pro??cess for 3/8 of ½. During class time the teacher alternately broke the class into small discussion groups and brought the groups together for whole class discussion. She called several students to the front of the room to show how they attacked the problems. Students were able to explain their solutions using appropriate mathematics language and by drawing rectangles on graph paper and shading the sections that represented the fractional parts. By exploring this one problem in depth, students began to move toward abstract understanding that ½ **of** 3/8 was the same thing as ½ **x** 3/8. The teacher continually used phrases like, 'You have a good strategy.' During the lesson she continually tied explanations back to a MSPAP rubric. The evaluator asked a group of girls how math this year compared to last year. One girl replied, 'It's much better this year. It's hands-on. Last year we just had to show we knew how to do problems. This year we have to explain how we got our answers and we are learning why we are doing them.'"

A teacher who was struggling with the same topic:

> "In this 5th grade class the teacher began by asking, 'If we had to multiply ½ times 1/3 how would we start?' Two students attempted to answer the teacher but could not do so. The teacher gave each student a piece of square paper. She told them to fold the paper in half and color one-half. Then she said, 'Show me how you could figure out 1/3 of ½ by just folding the paper.' Students tried to fold the colored part into thirds. The teacher called on one student to explain how she folded the paper. She had folded the paper correctly but could not verbalize what 1/3 of ½ was. The teacher modeled again, asking, 'What was 1/3 of ½?' Finally, one child said, '1/6'? The teacher moved on to another problem displayed on the overhead. It stated, 'Show me 3/4 with the square paper. How could you show me ½ of 3/4?' Students folded the paper (which by now had already been folded into fourths), attempting to fold 3/4 of it into halves. Most students were totally confused and verbalized that they had no clue what was going on. When the teacher asked who was confused, most students raised their hands. The teacher then asked what the lowest common denominator was..."

A scatter-shot approach – jumping from one topic to the next without checking for meaning:

> "The teacher began the lesson for this 3rd grade class with the following warm-up problem:
>
> 342 325 354 337
>
> ____ + ____ = ____ + ____
>
> Students were supposed to use the numbers to complete the equation so both sides would be equal. After giving students an opportunity to think, the teacher asked for a show of hands from those who had thought of a way to solve the problem. No hands were raised. The teacher asked, 'What do I see between the second and third spaces? What does that tell me?' One student was called upon and he was able to say that it meant that the sum of the numbers on the left of the equal sign is the same as the sum of the numbers to the right of the equal sign....
>
> Students appeared to be just catching on to the strategies for the warm-up problem when the teacher asked the students to find the solution for 7 x 6. After working on this problem for awhile, the teacher gave students a worksheet in which they were to identify key words to help them solve word problems. After reading the first word problem, the teacher asked students what they needed to know to do the problem. 'What was the problem asking?' The problem was, 'Mrs. S. bought 6 bags of oranges. There were 10 oranges in each bag. How many oranges were in each bag?' Many students tried to solve the problem without recognizing that the answer was stated in the question. They started drawing arrays and trying to multiply. Before the students had the opportunity to understand where they had made their error in the bag of oranges problem, the teacher asked students what they would do if the problem had required them to multiply. She then drew an array for 10 x 6.
>
> Just before the end of class the teacher told students to stop their work and take out their response logs. She told them that they had to write in their journals today. She placed great emphasis on the need to write to make the math activity meaningful. Students were supposed to write about a time in their lives when they had used multiplication and division. A student asked, 'What if I haven't?' The teacher said, 'Make something up.'"

Building on Prior Knowledge

The Singapore pilot principals reported to us that mathematics instruction is more sequential now than it was in the past, and they feel that the Singapore curriculum more effectively builds on students' prior knowledge. The following are some of the comments that were made by the principals.

> "Singapore Math is more rigorous; it challenges students to think and work through complicated materials. The curriculum is different because review is kept to a minimum. The scaffolding is a positive thing. The curriculum builds on

> and uses previously learned skills. Students move through more complicated pro??cesses quicker. Singapore Math stresses patterns. It is very efficient.“
>
> “It’s a first through fifth grade program, so there’s a definite sequence from one grade to the next. In the past we may have had a different series of textbooks in the different grades. Although we followed the ISM curriculum, the resources were different. Now we’re all operating on the same system.”
>
> “There is a nice flow to Singapore. It builds on what students learned previously. Last year’s math was very choppy. “

Teachers’ comments indicate that some teachers see more value in the Singapore curriculum’s structure than do others.

> “Singapore constantly reviews what came before. At first I fought that, but now I see that it is really helpful. I have had a lot of kids out, but the way Singapore reviews and goes back, even those kids are getting it. The kids are really catching on – even the low ones. The questioning is the important part.“
>
> “I like Singapore. It gives students more in-depth learning about place value. I think that multiplication will be easier with that deeper understanding of place value.”
>
> “Some of the concepts introduced via Singapore are not ordered the way I would do it. For example, some harder skills are before easier ones. I do a lot of reviewing which has put me behind schedule.”

In an attempt to build on students’ prior knowledge, 75 percent of the Singapore pilot teachers reported on the surveys that they were making more connections to prior concepts than they did in the past. Fifty-four percent of the teachers attributed this change in practice to the Singapore curriculum, and 21 percent attributed it to the training or to the training and curriculum combined. Ninety-eight percent of the teachers reported that they took students’ prior understanding into account when planning instruction. Illustrations from the classroom observations show that some teachers are more adept at building on students’ prior knowledge than are others.

Effective review to build on prior knowledge:

> “The focus of this 2nd grade lesson was on meters and centimeters. The teacher asked students to review what they had been doing in math this week. The teacher asked, ‘Before we measure, what do we do?’ Students responded, ‘We estimate.’ The teacher asked students to explain what ‘estimate’ meant. They were complimented for their guesses and answers. The teacher asked students to show her with their arms what a meter was and what a centimeter was (giving them an opportunity to show that they basically understood the difference).”

Ineffective attention to prior knowledge:

> "As the 5th grade students came into the room, they began a warm-up activity that required them to write down the place value of the following four numbers:
>
> 4.36 316.452.793 1.832
>
> The teacher ended the warm-up by asking students for the right answers and asking students to explain how they arrived at their answers. However, as students made efforts to give answers, the teacher accepted responses without any explanations. The teacher called upon one student to write the numbers in order on the chalkboard. Then he asked all students to read the numbers together in unison. There was little evidence of student understanding of the warm-up problem or the concept of place value.
>
> The teacher distributed a xerox copy of a 100's grid. He wrote the decimal .45 on the board and told students to shade it in on the 100's grid. He then asked the students how many tenths and hundredths were in .45. Students were not sure. The teacher told students to show the four tenths on the 100's grid. He then asked which blocks, on their grids, represented the hundredths. The students said that they were confused. The teacher said that he would do another example with them. He told them to turn the 100's grid over and to show the decimal .19. The teacher asked how many tenths and hundredths there were in .19. There was no discussion or reference to students' previously stated confusion; rather the teacher just kept moving through the example in the same fashion as he did the first example."

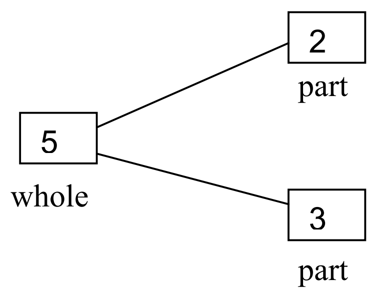
Examples such as these vignettes and the scatter-shot lesson described earlier suggest that some teachers do not have a good grasp on how to communicate effectively many mathematics concepts. In many cases the teachers probably did not take enough mathematics courses, themselves, to develop full understanding of the mathematical theory underlying these concepts. As time goes on, however, perhaps the inherent structure of the Singapore curriculum (or similar curricula that may be adopted in the future) will assist teachers in building the concept base and prior knowledge that students need to continue to move on to more complex mathematics concepts. The following examples, taken from the Singapore curriculum materials, show how a well-structured curriculum can provide the building blocks upon which later instruction may be scaffolded.

In the Singapore curriculum early addition is introduced through the concept of **number bonds**. Number bonds provide the basic structure for thinking about problem solving which continues through the grades as students learn more sophisticated mathematics concepts. We begin with a discussion of 5 penguins, 2 of whom are swimming, and 3 of whom are not. This is expressed using the number bond shown in Figure 4. Students are then asked to make up other "stories of 5" about the penguins and to draw number bonds to illustrate these stories, e.g.;

- 2 are adults and 3 are children;
- 4 are awake and 1 is sleeping.

Figure 4

Illustration of a Number Bond Representing 5 Penguins; 2 of whom are Swimming, and 3 of whom are Not.



By constructing all possible number bonds for the number 5, then moving on to similar stories (number bonds) of 8, 9, and 10, students acquire a sound conceptual understanding of numbers and basic addition. The pictorial representation of a number bond is repeated as students encounter subtraction later on in the year. The visual imagery portrayed in the number bond of a whole being made up of several parts forms the basis for attacking word problems in later years. Students use the concept of part/whole to determine what they know, what they need to find, and how to attack the problem. As one student described it:

> "If we know both parts and need to find the whole, we use addition or multiplication. If we know the whole and one part and need to find the other part, we use subtraction or division."

Another illustration of the structural underpinnings of the curriculum is the introduction and continued reliance on the concept of **fact families**. Students learn to construct fact families that link addition and subtraction or multiplication and division. Figure 5 presents, first, an example of a fact family for addition/subtraction, and second, an illustration of a multiplication/division fact family.

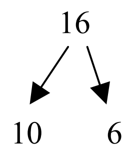
Figure 5

Illustrations of Fact Families

2 + 3 = 5 3 + 2 = 5 5 – 2 = 3 5 – 3 = 2	2 x 4 = 8 4 x 2 = 8 8 ÷ 2 = 4 8 ÷ 4 = 2

The classroom observations provided several instances of effective use of number bonds and fact families.

Number bond:

> "This 1st grade class is learning how to subtract a one-digit number from a two-digit number, subtracting from the ones place. The students used 10-frames to show number bonds and manipulate the bonds to show subtraction. The teacher asked the students to show a number bond for 16, where 10 was one of the numbers. The students showed:
>
> 
>
>
> Using this number bond the teacher asked the students to explain how they could solve the subtraction problem 16 – 2. The students explained how they found the solution by subtracting 2 from the 6 in the number bond, which left 4 ones and one 10."

Fact family:

> "The teacher asked the 3rd grade students what a 'fact family' was. Students gave the example of 2x3, 3x2, 6 divided by 2, and 6 divided by 3. The teacher asked if someone could explain multiplication. Only a few hands went up so the teacher told students to discuss the question in their teams. After giving students the opportunity for wait time and for group discussion, the teacher asked the question again. Many hands went up. The teacher called on one group and they reported that multiplication was repeated addition. The teacher asked students to explain what they meant by repeated addition. Then the teacher distributed manipulatives (counters/chips) to the students. The teacher explained that they had to take counters and show an array that modeled 2x4. The teacher asked students for the fact family that went along with 2x4. Their fact family was to include another multiplication problem and two division problems. Students were able to do this task with success."

Use of a Precise Vocabulary and Numerical Language

One of the positive features of the Singapore Math curriculum is the preciseness of the mathematical vocabulary that is used, and the consistency with which this vocabulary permeates texts and workbooks across the grades. This starts as early as the beginning of first grade when the foundation is laid for number sense. In addition to using words such as number bond and fact family to describe basic mathematical relationships, students encounter concepts such as **set**, **more**, and **less** as part of their daily learning. Simple addition problems are presented as **number sentences**, a concept that is carried through the grade levels as students learn about subtraction, multiplication, division, and fractions. The word **algorithm** is used to describe the various steps in a computational process (e.g., the steps in a long division problem). The following vignettes illustrate appropriate use of mathematical language.

Number sentence:

> "The teacher of this 1st grade class used various arrangements of 10 bears to illustrate number sentences using addition. For example, she put 2 bears in one group and 8 bears in the other. She then asked the students to tell her the number sentence for this grouping (2 + 8 = 10). This process was repeated for other groupings: 3 and 7; 4 and 6, etc."
>
> "In a 3rd grade class the teacher wrote a multiplication number sentence on the board and asked students to draw a picture (array) to illustrate the number sentence and to find the answer. Then the students were asked to write their own number sentences, illustrate them with arrays, and solve the number sentences they wrote."

Algorithm:

> "Students in this 4th grade class were using 10's rods and unit's cubes to represent division. As the students worked with the rods and cubes, the teacher wrote the division algorithm on the board. The teacher told students to look at the problem and analyze how their solutions using 10's rods and unit's cubes showed the same thing as the written algorithm. Students worked in pairs to discuss how the processes involved using the rods/cubes and writing the algorithm showed the same thing."

The evaluation team observed many examples of the use of precise mathematical language in Singapore pilot classes. It is important to note that this precision of language was most consistently observed in mathematics lessons in Schools 1 and 2. It should also be noted that the use of such precise language in these classes constitutes an increased rigor in the language of mathematics compared to the past. In prior studies of elementary school mathematics instruction[10] the evaluation team found no evidence of implementation of rigorous mathematical language.

Shift in Beliefs About How and What Children Can Learn

Information provided by principals and teachers indicates that they are changing their beliefs regarding how and what children can learn. Seventy-one percent of the teachers felt

[10] Gross, S. *Final Report - Mathematics Content/Connections and Elementary Science in Montgomery County (Maryland): A Comprehensive Transformation of a System-wide Science Program.* Rockville, MD: Montgomery County Public Schools, July 1999.

that teachers in their schools had a shared vision of effective mathematics instruction, and 81 percent reported that they regularly shared ideas and materials related to mathematics and instruction (see Table 11). Teachers in Schools 1 and 2 reported sharing of vision and materials significantly more often than did teachers in Schools 3 and 4. Moreover, when the evaluation team visited schools to observe classroom instruction, they learned that the teachers in School 1 planned a week's worth of lessons together in grade level teams and taught these lessons to all their classes. Often these planning sessions took place on the weekends – yet another example of the culture shift in this school.

Eighty-six percent of the Singapore pilot teachers reported that they expose students to mathematics topics earlier than they did in prior years, and the majority attributed this change to the Singapore curriculum. Sixty-three percent of the teachers felt that their students could handle mathematics content at higher levels than was expected in the past. Significantly more teachers at Schools 1 and 2 felt positively about this statement, compared to teachers in Schools 3 and 4.

Table 11

Singapore Pilot Teachers' Responses Regarding the Vision of Mathematics Instruction in Their Schools (n=63)

Statements Regarding Vision	Strongly Agree/ Agree	No Opinion	Disagree/ Strongly Disagree
Teachers in this school have a shared vision of effective mathematics instruction.	71% *	10%	19%
Teachers regularly share ideas and materials related to mathematics instruction.	81 *	5	14
I feel supported by colleagues to try out new ideas in teaching mathematics.	90	5	5

* Teachers in Schools 1 and 2 agreed with these statements significantly more strongly than did teachers in Schools 3 and 4.

The principals and teachers in Schools 1 and 2 suggested that the belief that students could handle higher level mathematics concepts was due to the progress that students had made using the Singapore Math curriculum, and the principals indicated that, as a result of this prog??ress, teachers had higher expectations for students and the students responded well to these expectations. According to one teacher:

> "Ninety-eight percent of the students are moving along much faster than if we were using ISM. The average first graders moved so far along in Singapore Math [by March] that they now know as much as the first graders did last June. Up until now we haven't been giving first graders much credit. Last year's low first graders are now doing regrouping in addition and subtraction [in second grade].

> They are grasping the processes. We are clear how they are doing on word problems."

Nonetheless, many teachers in Schools 3 and 4 were concerned about providing higher level mathematics instruction to their students. The concerns included:

- The Singapore Math curriculum materials require a lot of reading. Students do not have sufficient reading skills to handle the materials. This is especially true for ESOL students.
- The Singapore curriculum assumes that students have prior knowledge that has not yet been taught to them. This is especially true for students in grades 3, 4, and 5.

The following comments further illustrate teachers' concerns about their students. Most of the comments address concerns regarding placing upper grade elementary students in the Singapore curriculum without the prerequisite skills that the curriculum materials assume. This problem should take care of itself over time as students participate in the Singapore curriculum for additional years.

> "The students don't all know their multiplication and division facts. Singapore Math assumes they know this already, but because it is more advanced than ISM, the students have gaps. I'm also worried about adding and subtracting with regrouping – these kids don't know this. In a few years we will have caught up with the Singapore Math curriculum and these will no longer be problems."

> "The Singapore curriculum is overwhelming for third grade when kids have missed Grade 1 and 2 instruction. I feel I am not covering enough."

> "Fifth graders don't have the background to be successful with Singapore Math. They have been in a different math system all their school years. Parents and students are both frustrated."

> "There are several assumptions in Singapore Math that students have prerequisite skills. They don't and this is a struggle."

> "Some of the math skills [in Singapore] are very hard. It is difficult for students to explain their learning and thinking. Singapore is challenging and a lot of students are frustrated."

Yet other comments indicate that many teachers are trying to address these concerns in positive ways.

> "I have some students who ask to come in for recess or stay after school to work with me on their understanding. This is because the pace of curriculum is moving so fast."

> "I have tried to set an atmosphere of comfortable learning for the slower math students. Many at the beginning felt Singapore to be overwhelming. At the same time, I have 9 exceptional students who need more of a challenge. I have needed to pull from my resources for them."

Many parents shared the concerns of placing older students in the Singapore Curriculum. They, too, commented on the prerequisite skills that their children lacked, and reported that their children often became frustrated because of this. They also reported that, since the Singapore Curriculum was new to them as well, they did not know how to help their children with their homework. Parents of first and second grade students did not share these concerns.

Processes Related to Instructional Materials

The Singapore Texts and Workbooks

Classroom observation data show that in the Singapore pilot classes, on average, textbooks and workbooks were in use for just over one-fourth of the instructional time (see Table 12). In the Control A classes, textbooks and workbooks were observed in use for only 3 percent of the time. This difference is statistically significant. In contrast, teachers in the Control A schools used teacher-made worksheets 1 ½ times as often as did teachers in the Singapore pilot schools. Thus, it appears that the Singapore Math instructional materials helped to fill a void that has typically been filled by teachers creating their own instructional materials for mathematics.

Table 12

Percentage of Time Instructional Materials Were Observed in Use in Mathematics Lessons in Singapore Pilot and Control A Schools

Materials	Schools 1 & 2	Schools 3 & 4	All Singapore	Control A
Texts/workbooks *	26%	28%	27%	3%
Worksheets	20	22	21	33
Chalkboard/over-head	41	43	42	41

* Difference between Singapore pilot and Control A classes is statistically significant.

No meaningful difference was observed in the use of the Singapore materials by teachers in Singapore pilot Schools 1 and 2, compared to teachers in Schools 3 and 4. Also, the incidence of teacher use of the chalkboard or overhead projector did not vary among the different school types. Teachers continue to use these tools to model or explain mathematics concepts, and to have students show others in the class how they solved problems. Evaluation findings suggest that the Singapore instructional materials were well received in the pilot schools. Principals, teachers, parents, and students reflected that the books are well organized and well illustrated. Additionally, students reported that they liked the small size of the books – they are easier to carry in backpacks than the more typical heavier and larger trade textbooks.

Earlier in this report we stated that the Singapore curriculum is based on three overriding strategies for teaching mathematics:

1. concrete – working with manipulatives to express mathematical concepts;
2. pictorial – using pictures of objects to illustrate mathematical concepts (e.g., showing fractions as parts of a geometric figure such as a rectangle or circle); and
3. abstract – use of algorithms, for example, to solidify students' understanding of mathematical concepts (e.g., division).

We found manipulatives and pictorial representations of mathematics concepts in use in many of the classes that we observed, but seldom saw extensions of the concrete and pictorial to the abstract use of formulas and algorithms. Differences were found in the use of manipulatives and pictorial representations between the Singapore pilot and Control A classes.

Use of Manipulatives

Principals, teachers and students in the Singapore pilot schools reported that manipulative materials are used more for mathematics now than they were in the past. According to one teacher:

> "Most of the students are interested in math, especially when I use manipulatives.
> I use more manipulatives with Singapore than I did previously."

The classroom observation data show that teachers used manipulative materials to model instruction about ten percent of the time (see Table 13). Manipulatives were observed in students' hands for approximately one-fourth to one-third of the instructional time in Singapore pilot classes, and over 40 percent of the time in Control A classes, a difference which is statistically significant. However, the numbers do not convey an important distinction in the way manipulatives were used in the various classroom settings. In Singapore pilot Schools 1 and 2, teachers attempted to use the manipulatives in the way they were intended: as a concrete way of expressing mathematics concepts upon which abstract concepts could be built, i.e., their use was a way of scaffolding instruction. In contrast, in the Control A schools and Singapore pilot Schools 3 and 4, use of manipulatives tended to be the end product (i.e., to show how), rather than a means whereby students could develop the deeper understanding needed to explain why the more abstract mathematics algorithm worked. The following quote from a teacher illustrates use of manipulatives in conformance with the Singapore instructional model.

> “I use manipulatives 3-4 days when I introduce a topic. The last day or so I do it [the algorithm] on the board while the students use the manipulatives. Then we move to no manipulatives at all.”

Table 13

Percentage of Time Manipulatives Were Observed in Use in Mathematics Lessons

Use of Manipulatives:	**Schools 1 & 2**	**Schools 3 & 4**	**All Singapore**	**Control A**
by teacher	7%	9%	8%	13%
by students	33	24	28	43 *

* Difference between Control A and Singapore pilot classes is statistically significant.

Use of Pictorial Representations

The observation data show that, although the incidence of using drawings or illustrations to represent mathematics concepts was limited, overall, students in Singapore pilot classes used drawings or illustrations almost twice as often as did students in the Control A classes (see Table 14). Typically, the drawings and illustrations were based on exercises provided in the Singapore textbooks and workbooks. Sixty-six percent of the teachers reported that they use more pictorial methods of illustrating mathematics concepts than they did in the past. The majority attributed this change to the Singapore curriculum.

Table 14

Percentage of Time Pictorial Representation Was Observed in Use in Mathematics Lessons

Use of Pictorial Representation:	**Schools 1 & 2**	**Schools 3 & 4**	**All Singapore**	**Control A**
by teacher	9%	6%	8%	4%
by students	16	12	14	8
Students represent mathematics con-cepts using pictures **or** manipulatives	39	35	37	29

The following statement is one teacher's self report of how she uses pictorial representation in her lessons:

> "I've found it effective to have one student do a problem pictorially while his/her partner does the computation, and then having them reverse roles."

The following vignettes illustrate effective use of pictorial representations that we saw in our classroom observations.

> "The teacher started the class by asking the 3rd grade students to tell her what they did yesterday. A student called out, 'arrays.' The teacher asked what an array was. Another student answered by saying that it was a drawing. The teacher then asked if anyone could explain what an array was by using words. One student replied that it was a 'picture of a multiplication problem.'"
>
> "This 5th grade lesson began with the teacher and students going over a problem: 'After spending $30 on a dress, Maria has 3/8 of her money left. How much money did she have?' The teacher asked a student come up to the overhead to illustrate the problem. The student drew a rectangle and divided it into 8 parts. The teacher then asked the student to show what part of the rectangle represented the $30. The student showed what part this was by bracketing it [5/8]. She also bracketed the whole [8/8] to represent the total amount of money Maria had. The teacher asked the students what they needed to do next. A student replied, 'We need to divide $30 by 5 because we need to know what one unit is.' The teacher asked why this was so, and the student said, 'We need to find 8 units - the whole.' The teacher then reviewed the solution to the problem using the language 'part, part, whole.' One part is the $30 that was spent, which is 5/8. One part is the 3/8 that was left. The whole consists of both these parts."

<u>Processes Related to Teacher Training</u>

Instructional Strategies

Earlier we noted that three types of training were provided to teachers in Singapore pilot schools:

- a summer workshop in which the teachers were introduced to the Singapore textbooks, workbooks and teachers' manuals;
- quarterly after-school sessions in which mathematics specialists modeled effective use of instructional materials and strategies; and
- school-based sessions conducted by the mathematics specialists assigned to the schools (these sessions typically covered topics specific to grade level instruction).

In this section of the report we reflect on what principals, teachers, parents, and students reported about mathematics instruction, and what the classroom observations showed regarding teachers' use of effective instructional strategies for teaching mathematics.

Principals reported that there have been many changes in how mathematics instruction is implemented in their schools. They reported that they see more time being spent on mathematics instruction. In early grades the emphasis is on place value, number sense, and number bonds. Principals also reflected that they see more time being spent on problem solving and teaching students how to solve problems.

Parents and students agree with this assessment. According to the parents:

> "The teachers teach step-by-step directions for word problems. They teach the process of figuring out what you know and what you need to know to solve the problem. That process is different from in the past. Students get the concept of what they need to do to solve problems."
>
> "The multiple strategies allow students to gain confidence because they can find a strategy that is successful for them."

When teachers reflected on how their mathematics instruction has changed, they offered the following comments:

> "I've had a lot of success so far this year using Singapore Math as a basis to help build on concepts and to build a 'tool box' of strategies."
>
> "I use real life examples to explain what process may be needed."
>
> "This is the first time that we did a variety of options for expanded notation."
>
> "This is the second day on subtraction. I try to present more than one strategy to do it."

When teachers were asked on the survey to indicate areas in which their instruction had changed, 80 percent reported that they used a wider variety of strategies to teach mathematics than they did in the past (see Table 15). Fifty-four percent of the teachers reported that this change was due to the Singapore curriculum, and 27 percent attributed it to the training they had received or to the training and curriculum combined. Additionally, 80 percent of the teachers indicated that they facilitate more classroom discussion than they did in the past, and 77 percent reported that they ask more open-ended questions. Teachers in Schools 1 and 2 reported the greatest impact of training on their teaching practice. These schools also had the highest percentages of teachers who reported that they had changed.

Table 15

Areas in Which Singapore Pilot Teachers Reported That Their Mathematics Instruction Has Changed, and What Caused The Change

Area of Change	No change in this area	Change due to training	Change due to curriculum	Change due to training and curriculum
I facilitate more classroom discussion.	20%	18%	45%	18%
I use a wider variety of strategies.	20	11	54	16
I ask more open-ended questions.	23	25	38	14
I facilitate more hands-on activities.	45	16	34	5
I involve students more in decision-making.	43	9	41	7

Many teachers reported that they now facilitate more hands-on activities in mathematics lessons, and that they involve students more in decision-making. However, the percentage of teachers who reported change in these areas was substantially lower than was found in the other areas of change.

The teachers were also asked to respond to several items that the National Council of Teachers of Mathematics (NCTM) promote as important features of mathematics instruction.[11] Practically all teachers were in agreement that they included many of these features in their classroom instruction (see Table 16). However, the teachers agreed most strongly with the statement, "I provide concrete experience before abstract concepts." This is in keeping with the Singapore Math curriculum's emphasis on introducing concepts concretely and then moving to abstract representation. On the other hand, the teachers reported that they engaged students in inquiry-oriented activities and in applications of math in a variety of contexts less frequently than they did other features of instruction.

Findings from the classroom observations show that teachers in both the Singapore pilot and Control A schools do many things to encourage students' mathematics understanding. We observed teachers questioning students for understanding more than 70 percent of the time, and modeling appropriate mathematical processes for students one-third of the time (see Table 17). Generally speaking, there was not much difference between Singapore pilot and Control A classes in the features of mathematics instruction that were observed. However, we found that Singapore pilot teachers stressed some areas more than did Control A teachers. These were:

- helping students to find relationships between concepts, procedures, or topics in mathematics;

[11] NCTM. *Principles and Standards for School Mathematics*. Reston, VA: 2000.

- encouraging alternative solutions to problems; and
- encouraging student decision-making.

None of these differences were statistically significant.

Table 16

Singapore Pilot Teachers' Responses Regarding Features of their Mathematics Instruction

Features of Mathematics Instruction	Strongly Agree	Agree	No opinion/ disagree
I provide concrete experience before abstract concepts.	62%	33%	5%
I develop students' conceptual understanding of mathematics.	41	57	2
*I make connections between math and other disciplines.	43	49	8
I have students work in cooperative learning groups.	51	41	8
I have students participate in appropriate hands-on activities.	49	51	0
I engage students in inquiry-oriented activities.	21	68	11
I engage students in applications of math in a variety of contexts.	21	69	10
I use informal questioning to assess student understanding.	46	51	3

Additionally, we found that teachers in Schools 1 and 2 placed somewhat different emphasis on three features of mathematics instruction than did teachers in Schools 3 and 4.

- Students in Schools 1 and 2 spent significantly more time explaining their thinking than did students in Schools 3 and 4.

- Students in Schools 1 and 2 spent less time practicing computation in isolation than did students in Schools 3 and 4.

- Students in Schools 1 and 2 spent more time solving problems or performing computations in a contextual setting than did students in Schools 3 and 4.

Differences in percentages for these last two features were not statistically significant.

Table 17

Percentage of Time Various Features of Mathematics Instruction Were Observed in Mathematics Lessons

Features of Mathematics Instruction	Schools 1 & 2	Schools 3 & 4	All Singapore	Control A
Students find relationships between concepts, procedures or topics	24%	21%	23%	13%
Students explain their thinking	56 *	40	48	46
Students practice computation in isolation	27	35	31	30
Students solve problems or perform computations in a contextual setting	25	17	21	23
Teacher questions students for understanding	71	68	69	75
Teacher encourages alternative solutions to problems	15	13	14	10
Teacher encourages student decision-making	8	14	11	4
Teacher models mathematical processes for students	36	34	35	33

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.

Finally, the evaluation team rated mathematics lessons on several attributes, using a 3-point scale. Table 18 presents average ratings of these attributes for teachers in the various school settings. A score of "1" indicates that the attribute was observed little or not at all. A score of "2" indicates that the attribute was observed somewhat, and a score of "3" indicates that the attribute was observed a great deal of the time.

The ratings indicate that, overall:

- students participate in hands-on and minds-on activities;
- students participate actively in mathematics lessons;
- students use a variety of procedures to solve problems;
- teachers call on many students during the classroom period;
- teachers provide meaningful activities for students; and
- teachers deal effectively with student confusion.

Features that were observed less frequently include:

- students answer open-ended, higher-order questions;
- teachers provide time during the lesson for reflection and closure on key concepts;
- and student work is on prominent display in the classroom.

While, for the most part, ratings of the attributes were similar for Singapore pilot and Control A classes, some important differences did emerge, both between Singapore pilot and Control A classes, and between classes in Schools 1 and 2 and classes in Schools 3 and 4.

- Students in Schools 1 and 2 participated significantly more actively in mathematics lessons than did students in Schools 3 and 4.

- Teachers in Schools 1 and 2 provided meaningful activities for students significantly more often than did teachers in Schools 3 and 4.

- Students in Control A schools participated significantly more actively in mathematics lessons than did students in Schools 3 and 4.

- Teachers in Control A schools called on significantly more students during lessons than did teachers in Schools 3 and 4.

Table 18

Observers' Ratings of Various Attributes of Mathematics Lessons

Attribute	**Schools 1 & 2**	**Schools 3 & 4**	**All Singapore**	**Control A Schools**
Student work is displayed.	1.03	1.13	1.08	1.16
Students participate in hands-on and minds-on activities.	2.25	2.00	2.13	2.00
Students answer open-ended, higher-order questions.	1.91	1.63	1.77	1.69
Students use a variety of procedures to solve problems.	2.09	1.83	1.97	2.03
Students participate actively in lesson.	2.28 *	1.93	2.11	2.25 **
Teacher calls on many students.	2.25	2.07	2.16	2.47 **
Teacher provides meaningful activities for students.	2.19 *	1.80	2.00	2.03
Teacher provides time for reflection and closure.	1.59	1.53	1.56	1.34
Teacher deals effectively with student confusion.	2.31	2.13	2.23	2.13

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.
** Difference between Control A schools and Schools 3 and 4 is statistically significant.

Teachers' Deeper Understanding and Presentation of Mathematics Topics

Principals of the Singapore pilot schools reported that teachers were meeting together to plan mathematics lessons and were deepening their understanding of how students learn and how to present mathematics concepts. The following comments reflect principals' observations in these areas.

> "Math is being talked about, and that is powerful. Teachers are discussing better ways to instruct children, and children are finding that they have the ability and skills to figure out problems. They are more confident in the ways they solve problems."

> "This year I saw much more conversation and dialogue about mathematics among the teachers. This was driven by necessity. There was a lot of informal lesson study occurring. Now there is a lot of discussion and excitement and the willingness to try."

Teachers were asked to reflect on the extent to which the training sessions offered to them enhanced their mathematics instruction in several areas. Table 19 presents their responses. Overall, about one-fourth of the Singapore pilot teachers reported that they had gained a great deal of mathematics content knowledge through the training, and about one-fourth felt that they had greatly increased their ability to implement high-quality instructional materials in math. Over 40 percent of the teachers reported they were now able to employ a greater variety of instructional strategies in math, and were more motivated to teach math. Thirty-five percent reported a greater understanding of how students think and learn.

Table 19

Percentage of Singapore Pilot Teachers Who Reported That Training Enhanced Their Mathematics Instruction to a Great Extent

Aspects of Mathematics Instruction	Schools 1 & 2	Schools 3 & 4	All Singapore
Increased mathematics content knowledge	33%	22%	27%
Increased ability to employ a greater variety of instructional strategies	59 *	32	45
Increased ability to implement high-quality instructional materials	41 *	14	28
Increased understanding of how students think and learn	40	29	35
Increased motivation to teach mathematics	37	43	41

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.

Throughout this report we have highlighted the effects of teacher participation in the training sessions. The teachers' self-reports of benefits they acquired from the training are consistent with the earlier findings presented in this report that link extent of teacher participation in training to changes in how mathematics instruction is conceptualized and implemented in the Singapore pilot schools. In two key areas of mathematics instruction, the teachers in Schools 1 and 2 reported significantly greater benefits to their instructional practice when compared to teachers in Schools 3 and 4. These areas are:

- increased ability to employ a greater variety of instructional strategies; and
- increased ability to implement high-quality instructional materials.

This is not surprising since these were two major areas of emphasis in the teacher training provided by the Central Office mathematics specialists.

Finally, teachers were asked to rate how well prepared they were to implement various aspects of mathematics instruction. Table 20 contains the percentage of teachers who felt very well or fairly well prepared in each area. The teachers in the Singapore pilot schools feel very well or fairly well prepared in the majority of the areas questioned. A few departures from this overall finding are noteworthy.

- Teachers feel less well prepared to recognize and respond to student diversity than they feel about other areas of mathematics instruction.

- Teachers feel least well prepared to involve parents in the mathematics education of their children.

- Teachers in Schools 1 and 2 feel significantly better prepared to lead classes using investigative strategies than do teachers in Schools 3 and 4.

- Teachers in Schools 1 and 2 feel significantly better prepared to involve parents in the mathematics education of their children than do teachers in Schools 3 and 4.

Table 20

Percentage of Teachers Who Felt Very Well or Fairly Well Prepared to Implement Various Aspects of Mathematics Instruction

Aspects of Mathematics Instruction	Schools 1 & 2	Schools 3 & 4	All Singapore
Teach mathematics content	88%	86%	87%
Lead a class using investigative strategies	93 *	74	84
Mange a class engaged in hands-on or project-based work	97	84	91
Encourage student interest in math	97	94	95
Recognize and respond to student diversity	81	81	81
Involve parents in the math education of their children	72 *	48	60

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.

Processes Related to Assessment

It may be recalled that the Singapore pilot and Control A schools were provided with quarterly assessments that were aligned with the Singapore curriculum. Singapore pilot teachers used these assessments in place of the ISM assessments in all four quarters of the year, and, depending on the school in which they taught, teachers in Control A schools used the quarterly assessments for the last 3 or last 2 quarters of the year. The following comments regarding implementation of the quarterly assessments were provided by principals in the Singapore pilot schools.

> "The assessments seemed to be rushed in the way they were put together and distributed in the beginning. There were many errors in them early on. The errors got fewer as time went along."

> "The assessments were aligned with content for the most part, although initially, the format of the assessments were not presented in the same way that the problems were presented in the Singapore text and workbooks. The Singapore assessments are generally more appropriate than ISM assessments. The Singapore assessments provide teachers more of a sense of the students' total math ability."

> "I think the Singapore assessments are more reflective of students' true knowledge and retention than are the ISM assessments. I prefer the format of the Singapore assessments because I think it is a more accurate assessment of what students retain."

> "There appears to be more retention with Singapore Math because the assessments scaffold – they build on the various skills."

> "I like the idea of giving assessments quarterly. It's a good way to get a measure four times a year of how the kids are progressing. I like testing them on a variety of different concepts and topics at once over the length of a quarter, rather than just at the end of a unit. That allows us to get a better understanding of what the students know. There is a writing component that is really missing from ISM. In the Singapore assessments you can really see how the students explain their thinking and see how they solved the problems."

In contrast, while many teachers liked the new quarterly assessments, some teachers continued to have concerns about them throughout the year. According to one teacher:

> "I have not covered half of the quarterly assessment problems. They are not appropriate for this class."

These concerns will hopefully diminish as more students experience several consecutive years of Singapore Math instruction and assessment.

Outcomes

Accelerated Student Progress Through the Mathematics Curriculum and Students' Deepened Understanding of Mathematics Concepts

Teachers' Assessments of Student Progress

Comments from Singapore pilot teachers suggest that their students have acquired deeper understanding of critical mathematics concepts than they did in prior years. Teachers pointed to students' greater understanding of number bonds, place value, and number sense; measurement; and problem solving. When they were asked to comment on the progress made by students in their mathematics classes compared to earlier years, 73 percent of the pilot teachers reported that their students made greater progress than was true in the past. Teachers in Schools 1 and 2 reported significantly greater student progress than did teachers in Schools 3 and 4 (87 percent vs. 63 percent). In contrast, only 33 percent of the Control A teachers noted greater student progress compared to prior years. Since Control A schools did not receive new curriculum materials, this finding is not unexpected.

Quarterly Assessment Results

Table 21 shows the results from the first year's implementation of the quarterly assessments in Singapore pilot and Control A schools. The table shows, by grade level and quarter, the total number of items on the assessment and the mean number of items correct for students in each school category. Since the assessments were developed as the year progressed, no validity or reliability studies have been conducted. Nor has a standard of acceptable performance been determined. In the second year of the evaluation study OSA is working with mathematics curriculum staff to assess the merits of the assessment items. Once that process is complete, the mathematics curriculum staff may want to consider establishing standards of acceptable performance. For purposes of this report, discussion is based on the relative performance of students in each school category.

Table 21 shows that no group of students attained average performance that approached what might be considered full mastery of the assessment items and objectives. In each school group, for each grade level and quarter, group average scores ranged from approximately half to two-thirds of the maximum possible score for the assessment. Many factors could have produced these results. The assessments may have been too long for students to complete during one class period. Individual items may have been too difficult or worded in a way that was confusing or too advanced for the students' grade level. Or, the assessment results may be indicative of the knowledge gaps resulting from the transition from ISM to the Singapore curriculum and assessments. Hopefully we will be able to better determine through further analyses which, or how many of these possibilities actually affected students' performance.

Table 21

Mean Performance of Singapore Pilot and Control A Students on the Quarterly Assessments

Grade/Quarter	Total # Items	Schools 1 & 2	Schools 3 & 4	All Singapore	Control A
First grade					
Quarter 1	20	14.1	13.7	13.9	--
Quarter 2	25	18.6	18.5	18.5 **	15.3
Quarter 3	23	17.9 *	16.5	17.3 **	13.5
Quarter 4	19	13.5	13.6	13.5 **	9.7
Second grade					
Quarter 1	25	18.3 *	12.3	15.5	--
Quarter 2	19	11.0 *	7.9	9.5 **	5.2
Quarter 3	27	20.0 *	14.6	17.3 **	12.4
Quarter 4	28	20.6 *	16.8	18.9 **	13.9
Third grade					
Quarter 1	34	22.0 *	19.8	21.0	--
Quarter 2	25	18.5 *	14.3	16.4 **	13.6
Quarter 3	25	14.3	13.9	14.2 **	13.2
Quarter 4	26	17.7 *	14.5	16.2	15.3
Fourth grade					
Quarter 1	22	14.1 *	12.9	13.7	--
Quarter 2	20	13.5 *	11.4	12.8 **	9.1
Quarter 3	31	19.1 *	12.5	16.6 **	9.7
Quarter 4	28	21.4 *	14.4	18.9 **	15.2
Fifth grade					
Quarter 1	48	30.0 *	21.9	26.7	--
Quarter 2	27	19.0 *	13.5	16.6 **	9.5
Quarter 3	47	34.5 *	22.0	29.2 **	15.8
Quarter 4	26	17.2 *	13.4	15.7 **	7.2

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.
** Difference between Singapore pilot and Control A schools is statistically significant.

Despite all of these considerations, notable patterns of performance were observed. For most of the assessments, students in the Singapore pilot schools significantly outperformed students in the Control A schools. Additionally, for many of the assessments, students in Schools 1 and 2 significantly outperformed students in Schools 3 and 4. This pattern is more pronounced in Grades 4 and 5 where differences between Schools 1 and 2 and Schools 3 and 4 are much larger than they are in earlier grades.

The totality of the data suggest that, where the Singapore curriculum was well implemented, students were able to move ahead in mathematics understanding at far greater rates than was true where the curriculum was not well implemented or not implemented at all. It also appears that where the curriculum was well implemented, teachers were able to surmount the obstacles created by the knowledge gaps that existed among upper grade students.

Students' Mathematics Achievement

Students' mathematics achievement was examined in three ways: performance on the CTBS, performance on the MCPS mathematics criterion-referenced tests (CRTs),[12] and middle school mathematics course enrollment for students who were in the Singapore pilot as 5th graders. The analyses of CTBS and CRT performance are the only sections of this report that provide comparisons between all three levels of schools that were initially planned for the evaluation study – Singapore pilot, Control A, and Control B schools. This has been done so that we could assess whether just the simple focus on math for the Control A schools allowed them to move students further along in math performance than was true in the past. As the following tables and discussions show, students in the Control A schools do not appear to have made any meaningful gains in mathematics performance that could be attributed to their schools being exposed to the pilot. However, implementation of the Singapore curriculum and instructional strategies appears to have had positive effects on the mathematics achievement of students in Schools 1 and 2.

CTBS Performance

Table 22 presents the CTBS performance for students in 2nd and 4th grades in years 2000 and 2001 in the Singapore pilot and control schools. In 1999-2000 students had the traditional MCPS mathematics curriculum. In 2000-01 students in the Singapore pilot schools (especially in Schools 1 and 2) were exposed to the Singapore curriculum and instructional strategies.

In spring 2000, for both Grades 2 and 4 and for both the mathematics and mathematics computation sub-tests of the CTBS, there were no statistically significant differences between Singapore pilot and control schools, or between Singapore Schools 1 and 2 and Schools 3 and 4. In spring 2001, however, 2nd grade students in Schools 1 and 2 significantly outperformed students in Schools 3 and 4 on the mathematics and mathematics computation sub-tests, and 4th grade students in Schools 1 and 2 significantly outperformed students in Schools 3 and 4 on the mathematics sub-test. Fourth grade students in Schools 1 and 2 also outperformed students in Schools 3 and 4 in mathematics computation, but the difference in scores was not quite statistically significant. Additionally, in 2001, students in the Singapore pilot schools significantly outperformed students in the Control A schools in Grades 2 and 4 on both CTBS sub-tests, and they statistically outperformed students in the Control B schools in mathematics computation.

[12] The MCPS CRTs were discontinued after the spring 2001 administration.

Table 22

CTBS Mean National Percentile Scores for Students in Grades 2 and 4 in 2000 and 2001

Sub-test/Grade/Year	Schools 1 and 2	Schools 3 and 4	All Singapore	Control A	Control B
Mathematics					
Grade 2					
2000	63	57	60	64	59
2001	71 *	57	65 **	58	64
Grade 4					
2000	75 *	69	72 **	63	69
2001	71	69	70 **	61	68
Mathematics Computation					
Grade 2					
2000	62	62	62	64	57
2001	80 *	68	75 ***	60	67
Grade 4					
2000	68	65	66	63	68
2001	76	71	74 ***	62	63

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.
** Difference between Singapore pilot and Control A schools is statistically significant.
*** Differences between Singapore pilot and Control A and B schools are statistically significant.

CRT Performance

Although the CRTs were recently eliminated, we thought it would be prudent to analyze student performance on the mathematics CRTs to investigate the effect on student performance of adoption of a new curriculum. In earlier curriculum pilot efforts, some teachers were reluctant to embrace the new curriculum program because of concerns that the new curriculum did not completely align with the sequence in which objectives were assessed on the CRTs. Thus, the CRTs were viewed by some MCPS curriculum supervisors and principals as impeding the progress toward reform of the elementary and middle school mathematics curricula. Analyses of the mathematics CRT performance of 3rd and 5th grade students in 2000 and 2001 suggest that the existence of the CRTs as a system-wide assessment package did not interfere with the mathematics learning of students in schools where the Singapore Math curriculum was well implemented. This finding is true despite the fact that there was only about 50 percent overlap between how mathematics objectives were sequenced on the CRTs and how they were sequenced in the Singapore curriculum.

What we discovered was that 3rd and 5th grade performance of students in Control A and Control B schools was very similar in both the 2000 and 2001 administrations of the CRTs (see Table 23). This would make sense since no major changes were made in mathematics instruction in these schools. However, when we examined student performance for Schools 1 and 2 and for Schools 3 and 4, the findings were fairly consistent with what we found in the 2nd and 4th grade CTBS analyses. Third grade students in Schools 1 and 2 significantly outperformed students in Schools 3 and 4 on the multiple choice and open-ended sub-tests as well as the total mathematics score in both 2000 and 2001. However, while the performance of 3rd graders in Schools 1 and 2 was slightly improved from 2000 to 2001, the performance of 3rd graders in Schools 3 and 4 declined markedly during this period. For 5th graders, students' scores on the multiple choice sub-test improved from 2000 to 2001 in Schools 1 and 2, but they declined in Schools 3 and 4. Thus, it appears that sound implementation of the new Singapore curriculum did not adversely affect students' performance on the CRTs, but ineffective or spotty implementation of the curriculum had an adverse effect.

Table 23

CRT Mean Scale Scores for Students in Grades 3 and 5 in 2000 and 2001

Sub-test/Grade/Year	Schools 1 & 2	Schools 3 & 4	Control A	Control B
Multiple Choice				
Grade 3 2000	705 *	671	688	708
2001	710 *	642	696	705
Grade 5 2000	683	686	671	681
2001	691 *	670	674	684
Open-ended				
Grade 3 2000	658 *	635	640	654
2001	666 *	617	652	647
Grade 5 2000	673 *	635	618	624
2001	662 *	622	617	647
Total				
Grade 3 2000	681 *	653	664	680
2001	687 *	628	674	677
Grade 5 2000	678	669	653	661
2001	678 *	655	654	670

Moreover, for the one group of students that we were able to follow longitudinally from 2000 to 2001 we observed some interesting differences. In 2000, when the they were in 4th grade, students in Schools 1 and 2 and Schools 3 and 4 performed comparably on the multiple-choice sub-test and the total battery (see Table 24). On the open-ended sub-test, however, students in Schools 3 and 4 significantly outperformed students in Schools 1 and 2. As 5th graders, the students in Schools 1 and 2 pretty much held their own with a slight decline in performance on the multiple choice sub-test, but students in Schools 3 and 4 declined substantially. As a result, when they were in 5th grade, the students in Schools 1 and 2 had statistically higher multiple choice, open-ended, and total scores than did their peers in Schools 3 and 4.

Table 24

CRT Mean Scale Scores for Students in Grade 5 in 2001 Compared to Their Performance as Fourth Graders in 2000

Sub-test/Grade/Year	Schools 1 & 2	Schools 3 & 4	Control A	Control B
Multiple Choice				
Grade 4 2000	725	711	682	690
Grade 5 2001	692 *	673	674	684
Open-ended				
Grade 4 2000	651	683 **	627	642
Grade 5 2001	658 *	630	617	631
Total				
Grade 4 2000	688	697	657	666
Grade 5 2001	678 *	659	654	671

* Difference between Schools 1 and 2 and Schools 3 and 4 is statistically significant.
** Difference between Schools 3 and 4 and Schools 1 and 2 is statistically significant.

Middle School Mathematics Course Enrollment

At the outset of the Singapore pilot there was some concern about placing 5th grade students in the Singapore curriculum because of possible gaps in earlier years of their mathematics instruction. Also, some parents were concerned about the articulation between 5th grade and middle school 6th grade for these students. In this section of the report we briefly examine 6th grade mathematics course enrollment for students in fall 2001, who experienced Singapore math as 5th graders in 2000-01, and compare the course enrollment to that of students who were 6th graders in fall 2000 and had no exposure to the Singapore curriculum in 1999-2000. The course enrollment data indicate that experiencing the Singapore curriculum as 5th graders has not been detrimental to the students' mathematics course placement in 6th grade (see Table 25).

Students in Schools 3 and 4 appear to have been placed in comparable 6th grade courses in fall 2001 as were students from the same schools in fall 2000. For Schools 1 and 2, however, 6th graders in fall 2001 had somewhat higher mathematics course placements than did students from the same schools in fall 2000. A smaller percentage of the 2001 6th graders were placed in Math A, compared to those placed in Math 6 or Math A in 2000, and conversely, higher percentages of the 2001 6th graders were placed in Math B or Math Investigations, compared to those placed in Math 7, Math B, or Math Investigations in 2000. For students in the Control A schools, the major shift in course enrollment from fall 2000 to fall 2001 occurs between placement in Math 6 honors versus Math B. Whereas in fall 2000 35 percent of the students in Control A schools were placed in Math 6 g/t, course placement for the g/t level 6th grade students in fall 2001 was Math B.

Table 25

Sixth Grade Mathematics Course Enrollment in Fall 2001 and Fall 2000

Mathematics Course	**Schools 1 and 2**	**Schools 3 and 4**	**Control A**
Math 6 (regular) or Math A			
Fall 2000	53%	50%	44%
Fall 2001	46	52	65
Math 6 (g/t) or Math A			
Fall 2000	17	0	35
Fall 2001	0	2	0
Math 7 or Math B			
Fall 2000	21	27	8
Fall 2001	32	22	26
Math Investigations			
Fall 2000	8	20	11
Fall 2001	19	15	8
Algebra			
Fall 2000	0	4	0
Fall 2001	0	8	0

Students' Attitudes About Mathematics

On balance, parents and students reported in the focus group discussions that students have better attitudes about math now that they have been exposed to the Singapore curriculum and new teacher strategies. When asked how they felt about mathematics, many more parents and students reported that the students loved math (62 and 43 percent, respectively), compared to the number reporting that the students strongly disliked math (17 and 12 percent, respectively). Comments provided by parents and students attribute these attitudes to the changes in instruction brought about by the Singapore pilot.

> "I'm more successful in math this year."

> "We're moving at a faster pace and the work is more challenging. I like this."

> "My child is more enthusiastic and more confident in math this year. The confidence my child gained from Singapore transfers to other subjects."

> "My child loves the Singapore homework."

<u>Parents' Satisfaction</u>

At the outset of the Singapore pilot many parents shared the concerns of teachers regarding the wisdom of placing upper grade elementary students in the Singapore curriculum. They feared that their children would not be able to keep up with the mathematics content because of gaps in their earlier mathematics instruction. Many parents modified this view as the school year progressed and they noted that their children were able to handle the Singapore mathematics curriculum and, in fact, appeared to be learning much more and acquiring greater depth of understanding of fundamental mathematics concepts. However, for students with learning disabilities or second-language learners, parents continued to have concerns.

Another concern expressed by parents was that the presentation of mathematics in the Singapore curriculum was substantially different from earlier mathematics instruction, and many parents felt they were unable to help students with their mathematics homework or monitor their children's progress in mathematics. Principals echoed the parents' concerns and were frustrated at the outset that they did not have materials to familiarize parents with the Singapore content and teaching strategies. Nonetheless, the Singapore pilot schools held information sessions for parents at the beginning of the school year to address parents' concerns. As teachers, students, and parents became more familiar and proficient with the Singapore materials and methods, many of these problems worked themselves out. Parents reported that as the school year progressed, their children became more independent in completing their mathematics homework, and were even able to explain the various strategies to their parents.

Finally, parents of some fifth grade students expressed concern about how the transition from elementary school to middle school would work out now that their children were being instructed in the Singapore curriculum. The following parent comments illustrate how attitudes changed as the school year progressed.

> "I feel fortunate that my child has Singapore math, but at the beginning, he lacked the resources for understanding the concepts fully. As he is catching on I'm happier, but I could use additional guidance on terminology."

> "Initially my daughter needed lots of help with her homework, but she has become self-sufficient."

> "My child has a better understanding of concepts and the relationship between concepts now. ISM left him just meeting goals, now he can internalize concepts."

> "My child's understanding of math has increased as the year has progressed, but it was a struggle until around December."

“My child is getting the same grades in math this year as she got last year, but this is not a meaningful comparison. Last year was rote learning and this year is analytical.”

“My son heard my wife and me talking about something we were planning. As he walked past us, he said, ‘That’s a division problem. You should use division to figure that out.’ I am a happy man!”

Summary and Recommendations

Summary

In summary we return to the four questions that were posed in the original evaluation study design and answer them based on our analyses of the totality of data available to us.

1. What is the effect of the Singapore Math curriculum on classroom instruction and student achievement?

The data suggest that where the Singapore Math curriculum was implemented as designed, classroom instruction became more coherent. The curriculum enabled teachers to present mathematics concepts in a logical sequence, cover them in-depth, and include a new level of rigor in appropriate mathematics language and concept formation. This resulted in greater confidence on the part of students and improved mathematics performance.

2. What is the effect of teacher training on classroom instruction and student achievement?

The data suggest that when teachers and principals attended the training sessions together and jointly discussed and planned mathematics lessons, classroom instruction improved. Teachers reported that they had a wider repertoire of instructional strategies that they were comfortable with, and the evaluation team observed a greater variety and more effective use of the strategies in mathematics lessons. Teachers felt that their newly-attained knowledge and skills led to improved student attitudes towards mathematics because mathematics lessons were more interesting and more challenging, provided students with multiple and effective strategies for solving mathematics problems, and it would lead to improved achievement. Parents noted these changes, and by and large, expressed satisfaction with the changes in mathematics instruction.

3. What effect does the model of student assessment have on classroom instruction and student achievement?

Principals and teachers reported that the new quarterly assessments provided more information about students' strengths and weaknesses in math than was true with the ISM assessments. They also perceived that the quarterly assessments tested a deeper level of understanding of mathematics than was true for the shorter, more frequently administered ISM assessments. Students in schools where the Singapore curriculum was well implemented scored higher on the quarterly assessments than did students in schools where the curriculum was less well implemented. However, our data analysis did not produce any links between use of the quarterly assessments and gains in student achievement. Further investigation needs to take place regarding the validity and reliability of the quarterly assessments.

4. If we wanted to expand the pilot to other MCPS schools, which aspects of the Singapore pilot would best lend themselves to other school contexts within MCPS?

The totality of the data suggest several important factors to be considered in either expanding the Singapore pilot or implementing a new curriculum effort. First, it is important to have a common school vision of effective instruction and expectations for student achievement. The principal's leadership skills can enhance movement to the common vision in several ways: providing materials and supplies to support the curriculum; setting aside time during the school day for teachers to plan lessons and discuss students' performance; and conveying the message that the new curriculum effort is important and relevant, and we will all dig in and do it.

Second, it is important that MCPS administration provide both curriculum materials and training supports to the schools. As the data collected in this evaluation study show, the schools in which the teachers and principals participated fully in training opportunities made the greatest growth in changes in classroom instruction, changes in teachers' attitudes regarding what students could learn, and subsequent gains in student performance.

Finally, it is important that time and resources be provided to allow the curriculum implementation process to percolate and mature, and to work with the community to gain acceptance of the change. Principals in the Singapore pilot schools felt that MCPS did not do an effective job in including parents in the decision process or informing them regarding how the new curriculum would affect them and their children. Nonetheless, one school's administrator was able to overcome these obstacles by providing several information meetings for parents to learn about the new curriculum and share concerns.

It was not the Singapore Math materials in and of themselves that caused change in the classrooms. Rather, the successful schools were characterized by teachers and principals who embraced the concepts of change and worked together to develop a professional learning community. These characteristics included:

- regular attendance at training by the principal and teachers;
- development of a common vision for mathematics instruction;
- attention to the needs and concerns of parents; and
- devotion of school resources (e.g., money, scheduling, and staff supports) to enhance the implementation of the Singapore curriculum.

The OIPD mathematics staff have indicated that the concerns raised in this report have been and will continue to be considered as the new mathematics framework and curriculum packages are piloted and implemented in schools. It will be interesting to observe how the process works in the coming school year's pilot of the new elementary mathematics curricula.

It is evident that in two of the Singapore pilot schools staff spent considerable time and effort on implementation issues and changes in instructional practice. When they embarked on the Singapore pilot adventure, it was with the understanding that the pilot would be a 3-year effort. However, with the upcoming cluster-wide implementation of one of the two new elementary mathematics curriculum packages in Grades 1 and 2, principals of the Singapore pilot schools have some questions regarding whether it would be better to stay with the Singapore curriculum for a third year or switch to one of the two new curricula. On the one hand, there is something to be said for continuing the momentum of the Singapore curriculum for another year. On the other hand, massive training efforts are being mounted for teachers in Grades 1 and 2 in summer 2002, and principals and teachers in the Singapore pilot schools might feel they have been left behind if they do not participate in the training this year. To address these concerns, OIPD staff has provided assurances that there will be special training sessions this summer for teachers in Singapore pilot schools. In these sessions teachers will learn how the Singapore curriculum aligns with the new MCPS mathematics curriculum framework. OIPD plans on providing additional training to teachers in these schools next year if the schools adopt one of the new mathematics curriculum packages.

There are also concerns regarding the extent of alignment between the Singapore curriculum and the new end-of-unit assessments that are being developed to support the two new elementary mathematics curriculum packages. It will be important to continue to monitor the progress of students in the Singapore pilot schools, whether they continue to be assessed on the quarterly Singapore assessments, or whether they are assessed on the new end-of-unit assessments. Most importantly, however, clear communication needs to be provided to the Singapore schools regarding interim and future steps that will be put in place to transition them into whatever mathematics curriculum is selected down the road as the "official" MCPS elementary mathematics curriculum.

Recommendations

Recommendation 1: Careful consideration should be devoted to the concerns of principals in the Singapore pilot schools as new pilot programs are rolled out. Transition activities to bring the Singapore pilot schools into the mainstream implementation of the new mathematics curricula will need to be formulated and communicated to the Singapore pilot principals and teachers. Additionally, as MCPS makes decisions regarding the effectiveness of the two proposed new pilot curricula for the coming school year, we need to be mindful of the amount of time that is needed for the implementation process itself, and the level of support schools will need to implement and then maintain the curriculum. These constraints must be considered as evaluation activities are proposed and carried out, and inferences about programmatic success are formulated.

Recommendation 2: Regardless of which curriculum program or textbook series is selected to support MCPS's continuing improvement of elementary mathematics, we need to provide training to teachers in effective strategies for teaching the curriculum. The adoption of a new curriculum may provide important structures for how mathematics should be taught or sequenced, but without training in effective instructional strategies, mathematics lessons will not change in meaningful ways.

OIPD will provide training to teachers in Grades 1 and 2 in summer 2002, and to teachers in Grades 3 through 5 in the Tier 1 Title I schools and the 6 non-Title I pilot schools. Similar training will need to be provided to the remaining teachers in Grades 3 through 5 as MCPS moves ahead with system-wide adoption of new elementary mathematics curricula. This training cannot be a one-shot experience. Summer institute training should be supplemented with follow-up training during the school year. And, to insure system-wide adoption of the new curriculum as well as to maximize the opportunities for all teachers to acquire essential skills and strategies for mathematics instruction, training may need to be viewed as a multi-year offering. Additionally, MCPS will need to provide ongoing supplementary training to meet the needs of new teachers who will be hired in the future.

Recommendation 3: If quarterly or end-of-unit assessments will continue to be used to support mathematics instruction, further development needs to take place on the assessment items. Validity and reliability checks need to be conducted, and teachers need to have a sense of the level of performance on the assessments that indicates students' acceptable mastery of the objectives. Training will probably be needed to provide teachers with a complete understanding of the different performance levels that their students might attain, and how best to interpret these performance levels as they plan subsequent instruction for the students.

Recommendation 4: Although students in upper elementary grades appear not to have been adversely affected by being thrust in the Singapore curriculum, implementation would have been easier and more palatable for teachers and parents if the curriculum were implemented incrementally, starting with the primary grades initially and then moving to the upper grades. MCPS is already moving in this direction by beginning system-wide implementation of new curricula in Grades 1 and 2.

Recommendation 5: Since the principal's involvement and leadership is critical to the successful implementation of curriculum reform, principals should be formally included and given a voice in the decision-making process for future reform efforts. Perhaps the principals and other key staff in Schools 1 and 2 could serve as consultants to MCPS curriculum staff on strategies for including principals in the future. They also could provide valuable information to their colleagues regarding how they used their instructional leadership skills to make positive change happen in their schools.

Recommendation 6: Careful consideration should be devoted to effective ways of building parent knowledge and obtaining their support of future curriculum efforts. Also, school staff need information packets and a variety of resources (such as sample agendas and personnel they could invite to their schools to assist with information meetings) that they could use in working with their communities.

Recommendation 7: The principals of the four Singapore pilot schools tried various ways of supporting mathematics instruction. One of the schools had a full-time mathematics specialist. One school reallocated the teacher/student ratio to free up a half-time position to support mathematics. In this school the half-time person was used, in part, to provide parent outreach. In the other two pilot schools part of the staff development teacher's responsibilities was to support teachers in mathematics instruction.

To assist the Title I schools in implementation of the new mathematics curricula, each school will have a half-time mathematics specialist. We recommend that MCPS collect data regarding how these specialists spend their time, and examine which aspects of the support they provide to teachers appear to be most useful and effective.