The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

Volume 8, Spring 2005

SPECIAL ISSUE
Mathematics Specialists

Virginia Mathematics and Science Coalition

The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

Volume 8, Spring 2005

SPECIAL ISSUE
Mathematics Specialists

Virginia Mathematics and Science Coalition

The Journal of Mathematics and Science:
COLLABORATIVE EXPLORATIONS

SPECIAL ISSUE
Mathematics Specialists

Coordinating Editor
for this Special Issue

Loren D. Pitt
Department of Mathematics
University of Virginia

Funding for this Special Issue was provided by
the ExxonMobil Foundation,
the Virginia Council for Mathematics Supervision, and
the Virginia Council of Teachers of Mathematics
through the
Virginia Mathematics and Science Coalition

Coordinating Editor's Remarks

A number of national reports focused on improving student learning in mathematics, coupled with strengthening teachers' understanding of mathematical concepts, have called for the placement of Mathematics Specialists in elementary schools, K-6. These reports (*The Mathematical Education of Teachers*, 2001; *Adding It Up: Helping Children Learn Mathematics*, 2001; National Council of Teachers of Mathematics (NCTM) *Principles and Standards of School Mathematics*, 2000; *Keys to Math Success: A Report from the Maryland Mathematics Commission*, 2001) have converged around a common idea [1-4].

Each report advocates that a Mathematics Specialist or a Mathematics Teacher Leader be placed in elementary schools to be a resource in professional development, teaching, curriculum development, assessment, and parent and community education to improve the teaching, learning, and assessment process. The NCTM *Principles and Standards of School Mathematics* states: "There is an urgent and growing need for mathematics teacher leaders—specialists positioned between classroom teachers and administrators who can assist with the improvement of mathematics education." [3]

The work of a Mathematics Specialist, Mathematics Coach, or Teacher Leader Specialist, whatever the role is called, can be distributed within a number of different models. A Specialist can provide professional development within the context of actual classroom situations through long- or short-term co-teaching arrangements. Likewise, a Specialist can work with teachers through the context of grade-level planning and debriefing sessions built around a lesson study model. A Specialist can lead a parent series focused on key concepts in elementary mathematics. Also, s/he can design professional development sessions for the faculty and administrators focused on the implementation of a new curriculum. There are multiple opportunities to bring professional development in elementary mathematics directly into the school and classroom.

Well-qualified Teacher Leaders in a Specialist role can have a significant influence on strengthening the mathematical, pedagogical, and assessment knowledge of classroom teachers who are frequently under prepared to deliver a rigorous mathematics program to a classroom of diverse learners. While the role of a Reading Specialist has been a part of elementary schools for many years, interestingly a Specialist in mathematics has taken longer to develop.

With support from ExxonMobil Foundation, the Virginia Council of Teachers of Mathematics, and the Virginia Council for Mathematics Supervision, the Virginia Mathematics and Science Coalition is devoting this issue of *The Journal for Mathematics and Science:*

Collaborative Explorations to the Mathematics Specialist role and issues of implementation of Specialist programs. The articles contained here will address the following topics.

- Why a Specialist? What in the present condition of elementary mathematics education makes the Specialist role particularly timely? What does research tell us about the Specialist role, about its effectiveness as a school-based strategy?

- What are examples from the field (schools and districts) where the Specialist role (or Coach or Lead Teacher) has been integrated into a district's mathematics program? What does this work look like? What has worked? What are the lessons learned? What particular skill sets do Specialists bring to their work?

- What do we know about the content and pedagogical preparation for a Specialist's role? How can the work of teaching mathematics be redistributed to bring authority to the Specialist's role? How does this model help to integrate a different kind of professional development into the work of schools?

- What can we learn from Specialists in other disciplines? Can professional development in reading help inform the Mathematics Specialist role?

- What roles can be played by institutions of higher education and state departments of education in preparing Specialists? What is being done? What do those models look like?

An important secondary purpose of this issue is to tell the history of the Mathematics Specialist movement in Virginia and in selected school districts. This history illustrates the remarkable impact that the sustained efforts of a small group of advocates for Mathematics Specialists have had in the schools and in Virginia's educational system. The advocates for Mathematics Specialists have been joined by powerful voices in the Virginia Department of Education and the Board of Education. An important part of this story is the role that has been played by continued support from the ExxonMobil Foundation for our *Mathematics Specialist* efforts in Virginia. This ExxonMobil support was significant in the Coalition and its partners receiving substantial funding for their Mathematics Specialist projects from the National Science Foundation and the Virginia Department of Education. This is leading Virginia into an exciting new era in mathematics education.

References

[1] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[2] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.

[3] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[4] *Keys to Math Success: A Report from the Maryland Mathematics Commission*, Maryland State Department of Education, Baltimore, MD, 2001.

PART I: PREFACE

In 2002, the Virginia Mathematics and Science Coalition (VMSC) Board directed that a task force be established to prepare a case and write a report to present to Local Education Agencies (LEA), the Virginia Department of Education (VDOE), the Virginia Board of Education, and policy makers as to how a Teacher Specialist might improve student learning. Consideration was to be given to Mathematics Specialists at both the elementary and middle school levels. This report was to discuss job descriptions, competencies, preparation, and licensure.

Here, we include the report, the executive summary, and a definition that was developed by the National Science Foundation–supported Mathematics Specialists School and University Partners after the report was completed. We also include a history of the Mathematics Specialists movement as an introduction to the articles in this issue.

MATHEMATICS SPECIALISTS DEFINITION

MATHEMATICS SPECIALISTS SCHOOL
AND UNIVERSITY PARTNERS

Mathematics Specialists are teacher leaders with strong preparation and background in mathematics content, instructional strategies, and school leadership. Based in elementary and middle schools, Mathematics Specialists are excellent teachers who are released from full-time classroom responsibilities so that they can support the professional growth of their colleagues, promoting enhanced mathematics instruction and student learning throughout their schools. They are responsible for strengthening classroom teachers' understanding of mathematics content, and helping teachers develop more effective mathematics teaching practices that allow all students to reach high standards, as well as sharing research addressing how students learn mathematics.

The overarching purpose for Mathematics Specialists is to increase the mathematics achievement of all the students in their schools. To do so, they:

- Collaborate with individual teachers through co-planning, co-teaching, and coaching;
- Assist administrative and instructional staff in interpreting data and designing approaches to improve student achievement and instruction;

- Ensure that the school curriculum is aligned with state and national standards, as well as their school division's mathematics curriculum;
- Promote teachers' delivery and understanding of the school curriculum through collaborative long-range and short-range planning;
- Facilitate teachers' use of successful, research-based instructional strategies, including differentiated instruction for diverse learners such as those with limited English proficiency or disabilities;
- Work with parents/guardians and community leaders to foster continuing home/school /community partnerships focused on students' learning of mathematics; and,
- Collaborate with administrators to provide leadership and vision for a schoolwide mathematics program.

EXECUTIVE SUMMARY—BUILDING THE CASE: MATHEMATICS SPECIALIST

VIRGINIA MATHEMATICS AND SCIENCE COALITION
TASK FORCE

Given the increasing demands for all students to learn higher levels of mathematics and our agenda for improving the mathematics performance of all students, it is essential that schools have personnel prepared to address these challenges. Every child in Virginia must have excellent mathematics instruction to acquire an understanding of concepts, to gain fluency in procedures, and to become effective problem solvers. Experts in teaching and learning mathematics are also needed in the assessment and diagnosis of children who struggle with mathematics, and to serve as resources in planning and implementing interventions.

A number of national reports call for the placement of Mathematics Specialists in schools. A Mathematics Specialist is a teacher in the elementary or middle school who has interest and special preparation in mathematics content, scientifically based research in the teaching and learning of mathematics, diagnostic and assessment methods, and leadership skills. School-based Mathematics Specialists serve as resources in professional development, instructing children with learning difficulties, curriculum development, mentoring of new teachers, and community education.

The Task Force found school divisions in Virginia whose teachers and students are benefiting greatly from the multiple learning opportunities that Mathematics Specialists can bring into the school and the classroom. The Mathematics Specialist, working with the building-level administrator, can assume the responsibility for coordinating and providing leadership for the schoolwide mathematics program.

Mathematics Specialists can assume multiple leadership roles in schools, depending on the needs of the student population and teachers. Some Specialists work primarily in teaching roles with students in either pullout programs or in co-teaching situations. Others work providing job-embedded staff development for teachers. An additional essential role of the Specialist is supporting the work of the classroom teacher, and in developing a high quality, research-based mathematics program that ensures the success of all children in learning mathematics.

The Specialist role requires a comprehensive and rigorous preparation. Mathematics Specialists require deep knowledge of how children learn mathematics, of the use of various assessments in diagnosing student difficulties in learning mathematics, and of designing instruction for diverse learners. Individuals in Specialist positions require graduate level preparation including significant coursework on school mathematics. The validity of the position of Mathematics Specialists will require that Specialists hold an appropriate educational endorsement.

Programs to prepare Mathematics Specialists must include appropriate school mathematics content and model pedagogy essential for teaching that content. Collaborative efforts among colleges of education, colleges of arts and sciences, local school divisions, and the Virginia Department of Education are needed to bring about the appropriate preparation of Mathematics Specialists.

MATHEMATICS SPECIALISTS TASK FORCE REPORT

VIRGINIA MATHEMATICS AND SCIENCE COALITION
TASK FORCE

PREFACE

Charge from VMSC — In Fall 2002, the Virginia Mathematics and Science Coalition (VMSC) Board directed that a task force be established to prepare a case and write a report to present to Local Education Agencies (LEA), the Virginia Department of Education (VDOE), the Virginia Board of Education, and policy makers as to how a Teacher Specialist will improve student learning. Consideration should be given to Mathematics Specialists at both the elementary and middle school levels. This report should include, but is not limited to, job description, competencies, preparation, and licensure.

Committee on Mathematics Specialists:

Vickie Inge Chair
Stafford County School

Loren Pitt VMSC Liaison
President VMSC
University of Virginia

Susan Birnie
Alexandria City Schools

LouAnn Lovin
James Madison University

Yvonne Smith-Jones
Hopewell City Schools

Jacqueline Getgood
President Virginia Council of Teachers of Mathematics
Spotsylvania County Schools

Marcella McNeil
Portsmouth City Schools

Diane Tomlinson
Virginia Co-Director Coalfield Rural Systemic Initiative
Russell County Schools

Vandivere Hodges
President-Elect Virginia Council of Teachers of Mathematics
Hanover County Schools

Patricia Moyer-Packenham
George Mason University

Denise Walston
Norfolk City Schools

Betti Kreye
Montgomery County Schools

Patricia Robertson
Arlington City Schools

Susan Wood
J. Sargeant Reynolds Community College

Consultants and Reviewers:

Becky Baskerville
Dinwidde County Schools

Jerry Gambino
Fairfax County Schools

Beth Williams
Bedford County Schools

Janice Bryson
Richmond Mathematics and Science Center

Nancy Iverson
University of Virginia
School of Continuing and Professional Studies

Linda Zabrofsky
Prince William County Schools

David Carothers
James Madison University

Tina Weiner
Roanoke City Schools

Jay Wilkens
Virginia Tech

Donna Dalton
President Virginia Council of Mathematics Supervisors
Chesterfield County Schools

Introduction

Over the last decade, several compelling studies and reports have identified the strong connection between student achievement and the quality of teacher knowledge and skills [1-3]. Furthermore, Sanders and Rivers as well as Monk and King found that low-achieving students made significantly greater performance gains when assigned to effective teachers [4,5].

The National Research Council's report, *Educating Teachers of Science, Mathematics, and Technology* informs us that, "the kind and quality of teachers' in-service education can make a difference in how their students achieve" [6]. Richard Elmore reports that professional development focused on student learning must be tailored to address the difficulties encountered by real students in real classrooms [7]. School-based Mathematics Specialists will allow elementary and middle school level teachers to benefit from site-based and in-depth learning experiences which are ongoing, reflective, and close to classroom practice [8]. Efforts to support Teacher Specialist programs are taking root across the Commonwealth of Virginia as school divisions look for ways to raise student achievement by improving mathematics instruction. For the purposes of this report, we will define instruction as what teachers do. Instruction consists of the interactions involving teachers, students, and content. To frame our work and to guide our research we asked the question, "What interventions or deliberate efforts to improve instruction will be enhanced by a Mathematics Teacher Specialist, and what preparation is necessary to take on this role?"

We believe any efforts aimed at improving instruction require a departure in some degree from current practice. Implementation of these efforts requires teachers to learn new knowledge, skills, and practices, as well as increasing their capacity to use more effectively what they already know and can do [9]. Research informs us that teacher knowledge profoundly affects student achievement. Students perform better when they are able to learn from teachers who have a deep understanding of the mathematics in conjunction with a sound knowledge of teaching methods [6]. In today's high stakes education climate, students who are not taught by highly qualified teachers may be penalized. For example, they may be retained at grade level or not allowed to graduate. There is a need for highly qualified teachers, but the education profession is faced with a scarcity of teachers who possess a profound understanding of the mathematics they teach. Highly qualified teachers in all classrooms are mandated in the federal No Child Left Behind (NCLB) legislation.

To help teachers improve instruction and become increasingly expert, we must recognize teaching as a lifelong journey of learning rather than a final destination of "knowing" how to teach (Linda Darling-Hammond, in a March 2000 presentation to the WestEd Board of Directors). We must ensure that teachers have the necessary support as they move through the continual changes encountered on their journey. From our interviews and observations, we have learned that a variety of strategies are underway across the Commonwealth to improve instruction in mathematics. The common element among all of these interventions is that classroom teachers must make changes in their instructional programs and practices. In Virginia schools, these changes center around implementing new and innovative curricula, increasing teacher learning through professional development opportunities or coursework, restructuring instructional time, and establishing accountability for outcomes.

Effective mathematics teaching is complex, requiring both a broad base and a special content knowledge for successful instruction. The *2000 National Survey of Science and Mathematics Education* conducted by Horizon Research, Inc. for the National Science Foundation reported that only 60% of the elementary teachers in their survey felt qualified to teach mathematics [10]. Surveys and interviews with school division personnel indicate Virginia teachers at the elementary and middle school levels lack profound understanding of the content, as well as a comprehensive knowledge of content pedagogy. In elementary schools, teachers are typically generalists, with minimal coursework in mathematics. Often, these teachers have had only one or two mathematics courses in college. While Virginia has raised the requirements in mathematics coursework for those seeking middle school certification, many middle school mathematics teachers do not have the equivalent of a mathematics major or minor in college. In many cases, middle school teachers are former elementary teachers who have moved to middle school.

Virginia, just as other states, has an increasing number of teachers entering the classroom through alternative licensure routes. School divisions are finding that while these teachers may have the content knowledge for the workforce, they lack the specialized content knowledge and content pedagogy for effective teaching. Subject matter knowledge is not sufficient for effective teaching to take place [11]. In their government commissioned report, they also state, "[Without training in pedagogy] it appears that prospective teachers may have mastered basic skills, but lack the deeper conceptual understanding necessary when responding to student questions and extending lessons beyond the basics."

To address these issues, the Virginia Department of Education, along with Virginia school divisions, have provided staff development and coursework for teachers in both content and in pedagogy. School divisions have implemented mentoring programs for new teachers. The Task Force learned through informal observations and interviews that these interventions have not been sufficient for various reasons. Often it is not possible to scale up staff development learning opportunities to reach all of the teachers in a school. Most of these learning opportunities, as well as the mentoring programs, are not sustained over time; thus, the impact on teachers' beliefs and behaviors is marginal. Virginia teachers and administrators reported to the Task Force that ongoing, site-based assistance is necessary to adequately support teachers in the change process. One way to provide this sustained support is to develop and maintain a cadre of Mathematics Teacher Specialists who can offer meaningful and consistent site-based guidance to their colleagues.

Evolution of the Lead Teacher Program in Virginia

The concept of a content Teacher Specialist is not a new concept in Virginia, but it is an evolution of the Lead Teacher model established in Virginia more than ten years ago. In 1992, the Virginia Mathematics Coalition, now the Virginia Mathematics and Science Coalition (VMSC), joined with the Virginia Department of Education, the Virginia Council of Teachers of Mathematics, and others in a National Science Foundation-funded project, V-QUEST. The goal of V-QUEST was to prepare elementary and middle school teachers to serve as "Math Leaders" or "Science Leaders" in their schools. Over the three years of funding, participating K-8 mathematics and science teachers increased their content knowledge in mathematics and science along with content pedagogy during intensive and focused summer institutes. These Teacher Leaders returned to their schools to lead efforts toward improving teaching and learning in mathematics and science.

A 1997 report by Critchfield and Pitt documented the variety and effectiveness of Lead Teacher programs in nine representative Virginia school divisions three years after V-QUEST ended. These school divisions reported the Lead Teacher served as a curriculum leader and a resource for teachers, as well as providing staff development for teachers [12]. Several divisions attributed the rise in test scores to the work of the Lead Teachers. The report also illuminated the significant variations across Virginia in how the Lead Teacher program evolved and was sustained. The greatest differences were seen in the preparation and support for the Lead Teachers. In some divisions, there had been no additional training beyond the V-QUEST training. In other divisions, there was modest, unfocused, and inconsistent training. Some divisions were able to secure grant funding to support continued preparation for Teacher Leaders. One division secured an ExxonMobil Teacher Leadership Grant in mathematics. Several divisions participated in SCHEV Eisenhower grants focused on preparing Teacher Leaders. However, it was clear from this report that without a statewide infrastructure to prepare Specialists, these nine divisions had difficulty maintaining a pool of highly qualified Mathematics Specialists.

In March 2002, a survey of 43 Virginia school divisions conducted at a meeting of the Virginia Council of Mathematics Supervisors indicated that the Teacher Leader concept lives on in schools across the Commonwealth. However, there is no stability in the programs because there is no statewide agenda to continually prepare content-based Teacher Leaders or content

Specialists. In addition, there is presently no license to validate the Teacher Leader or to recognize teachers who have participated in learning opportunities that might prepare them to be Specialists.

Further analysis of the surveys revealed that 23 different titles are used to designate the state's Mathematics Teacher Leaders. The primary responsibility of these Leaders was to serve as liaisons between the school boards' central offices and the school sites. The surveys indicated a critical need for the Mathematics Teacher Leaders to take a more active role in providing staff development for teachers and leadership for the building level mathematics program. However, we learned from these surveys that a number of barriers stand in the way. Teacher Leaders need a deeper understanding of the mathematics content being taught. In addition, Teacher Leaders need more knowledge about mathematics content pedagogy (how both students and adults learn to make sense of mathematics), and they need to develop leadership skills as well as skills to facilitate adult learners.

On May 20, 2002 the Virginia Mathematics and Science Coalition, the Virginia Council of Mathematics Supervisors, and the Virginia Council of Teachers of Mathematics, with support from ExxonMobil Education Foundation hosted a forum, "Moving from Teacher Leaders to Mathematics Teacher Specialists," in Fredericksburg, Virginia. At this time, representatives from school divisions across Virginia indicated their commitment to providing high quality mathematics and science programs for all students. As school divisions continue to move forward to strengthen their instructional programs so that no child is left behind, what support will classroom teachers need? The participants in this forum agreed that a well-prepared Mathematics Teacher Specialist could be an effective support for classroom teachers.

Rationale for Mathematics Specialist

Rising Expectations for Students — Virginia educators and politicians have set forward an agenda to ensure that every student has the opportunity to study in a high quality mathematics program that prepares them for further study in mathematics, as well as to be productive members of society. Expectations for student learning have been defined in the nationally recognized framework, the Virginia *Standards of Learning* (*SOL*) [13]. A state assessment system has been implemented to monitor student progress toward meeting the Virginia *SOL* in mathematics. In grades K-8, Virginia students are assessed in mathematics at the end of grades 3, 5, and 8. Under the NCLB legislation, additional assessments in mathematics will be implemented at grades 4, 6, and 7. At the secondary level, students enrolled in Algebra I, Geometry, and Algebra II must take end-of-course assessments.

Accountability weighs in, as students must pass prescribed numbers of end-of-course tests in order to graduate. Each year, greater numbers of students are passing the *SOL* tests. However, many children across the Commonwealth are still not passing these assessments and are at risk of not graduating from high school. Most troubling are the results of tests at the elementary and middle school levels. An examination of the 2002 Virginia *SOL* test results posted on the Virginia Department of Education website reveals that 20% of third graders, 29% of fifth graders, and 29% of eighth graders did not pass the 2002 *SOL* grade-level tests in mathematics.

The disaggregated data from the 2002 *SOL* tests in mathematics reveal that across Virginia, there are gaps between the percentage of Caucasian students passing the tests and the percentage of the subpopulations who passed the tests. This can be illustrated by looking at a few of the smallest gaps. In mathematics at grade 3, there is a 22-point gap between the Caucasian and African-American populations, and a 29-point gap between the Caucasian population and the disabled population. We see similar differences between the Caucasian population and the Limited English Proficiency (LEP) population, as well as the Hispanic population.

While concerned with the numbers of students not passing as well as the gaps between populations, we are just as concerned that more students are not passing at the advanced proficient level. It is important to note that just passing these tests indicates only minimal expectations for students.

<u>Improving Instruction</u> — There is a pressing need for schools across Virginia to improve student learning, and we believe this will be best accomplished by implementing instructional programs grounded in the teaching and learning of significant mathematics for understanding. However, as subject matter becomes more complex, teachers need a deeper knowledge of that subject matter to help their students learn at higher levels [14,15]. Teachers must be supported in deepening their own content knowledge along with content pedagogy knowledge.

A number of national reports have begun to call for the placement of Mathematics Specialists in elementary schools. These reports (*The Mathematical Education of Teachers*, 2001; *Adding It Up: Helping Children Learn Mathematics*, 2001; National Council of Teachers of Mathematics *Principles and Standards of School Mathematics*, 2000; *Keys to Math Success: A Report from the Maryland Mathematics Commission*, 2001) have converged around this common idea [15-18]. Each report calls for qualified Mathematics Specialists to be placed in schools as a resource for improving instruction. We believe that school-based Specialists will serve as a resource in professional development, teaching, curriculum development and implementation, mentoring new teachers, and parent and community education.

Virginia teachers at the elementary and middle school levels must possess a deep understanding of the mathematics they are teaching, an understanding of how it connects to higher levels of mathematics, and a skillful use of methods to guide students in the learning of mathematics. Teachers must understand students' thinking and how students develop mathematical proficiency. In addition, teachers must continually refine their mathematics content pedagogical knowledge (in an ever changing teaching environment) to teach in such a way that every child becomes proficient in mathematics.

Teachers, and ultimately students, in Virginia can benefit greatly from the multiple learning opportunities content Specialists can bring into the school and the classroom. Well-prepared Teacher Leaders in a Specialist's role can have a significant influence on strengthening content, pedagogical, and assessment knowledge of those classroom teachers who are poorly prepared to deliver significant mathematics programs. Staff development must be seen as an integral part of teachers' professional lives. Job embedded professional development provided by content Specialists is critical for improving instruction and student learning [1, 19-20].

Mathematics Specialists

Role of the School-Based Specialist — Teacher learning is a catalyst for school reform and improvement in teaching and learning. As shown in this report, staff development efforts are unlikely to be either effective or enduring without carefully considering provisions to support the growth of teachers' understanding of their practices. Improvement in student learning is not as simple as teaching teachers how to teach differently, but requires working in classrooms in such a way that the teachers are continuously supported in the process of changing their teaching

practices. Teachers, with support from a building-level content specialist, can develop strong expertise in the teaching and learning of mathematics [7]. A Specialist is a teacher whose interest and special preparation in mathematics content and mathematics content pedagogy is matched with special teaching or leadership assignments to support teaching and learning [21].
Building-level administrators seldom have the time or the expertise in mathematics to lead the changes to improve instruction in mathematics. The NCTM *Principles and Standards of School Mathematics* states: "There is an urgent and growing need for Mathematics Teacher Leaders—Specialists positioned between classroom teachers and administrators who can assist with the improvement of mathematics education." [18] Teacher Specialists in Virginia's elementary and middle schools will be first-hand observers and participants in the school culture. These Specialists will be aware of the needs of the school, provide solutions that address those needs, and help ensure that every child becomes proficient in mathematics.

Adam Gamoran and colleagues used information from a multi-year study conducted by the National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA) to examine what successful schools and school divisions are doing to transform teaching in mathematics and science [22]. The teachers in this study reported that the most important resources of the change process were time spent planning and learning with other teachers and in collaboration with experts inside the school.

Franke, Kazemi, Shih, Biagetti, and Battey found that professional development was more effective in helping teachers make significant changes in their practice if teachers were able to reflect on their own students and practice rather than hypothetical students and situations [23]. Furthermore, Fennema, Carpenter, Franke, Levi, Jacobs, and Empson, in their work with teachers implementing Cognitively Guided Instruction, found that site-based support was paramount in facilitating changes in teachers' beliefs, knowledge, and instructional practice—changes that were found to ultimately enhance student achievement [24]. The Task Force believes that school-based Specialists in mathematics teaching and learning can fill the role of experts in teaching and learning and that their work can be distributed within a number of different models.

We have learned through interviews and surveys that within the past two years, several school divisions in Virginia have implemented building-level, "mathematics specialist" type positions. Each division and in some cases each school, has defined the role of that "specialist" type position to meet their individual needs. Since there is no state sanctioned definition of "mathematics specialist," there is no common language around this role, and school divisions have chosen to use different titles for the position. Not having state licensure results in no confirmation of who is highly qualified to fill the role. The Virginia stories below will illuminate both the benefits of the school-based "mathematics specialist," as well as the difficulties created without state licensure and institutionalized preparation programs.

- In Stafford County, full-time Mathematics Specialists have been placed in six elementary schools to co-teach classes, to provide site-based and job-embedded professional development to teachers and paraprofessionals, to coach first and second year teachers, to analyze student assessment data to inform instructional planning, and to provide parent education programs. Stafford is using a grant from the ExxonMobil Foundation to provide staff development to provide the skills and knowledge to meet the requirements of the job; however, this preparation is not recognized outside Stafford County.

- In Dinwiddie County schools, full-time Mathematics Resource Teachers in each elementary school are doing a "push-in" program where they go into teachers' classrooms to work with small groups of students and to model lessons for teachers. They also collaborate with teachers in analyzing assessment data and in planning mathematics instruction. Without state licensure, there is little recognition of their work outside Dinwiddie County.

- In 1988, Alexandria City schools began participating in the Chicago Math Project for Mathematics Specialists training. Two sets of Mathematics Specialists were trained during the grant period. However, once the grant ended, the initiative lost energy. The concept of a Mathematics Specialist was not recognized by the Commonwealth, and therefore was not self-sustaining. The project is underway once again with an ExxonMobil grant.

- For the past eleven years, Hanover County schools have participated in an ExxonMobil grant to prepare Teacher Leaders. In fact, these teachers have become strong and capable leaders within their schools and are ready to assume staff positions with release time to assist their peers. However, since there is no statewide designation for Mathematics Specialists, their preparation and expertise is not validated or readily identified.

- Eleven Title I schools and one targeted assistance Title I school in Prince William County added a full-time Mathematics Specialist's position in 2002-2003. Without state licensure or state sanctioned competencies, principals did not have immediate evidence of which applicants were most qualified for the job.

- Norfolk City schools have maintained Project Math Lead that was begun during the V-QUEST project. Significant staff development funds are dedicated to the ongoing training and support of these teachers. However, the qualifications of the Specialists vary greatly. In addition, there are thirteen Title I schools with Title I Mathematics Teachers and four additional schools with Mathematics Resource Teachers. Principals choose the teachers for these positions with no state licensure or identified competencies to inform their decisions. Statewide infrastructure for preparing Specialists and for licensing Specialists would enhance the Norfolk program.

As shown in the examples above, consensus continues to grow across Virginia that Mathematics Teacher Specialists can facilitate teacher learning, leading to improvement in student learning. Based on our research and from information gathered during interviews and surveys in Virginia schools, the Task Force recommends that school-based Mathematics Specialists be prepared to assume any or all of the following responsibilities.

Recommended School-Based Mathematics Specialist Responsibilities

- Translate mathematics standards and research into classroom practice to support implementation of the Virginia *Standards of Learning* and the National Council of Teachers of Mathematics *Principles and Standards of School Mathematics*.
- Plan and facilitate professional development sessions to focus on the needs of staff members in the implementation of a high quality and challenging mathematics program for all students.

- Work collaboratively with building administrators and staff to plan, implement, and evaluate effective mathematics programs that support the improvement of teaching and learning.
- Work collaboratively with teachers to implement a variety of instructional and assessment strategies to meet the needs of a diverse student population.
- Support teachers in identifying, implementing, and refining the use of instructional resources and strategies through coaching, co-teaching, and modeling lessons.
- Work collaboratively with administrators and teachers to analyze student work, to identify students' level of understanding and/or proficiency, to interpret assessment information to inform the instructional program as well as to assist teachers in differentiating instruction.
- Facilitate parent workshops in mathematics and share ways to work with their children in mathematics.
- Provide ongoing assistance to new teachers, especially first year teachers and "career switchers" in mathematics content and mathematics pedagogy.

Preparation for the Mathematics Teacher Specialist

The Context for Learning — Teachers in a program leading to an endorsement as a Mathematics Specialist need to be in an environment where they can work collaboratively, feel free to make mistakes, and learn from the mistakes. They need challenging mathematics content, which at the same time is related to school mathematics. Typically, higher education mathematics departments do not offer the kinds of courses that would be appropriate for these teachers [6]. It is crucial that the faculty in the college of arts and sciences and the faculty in the education department collaborate with school divisions to plan and deliver programs to prepare school-based Mathematics Specialists. Schools of education should look for ways to reinforce and integrate learning, rather than maintaining artificial barriers between courses in content and pedagogy [6].

The Task Force believes it is important that Specialists develop a broad range of vision about the mathematics curriculum, student learning, and teaching. Mathematics Specialists need to learn significant mathematics in situations where good mathematical content pedagogy is modeled. Based on current research in mathematics teaching and learning, they must increase their content knowledge as well as deepen their knowledge of both school mathematics content and content pedagogical issues. School-based Specialists will provide leadership in a variety of ways, and must have the opportunity to strengthen their own leadership skills, to develop facilitation skills for adult learning, to analyze and draw on current research in teaching and learning, and to become effective change agents. The Task Force recommends that Mathematics Specialists demonstrate the following competencies.

Recommended Competencies for Mathematics Specialists

- Support a commitment to every student learning mathematics.
- Possess a deep understanding of the mathematics that teachers teach including, a core knowledge base of concepts and procedures within the discipline of mathematics that incorporates the following strands: number systems and operations; geometry and measurement; statistics and probability; and, functions and algebra.
- Focus on a thorough development of basic mathematical ideas and skills, with an emphasis on understanding the sequential nature of mathematics and the mathematical structures inherent in the content strands.
- Display careful reasoning and an understanding of the connections among mathematical concepts and procedures in solving problems.
- Possess an understanding of and the ability to use the five processes: becoming a mathematical problem solver; reasoning mathematically; communicating mathematically; making mathematical connections; and, using mathematical representations.
- Possess the ability to use and interpret meaningful measures of students' skills and understandings in mathematics.
- Evaluate students' work and students' thinking and use this to inform instruction.
- Support the use of technology to improve teaching and learning mathematics.
- Demonstrate the ability to collaborate with teachers through co-teaching, mentoring, and coaching.
- Demonstrate the ability to identify teachers' individual professional development needs, and individualize staff development efforts to include both formal and job-embedded professional learning experiences.
- Demonstrate the leadership skills necessary to facilitate staff development in mathematics content, mathematics pedagogy, and assessment of student learning.

The Task Force reviewed the possible role and responsibilities that a Specialist in a Virginia school might take on, and the competencies necessary to carry out these responsibilities. Based on our review of research at the national level, as well as information gathered from school divisions in Virginia, we recommend that a candidate seeking an endorsement as a Mathematics Specialist have completed at least three years of successful classroom teaching experience in which the teaching of mathematics was an important responsibility. In addition, the Mathematics Specialist should have graduated from an approved Mathematics Specialists preparation program (master's degree level); or, completed a master's degree-level program in mathematics, mathematics education, or related education field with at least thirty semester hours of graduate coursework in the competencies described above, including at least 21 hours of coursework in undergraduate or graduate-level mathematics.

Recommendations for Mathematics Specialists Preparation Programs — Not only must Mathematics Specialists have mathematics content knowledge, but they must also possess a conceptual understanding of the principles underlying its topics, rules, and definitions [6, 16]. In addition, they must possess pedagogical content knowledge that includes, but is not limited to, useful representations, unifying ideas, clarifying examples and counter examples, helpful analogies, important relationships, and connections among ideas. Pedagogical content knowledge is a subset of content knowledge that has particular utility for planning and conducting lessons that facilitate student learning [25].

Teachers preparing to be Mathematics Specialists must have the opportunity to take classes that include content in number and operations, functions and algebra, geometry and measurement, as well as data analysis, statistics, and probability. Technology, as a tool for teaching and learning, should be integrated into coursework as appropriate. Furthermore, these classes should incorporate the five processes: becoming mathematical problem solvers, reasoning mathematically, communicating mathematically, making mathematical connections, and using mathematical representations. Classes must be relevant to the work of Mathematics Specialists, allowing them to develop a deep understanding of the mathematics content. Instructors must model effective content pedagogy and allow Specialists the opportunity to demonstrate their ability to implement effective teaching practices in their school. The key aspect is to verify that teachers can transfer what they have learned in the college setting to their work as a Specialist.

To build leadership skills, courses must be offered that will enable candidates to build a deep understanding of how students learn mathematics and of pedagogical knowledge specific to mathematics teaching and learning. Candidates will learn to develop curriculum that is based on current research, including national and state standards for mathematics, and will design instruction that meets the needs of diverse learners.

Coursework will enable candidates for the Mathematics Specialist endorsement to develop skills in analyzing individual student performance on a variety of assessment protocols, and in analyzing and interpreting individual as well as collective test data. They will use the results from these analyses to inform instructional decisions. In addition, candidates will learn to gather and interpret relevant data about instructional strategies and instructional programs to facilitate improvements in student learning.

Programs preparing Mathematics Specialists will include the opportunity for candidates to develop skills in planning, implementing, and evaluating job-embedded support, and in staff development for all teachers including the mentoring of new teachers. Candidates for the Mathematics Specialist licensure must possess the skills and knowledge necessary to effectively analyze and interpret research. Mathematics Specialists must develop effective communication skills to share research-based knowledge and skills with administrators, parents, and the greater community.

Recommendation for Mathematics Teacher Specialist Licensure

How do we ensure that mathematics receives equal attention in the elementary and middle school curriculum and in teacher instructional programs as literacy currently receives? This Task Force strongly believes that the foundation for student success in both reading and mathematics begins in kindergarten, and then must be nurtured throughout elementary and middle schools. Virginia state licensure provides professional recognition and legitimacy to reading programs and to Reading Specialists. Across Virginia, school divisions can immediately identify teachers who are prepared as experts at teaching reading by their license. In this same way, we believe that a teacher in a school who carries the title of Mathematics Specialist will immediately be recognized by other teachers, administrators, and parents for their expertise in teaching and learning mathematics.

In June 2003, the Virginia School Board approved the creation of a license for Mathematics Specialists. This endorsement will provide the needed impetus for higher education institutions to develop preparation programs for Mathematics Specialists. The collaborative efforts among colleges of education, colleges of arts and sciences, local school divisions, and the Virginia Department of Education will bring about the ongoing routine and appropriate preparation of Mathematics Specialists in Virginia.

References

[1] H. Wenglinsky, "How Schools Matter: The Link Between Teacher Classroom Practices and Student Academic Performance," *Education Policy Analysis Archives*, **10**(12) (2002).

[2] "Survey Finds Little Sign of Backlash Against Academic Standards or Standardized Tests," *Public Agenda*, New York, NY, 2000, Internet: http://publicagenda.org/press/press.release.detail.cfm

[3] J.F. Kain, "The Impact of Individual Teachers and Peers on Individual Student Achievement," Paper presented at 20th Annual Research Conference of the Association for Public Policy Analysis and Management, New York, NY, 1998.

[4] W.L. Sanders and J.C. Rivers, *Cumulative and Residual Effects of Teachers on Future Student Academic Achievement*, University of Tennessee Value-Added Research and Assessment Center, Knoxville, TN, 1996.

[5] D. Monk, and J.King, "Multi-Level Teacher Resource Effects on Pupil Performance in Secondary Mathematics and Science," in R.G. Eherenberg (ed.), *Choices and Consequences*, ILR Press, Ithaca, NY, 1994.

[6] *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium*, National Research Council, Washington, DC, 2000.

[7] R.F. Elmore, *Bridging the Gap Between Standards and Achievement: The Imperative for Professional Development Education*, Albert Shanker Institute, Washington, DC, 2002.

[8] *Ensuring Teacher Quality: A Continuum of Teacher Preparation and Development*, WestEd Policy Brief, 2000, Internet: http://web.WestEd.org/online_pubs/po-00-05.pdf

[9] D.K. Cohen and D. Ball, "Making Change: Instruction and its Improvement," *Phi Delta Kappan*, **83**(1) (2001) 73-77.

[10] *2000 National Survey of Science and Mathematics Education*, Horizon Research Inc., Chapel Hill, NC, Internet: http://2000survey.horizon-research.com.

[11] S.M. Wilson, R.E. Floden, and J. Ferrini-Mundy, "Teacher Preparation Research: An Insider's View from the Outside," *Journal of Teacher Education*, **53**(3) (2002) 190-204.

[12] S. Critchfield and L. Pitt, "Mathematics and Science Lead Teachers in Virginia: An Informal Evaluation of their Roles and Effectiveness," Virginia Mathematics and Science Coalition, 1997, Internet: http://www.vamsc.org/projects/lteacher.html

[13] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[14] I. Laczko-Kerr and D.C. Berliner, "The Effectiveness of 'Teach for America' and other Under-Certified Teachers on Student Academic Achievement: A Case of Harmful Pubic Policy," *Education Policy Analysis Archives*, **10**(37) 2002.

[15] *Keys to Math Success: A Report from the Maryland Mathematics Commission*, Maryland State Department of Education, Baltimore, MD, 2001.

[16] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[17] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.

[18] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[19] S.C. Purkey and M.S. Smith, "Effective Schools: A Review," *The Elementary School Journal*, **83**(4) (1983) 427-453.

[20] K.R. Howey, W.A. Matthes, and N.L. Zimpher, *Issues and Problems in Professional Development*, North Central Regional Educational Laboratory, Oak Brook, IL, 1985.

[21] B.J. Reys and S. Fennell, "Who Should Lead Mathematics Instruction at the Elementary School Level? A Case for Mathematics Specialists," *Teaching Children Mathematics*, **8**(5) (2003) 277-282.

[22] A. Gamoran, C.W. Anderson, P.A. Quiroz, W.G. Secada, T. Williams, and S. Ashmann, *Transforming Teaching in Math and Science: How Schools and Districts Can Support Change*, Teachers College Press, New York, NY, 2002.

[23] M.L. Franke, E. Kazemi, J. Shih, S. Biagetti, and D. Battey, "Changing Teachers' Professional Work in Mathematics: One School's Journey," in T.A. Romberg, T.P. Carpenter, and F. Dremock (eds.), *Understanding Mathematics and Science Matters*, Lawrence Erlbaum Associates, Mahwah, NJ, 2005.

[24] E. Fennema, T.P. Carpenter, M.L. Franke, L. Levi, V.R. Jacobs, and S.B. Empson, "A Longitudinal Study of Learning to Use Children's Thinking in Mathematics Instruction," *Journal for Research in Mathematics Education*, **27**(4) (1996) 16-32.

[25] L. Shulman, "Those Who Understand: Knowledge Growth in Teaching," *Educational Researcher*, **57** (1986) 1-22.

MATHEMATICS TEACHER SPECIALISTS IN VIRGINIA: A HISTORY

L.D. PITT
Dept. of Mathematics, University of Virginia
Charlottesville, VA 22904

Introduction

Responding to a widely held perception that many of Virginia's elementary teachers were inadequately prepared in mathematical content and content pedagogy, the Board of the Virginia Council of Teachers of Mathematics (VCTM) discussed in 1990 how the VCTM might address this issue. After considerable discussion, the Board concluded that placing Mathematics Lead Teachers in our elementary schools would be its most effective solution that might also realistically be achievable. The Board passed a resolution to this effect, and an official Position Statement in support of placing Mathematics Lead Teachers in elementary schools of the Commonwealth of Virginia was published in September, 1991 [1].

Shortly thereafter, the Virginia Mathematics Coalition (known as the Virginia Mathematics and Science Coalition [VMSC] since 1993) and the Virginia Council for Mathematics Supervision (VCMS) joined VCTM in this effort, and a movement began that has continued to the present time and which is quite remarkable for its accomplishments. Conceptually, a working consensus has developed over time that Mathematics Lead Teachers, who were regular classroom teachers with add-on duties, were sufficient and that to address the schools' needs would require the attention of Mathematics Teacher Specialists or Mathematics Coaches. These would be individuals without classroom assignments who could work at strengthening the mathematics instruction of all teachers. This consensus is not universal, but the strength of these views and the remarkable power that they have had in recent years is illustrated by the following facts:

- Today, Virginia is on the verge of adopting a K-8 Mathematics Specialist Teacher endorsement;
- In 2005, the Virginia House of Delegates and the Virginia Senate unanimously passed a joint resolution instructing the Virginia Board of Education to design a Mathematics Specialist endorsement;
- School divisions have begun placing the first generation of Specialists in their schools; and,
- Four universities have implemented master's degree programs designed to lead to the Mathematics Specialist endorsement.

Three years ago, none of these events were foreseen, and although much work remains to be done in documenting that Mathematics Specialists are one of the most effective and cost effective means to improve our students' learning of mathematics, we have made great progress on that front in the Commonwealth. Virginia has now moved to a point where issues of implementation are becoming critical. We are now trying to develop solid answers to such questions as:

- What is a Mathematics Specialist and what do Specialists do?
- What are the principle ingredients of content, content pedagogy, and leadership training Mathematics Specialists will need to be effective?
- How can we implement Mathematics Specialist training programs and quickly bring well-prepared Mathematics Specialists into the schools?
- What are the elements of school culture and administrative support that Mathematics Specialist programs need to be effective?

In this article, we present a brief history of these efforts. We hope that we have provided enough detail to give some insight into the special circumstances and key elements that have fostered our success. Perhaps the most remarkable aspect of the Virginia Mathematics Specialist story is the degree of collaboration that has developed between all the principal players. Our schools, our institutions of higher education, and the Virginia Department of Education have worked collaboratively on these issues for years, and answers that represent a broad consensus of opinion have emerged through this collaboration.

Mathematics Specialist History 1990–2000

At the state level, the first notable success of the Mathematics Lead Teacher movement in Virginia occurred in 1992 with the inclusion of Mathematics and Science Lead Teachers as a central component of the Virginia State Systemic Initiative or V-QUEST proposal. The funding for this project lasted three years. It represented a critical first step that initiated several important processes.

1) A significant partnership was initiated between the Virginia Department of Education and other key stake holders which ultimately led to significant systemic change.
2) The project piloted Lead Teachers and provided the initial training to a cohort of teachers that subsequently became mathematics leaders in Virginia schools.

3) Although the degree of success varied greatly in these initial school programs, for the first time numerous teachers and school administrators witnessed the positive changes that could result from having high-quality, school-based teacher professional development and curriculum leadership. Among the school divisions that began with V-QUEST Lead Teacher programs may be found a majority of the divisions that have provided Virginia's Mathematics Specialist movement with its leadership and vision.
4) The project provided the VMSC and its higher education partners with a project that they believed in, and which has kept the Coalition in constant contact with the schools and the mathematics leadership in the schools.

With the completion of V-QUEST, the VMSC Board was concerned that statewide momentum be maintained with the Lead Teacher project, and voted in 1996 to begin a sustained initiative to develop the concept of Mathematics and Science Lead Teachers, as well as develop our understanding of the training and support that Lead Teachers would need to be effective. This became the Coalition's highest educational priority.

As a first step on behalf of the Coalition, Critchfield and Pitt informally evaluated several of the early Virginia Lead Teacher programs, and identified elements common to the most successful programs and teachers [2]. As expected, they found significant differences in performance separating the schools with quality programs from those without. These differences included both the preparation of the Lead Teachers and the professional development and support that they received in the schools. Support for the Lead Teacher concept grew and evolved slowly and the concept was strengthened to become that of a Teacher Specialist. In 1999, an informal VMSC working group (subsequently referred to as the VMSC Specialist Partnership) began working to develop comprehensive models for Specialist roles, training programs, and school administration roles that could support quality mathematics instruction in our schools.

Several local phenomena eventually proved to be significant at the statewide level. For example, the schools of education at both George Mason University (GMU) and Virginia Commonwealth University (VCU) began graduate leadership programs in mathematics education, and the graduates of these programs began impacting the schools in geographic regions adjacent to the universities. We mention one example. In Hopewell Public Schools, a small urban Title I division south of Richmond, a graduate of the VCU program was employed in 2000 as the school division's first full-time Mathematics Lead Teacher. A year later, that school became fully accredited, and this process was repeated each year for the next two years with the division's other two elementary schools [3].

Two other local conditions that influenced the state efforts in important ways were provided by the ExxonMobil Elementary Mathematics Specialist projects in Hanover and Bedford counties. The Hanover project provided an important example for other school divisions to observe and emulate. The Bedford project proved important in Virginia as a result of Bedford's request for mathematics leadership and instruction for their Mathematics Lead Teachers from the University of Virginia (UVA). This was the catalyst that contributed to the establishment of the previously mentioned VMSC Specialist Partnership. The Bedford-UVA connection also provided the first formal contact between the Coalition and the ExxonMobil Foundation regarding Mathematics Specialists—a contact which quickly became a partnership that has greatly influenced events in Virginia.

Mathematics Specialist History 2000-2004

The recent developments in Virginia coincided with the publication of three national reports: *The Mathematical Education of Teachers*, 2001; *Adding It Up: Helping Children Learn Mathematics*, 2001; and, National Council of Teachers of Mathematics *Principles and Standards of School Mathematics*, 2000 [4-6]. These studies included calls for the placement of Mathematics Teacher Specialists in the elementary schools. In May 2001, with ExxonMobil support, a one-day conference was held for school administrators on standards-based mathematics instruction. Sixty school administrators and higher education faculty attended this meeting. At the same time, because of the emerging links with the network of ExxonMobil Mathematics Specialist projects, Virginians became aware that large school divisions with diverse populations in Albuquerque, New Mexico and Houston, Texas had Mathematics Specialists programs that were showing strong results; results that included enhanced achievement for special needs students.

The meetings and the national scene energized the Virginia movement with the effect that in May 2001, ExxonMobil funded the first of a sequence of statewide Virginia Forums on Mathematics Specialists. These have all been hosted by VMSC. The first one was held in Fredericksburg, and focused on statewide implementation of Specialist programs and was aimed at division mathematics coordinators and other central office school administrators. The meeting was attended by 78 individuals who included several central office personnel and who subsequently became important advocates for Mathematics Specialists within their divisions. A statewide dialogue began that grew stronger when it was learned that certain Virginia school divisions, including Hopewell and Norfolk, had begun implementing Mathematics Specialist programs and that positive results were being observed.

In Summer 2002, three significant milestones were passed. With the support of an Eisenhower grant from the State Council for Higher Education in Virginia, an informal partnership of eight school divisions, the VMSC, and UVA organized to create a model Mathematics Specialist curriculum. This VMSC Specialist partnership offered its first Mathematics Specialists Leadership Institute. Thirty-one participants attended. A second Institute was planned for 2003, and several new school divisions joined the partnership.

In the same summer, the presidents of the VMSC, VCTM, and VCMS wrote a joint letter to Virginia's Superintendent of Instruction urging consideration of the needs and benefits of elementary and middle school Mathematics Teacher Specialist licenses. The superintendent's response to this letter made the presidents aware that further progress would require building a broad base of support for the Mathematics Specialist concept throughout the education community in Virginia. Therefore, VMSC established a fifteen-member Specialist Task Force, led by Vickie Inge of Stafford County Schools, to prepare a carefully detailed case for obtaining elementary and middle school Mathematics Teacher Specialist endorsements, and for implementing Specialist programs in the schools. The report was completed in Spring 2003 and was published on the Coalition's website (http://www.vamsc.org/vms/index.html). This report also appears in this issue [7].

Before the Task Force had completed its report, the Virginia Department of Education used a draft version of it to write regulations for a new Mathematics Specialist endorsement that were approved by the Board of Education in Spring 2003. Moreover, Virginia's commitment to Mathematics Specialists became more evident when, in Fall 2003, the Commonwealth chose to make Mathematics Specialists one of the two focus areas in Virginia's first Mathematics and Science Partnership (MSP) competition. The purpose in doing this was to prepare the first cohort of Mathematics Specialists in advance of final approval of the endorsement.

The approval process began in Summer 2003, but the Board's entire package of licensure recommendations was later withdrawn because of issues that arose over other parts of the recommendations that were unrelated to Mathematics Specialist endorsement. This setback proved to be temporary and the endorsement approval process was back on track by mid-2004. In early 2005, the Virginia House of Delegates and the Virginia Senate unanimously passed a joint resolution instructing the Virginia Board of Education to design a Mathematics Specialist endorsement. Final approval is expected in 2006.

In response to the Virginia MSP initiative, the Coalition wrote and received a grant of nearly $750,000 for The Virginia Mathematics Specialist Project to develop a common set of five mathematics courses for Mathematics Specialists and to initiate Mathematics Specialist master's degree programs at three universities: Norfolk State University (NSU), University of Virginia (UVA), and Virginia Commonwealth University (VCU). Four of the five courses exist, and were piloted and taught in 2004 and in Spring 2005. The fifth, *Probability and Statistics*, will be offered at three locations in Summer 2005.

Throughout 2004, the Coalition's Mathematics Specialist Project continued to grow. The National Science Foundation awarded Virginia Commonwealth University and the VMSC two major grants. The first, The Mathematics Specialist: Research Study and Pilot Program, is a $4,444,898 grant supported by the Teacher Professional Continuum program to conduct a comprehensive research study on the impact of Mathematics Specialists on student learning and to offer courses for Mathematics Specialists at NSU, UVA, and VCU over the five-year term of the grant.

The second, Preparing Virginia's Mathematics Specialists, is a five-year, $3,726,915 MSP grant sponsoring summer institutes to prepare fifty Mathematics Specialists. The individual grants and their combined activities across Virginia are discussed in the last article in this issue [8].

With the support of these three grants, teachers have enrolled in more than 280 mathematics classes for Specialists, and more than eighty have taken the first *Leadership in Mathematics Education* course. Approximately eighty teachers are currently in the process of enrolling in the master's degree programs. In Spring 2005, the Virginia Department of Education extended funding of the Virginia Mathematics Specialist Project for a second year with an additional $295,000. This includes funds for a one-day, statewide "Spotlight on Mathematics Specialists" symposium to be held in May 2005, and a mandate to bring the project into Southwest Virginia, an area where it has not yet reached.

Lessons Learned

This is an exceptionally exciting moment for mathematics education in Virginia. The sustained effort of the Virginia mathematics education community has produced a major change in the model for K-8 mathematics education. This community strongly believes in the effectiveness and importance of well-educated and appropriately supported Mathematics Specialists. We also believe that ongoing research will ultimately validate these beliefs.

How did it happen that the efforts of a few educators, administrators, and mathematicians could bring about changes of this magnitude and importance? This is a speculative question and no answer will be definitive, but an informed opinion can at least provide a list of factors that seem to have been important.

The VMSC and the Mathematics Specialist project have been broad based, highly collaborative, and long term. School administrators, teachers, mathematicians and mathematics educators, politicians, and administrators from the Virginia Department of Education have succeeded in working together effectively and noncompetitively for a very long time.

This sustained collaboration led to the evolution of an unusually informed and tight community. Different constituencies in the community grew to understand each other's issues, constraints, and strengths far better than they did at the beginning. Higher education, the schools, and the education establishment became supportive partners in ways that were not envisioned earlier, and which would have been impossible on a short time scale. These sustained efforts were also essential in obtaining the support from the ExxonMobil Foundation that has been extremely important to the project.

To illustrate this, I will describe a personal example of transformation and its impact. My career has been spent as a research mathematician at a research university. At one stage in this process, I was asked to assume a leadership role in developing an outline for the mathematical preparation of future K-8 Mathematics Teacher Leaders, and I was largely ignorant of both the profound depth of understanding that is required to teach basic mathematics and of how mathematics is learned. One of my partners, a third grade mathematics teacher, advised me that I would profit from attending the summer leadership institutes in *Developing Mathematical Ideas* that are held at Mt. Holyoke College [9].

I took her advice and the experience proved to be extremely valuable. This provided me with an entirely new set of insights in learning and teaching mathematics, and, incidentally, most of these insights came from working with elementary teachers who were very limited mathematically. The experience had numerous consequences. It allowed me to become a stronger advocate on issues concerning elementary mathematics. I also became more effective in developing coursework for teachers. Together with colleagues from the schools and others from higher education, this led to the development of the five mathematics courses for Specialists that was mentioned earlier. The courses relate directly to the teachers' classrooms and appear to be very popular. Because this work was done in the context of the Coalition, the courses have been adopted at other universities in the partnership with appropriate refinements and revisions. In turn, the impact of the courses and their popularity has helped to fuel the growth in interest in Mathematics Specialists across the state.

There are four essential lessons that I have learned from these experiences:

- Our effectiveness and impact was greatly magnified through collaboration;
- All constituencies in the education community brought essential knowledge and made essential contributions to the effort; and, the inclusive nature of the partnership contributed to making everyone a more valuable partner;
- Our partnerships grow stronger over time, but this will only be true when partnerships are built upon mutual respect and inclusiveness, and when the partnership's goals are unchanging and focused on real problems; and,
- A little luck and great partners are excellent assets.

It has been a true pleasure to be part of this project.

References

[1] "Lead Teachers of Mathematics in the Elementary Schools; VCTM Position Statement," *Virginia Mathematics Teacher*, **18**(2) (1992) 21.

[2] S. Critchfield and L.D. Pitt, *Mathematics and Science Lead Teachers in Virginia: An Informal Evaluation of Their Roles and Effectiveness*, Virginia Mathematics and Science Coalition, White Paper, 1997.

[3] Y. Smith-Jones, "How Do You 'Hook' Elementary Teachers into Enjoying and Seeing the Beauty of Mathematics?" *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 63 – 65.

[4] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[5] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.

[6] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[7] "Mathematics Specialists Task Force Report," Virginia Mathematics and Science Coalition, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 5 - 22.

[8] R. Farley, W. Haver, and L.D. Pitt, "Financial Support for Mathematics Specialists' Initiatives in Virginia," *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 153 – 169.

[9] D. Schifter, V. Bastable, and S.J. Russell (eds.), *Developing Mathematical Ideas*, Dale Seymour Publications, Parsippany, NJ, 1999.

PART II: MATHEMATICS SPECIALISTS IN SCHOOLS

This section presents brief histories of six Virginia school divisions and one division from Arizona that have worked with Mathematics Lead Teachers and Mathematics Specialists over a period of several years, and all of which have now taken steps toward implementing full-time Specialists in their elementary schools. These divisions range from Hopewell, a small Title 1 metropolitan school division outside Richmond with three elementary schools, to the large urban division of Norfolk with 35 elementary schools. A few rural school divisions in Virginia have begun using Mathematics Specialists, but to our knowledge all are in the initial stages of this process, and there are no truly rural divisions included here.

The stories for each of these divisions are different, and we believe that much can be learned from the details of their individual stories. In each case, there have been some unique circumstances that were critical in moving the Mathematics Specialists forward in the division, and these special circumstances often hold the key to understanding what happened. There are also common themes in these stories; for example, there was a long history that resulted in a knowledgeable group of future Specialists and advocates. The nature of these advocates varies in the examples, but their existence proved to be crucial. These groups of individuals appear to have exercised a profound influence on their school cultures, and their knowledgeable advocacy created environments where the potential impact of Mathematics Specialists was understood, and where new approaches to funding were entertained.

It also appears that the activists in these school divisions supported each other. Progress toward implementing Mathematics Specialists in one school division often was answered by similar steps in other divisions. Networking opportunities that were available through the ExxonMobil-funded Mathematics Specialist projects fueled the larger movement. ExxonMobil also funded the Virginia Forums which have focused on Specialists' influence in Alexandria and other divisions. In addition, the progress toward a Mathematics Specialist endorsement that is associated with the Virginia Mathematics and Science Coalition Mathematics Specialists Task Force seemed to energize these efforts across Virginia.

MATHEMATICS SPECIALISTS IN ALEXANDRIA CITY PUBLIC SCHOOLS

S. BIRNIE
Alexandria City Public Schools
Alexandria, VA 22311

Introduction

In Fall 2004, the Alexandria City Public Schools (ACPS) placed full-time Mathematics Specialists in each of the division's thirteen elementary schools. This initiative represents the culmination of a sixteen-year effort in ACPS to improve the quality of mathematics instruction at the K-5 level. This was made possible by the collaborative support of the ACPS School Board, the ACPS administration, and the ExxonMobil Foundation.

Mathematics Specialists in ACPS serve as content-focused coaches who work with all teachers in their schools to provide differentiated, job-embedded professional development to move each teacher along a path of continuous improvement of performance. Outlined below are the essential features and milestones of the process that led to this exciting outcome.

Background

In 1988, Alexandria and 24 other school divisions began working with the University of Chicago's School Math Project (UCSMP). The Project focused on increasing the participants' mathematics content knowledge. It first trained trainers and then trained selected intermediate level teachers. From 1990 through 2002, ACPS trained three cohorts of approximately 25 teachers each as Mathematics Specialists. The teachers participated in more than 200 hours of instruction in mathematics content. The training was long term and targeted directly to teachers' practice. The teachers met for summer mathematics institutes and also attended monthly classes during the regular school day schedule. Over two years, the trainees developed strong mathematics backgrounds in areas relevant to the elementary curriculum, and gained expertise in techniques of teaching mathematics to intermediate and middle school students. They worked with the then newly released *Principles and Standards* (National Council of Teachers of Mathematics), and prepared to advise primary teachers in mathematics instruction [1]. Participants in the training praised this staff development as the best that they had ever attended.

In the period from 1992 to 2003, ACPS had Mathematics Specialists with classroom responsibilities: they taught their regular classes and acted as the "math experts" at the schools. They were consultants to other elementary teachers and advocates for mathematics. As much as

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 35 - 38

possible, they served on mathematics curriculum committees and acted as liaisons between the superintendent's Central Office and their schools.

Key Central Office and Board support for moving the Mathematics Specialist position to one without regular classroom duties occurred when three of the trained Mathematics Specialist teachers moved into principal and Central Office positions, and in 2001 when Rebecca Perry assumed the role of Superintendent of ACPS. Mrs. Perry immediately recognized the potential of improving mathematics instruction through a mathematics coach model. Also at this time, ACPS established an ExxonMobil Partnership supporting a Mathematics Specialist program. The application process for this grant included establishment of a planning task force which turned out to be a central piece of further development. The approximately ten members of the task force consisted of principals, previously trained Mathematics Specialists, and parents.

Throughout Summer 2002, the task force met for five different sessions and explored mathematics resources, such as *Adding It Up*, and developed a definition and a description of the roles and responsibilities for a Mathematics Specialist [2]. Vandi Hodges from Hanover County, Virginia, and Robyn Silbey from Montgomery County, Maryland, presented overviews of their Mathematics Specialist positions. Ms. Hodges' outline of the Hanover mathematics training program with Tom Rowan and the *Developing Mathematical Ideas* (*DMI*) courses gave the committee a new way to look at staff development [3]. Ms. Silbey's presentation focusing on her job as a Mathematics Specialist without classroom responsibilities was the first time that this role had been explained in detail in Alexandria. To have someone in this position explain the advantages of her support to teachers and principals proved to be an important step.

Networking with leaders from other school systems with Mathematics Specialists also proved to be critical, and key among these were people from other ExxonMobil sites. In Fall 2002, three Virginia divisions (Alexandria, Hanover, and Stafford) sent representatives to visit the Houston Independent School Division to learn about their Mathematics Specialist program. Lance Menster's advice and explanation of a "working model" for Mathematics Specialists was outstanding. This provided details about how to use Title I funds for the positions and led to more support in working with the City to fund Mathematics Specialists. This was critical because nine of the thirteen ACPS elementary schools are Title I schools, and these resources later proved to be essential in funding Mathematics Specialist positions in all schools.

Other important networking opportunities occurred at the ExxonMobil Directors Meeting, held each year at Mt. Holyoke with Virginia Bastable, Deborah Schifter, and Amy Morse (head of the Boston Math Coaches). These meetings provided many opportunities to reflect on the positions and to dialogue with other sites. Since 2002, ExxonMobil Foundation support has been used by the Virginia Mathematics and Science Coalition (VMSC) to host an annual Virginia Mathematics Forum on Mathematics Specialists. The 2003 Mathematics Forum proved to be especially important for the development of the ACPS Mathematics Specialist positions. Cathy David, ACPS Executive Director for Elementary Programs, attended this Forum. Ms. David had been trained as a Mathematics Specialist and was a member of our ExxonMobil Planning Task Force. She is also highly respected in Alexandria, and, after hearing the presentations of Skip Fennell and Lance Menster, she prepared a budget proposal for Mathematics Specialist positions in Alexandria and took this proposal to the superintendent and the Board.

The Virginia networking opportunities have also played special roles. At the 2003 Virginia Mathematics Specialist Forum, for example, Cathy David was impacted by hearing that other Virginia school divisions had Mathematics Specialist positions without classroom responsibilities, and this was critical in gaining her support. In addition, the Virginia Mathematics and Science Coalition's Mathematics Specialist Task Force and their success in moving the proposed Mathematics Specialist endorsement forward at the state level helped the ACPS school division create a vision of a Mathematics Specialist position similar to a Reading Specialist.

Summary

Today, the mathematics content training for Mathematics Specialists is an ongoing process. For example, several of our Specialists are enrolled in the newly developed mathematics courses in the Virginia Mathematics Specialist Project's endorsement programs. Our principals have also been trained using the *Lenses on Learning* (*LOL*) I modules to focus on the math leadership role in schools [4]. The *LOL* course was a particular success with our administrators. One principal commented, "I always thought that math was just learning how to go from one step to another. Now I know the bigger picture and how essential it is to have strong math leadership in elementary schools." Currently, we are using *LOL* II materials to continue our administrative training.

As to the 2003-2004 Virginia *Standards of Learning* (*SOL*) test scores, twelve of the thirteen ACPS elementary schools are fully accredited in mathematics [5]. The percentage of students who are passing the *SOL* test in the fifth grade is increasing. Scores at one of our Title I schools increased by 37% at the third grade level and by 26% at the fifth grade level. "Our teachers, administrators, and students have worked extraordinarily hard to reach these goals," said Superintendent Rebecca L. Perry. "We are confident that Jefferson-Houston Elementary will soon be fully accredited, given their new leadership, the support of the Mathematics Specialist, the commitment of their teachers, and the additional resources that have been provided to them."

References

[1] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[2] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.

[3] D. Schifter, V. Bastable, and S.J. Russell (eds.), *Developing Mathematical Ideas*, Dale Seymour Publications, Parsippany, NJ, 1999.

[4] C.M. Grant, B.S. Nelson, E. Davidson, A. Sassi, A.S. Weinberg, and J. Bleiman, *Lenses on Learning: A New Focus on Mathematics and School Leadership*, Dale Seymour Publications, Parsippany, NJ, 2002.

[5] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

MATHEMATICS SPECIALISTS IN THE ELEMENTARY SCHOOLS: "THE ARLINGTON STORY"

P. ROBERTSON
Arlington Public Schools
Arlington, VA 22207

Arlington Public Schools, a relatively small school district with 1,150 elementary teachers, serves an extremely diverse population of 10,000 elementary students in 22 schools. The overall student population includes 33% Hispanic, 14% African-American, 10% Asian, 42% Caucasian, 25% ESOL, and 37% on free or reduced lunch. More than forty languages and seventy countries are represented. In addition to 22 elementary schools, six middle schools, and four high schools, students attend five alternative or special programs.

Arlington Public Schools strives to deliver the highest quality instruction and curriculum to all of its students. Its goals are to ensure a rich and rigorous curriculum, provide sustained professional teacher development, improve SOL performance, and close the minority achievement gap.

Arlington schools have a total of 62 reading teachers, 25 of which are funded through Title 1. Special education and gifted programs also provide substantial services within the school day. Each elementary school is staffed with a .5 gifted resource teacher. Yet, elementary teachers in Arlington lack necessary in-school mathematics support. Some schools have developed ad hoc approaches, sometimes using their special education or gifted resource teacher positions to enhance mathematics instruction. While many of these approaches are creative and attempt to supplement the mathematics program, they are not efficient. They are not mathematics trained, and they are not targeted for the entire school system.

During the summers of 1992 and 1993, Arlington Public Schools participated in the Mathematics Lead Teacher State Initiative, a two-week summer training session for Mathematics Lead Teachers in selected schools. In Fall 1993, Arlington had a Mathematics Lead Teacher in twelve of its elementary schools. Since 1994, elementary and middle school principals have appointed Mathematics Lead Teachers for their schools. Currently, there are also Lead Teachers for science and social studies. Although these Lead Teachers act as leaders, they all have full-time teaching responsibilities.

In addition to their classroom obligations, the Mathematics Lead Teachers function as the primary advocate for mathematics instruction within each elementary school. The Lead Teachers encourage and support their colleagues by helping them interpret and effectively implement the

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 39 - 42

curriculum, by clarifying the expectations of the *Standards of Learning* (*SOL*), and by acting as a liaison between the Department of Instruction and the elementary schools [1].

The Mathematics Lead Teachers have many opportunities for professional development. At the elementary level, substitutes are provided quarterly for whole group meetings to enhance instruction and share ideas on how to help colleagues. Professional development activities include: questioning strategies, classroom discourse, teaching for understanding, and family involvement. In addition, Lead Teachers attend off-site professional conferences and assist the mathematics office in leading countywide workshops. Although the present Lead Teacher program helps with communication and the dissemination of materials, teachers in these positions have classroom responsibilities and therefore, cannot model lessons in other classrooms or help teachers plan using best practice strategies.

Our mathematics office continues to pursue initiatives that support teacher development in mathematics. After the current textbook adoption, training began in 1999 on the use of the NSF-supported *Investigations* curriculum materials, the supplemental program adopted with the textbook series [2]. A *Teaching for Understanding* group began in Summer 2000 and continues to meet regularly [3]. During the summer of 2002, Arlington Public Schools made the Wiggins and McTighe *Understanding by Design* model a countywide priority for instruction [4]. The mathematics office is providing opportunities for elementary teachers to write mathematics lessons using this model. Although these initiatives have had some impact at individual schools with individual teachers, the school system has not had the resources to fund a broad systemic project for elementary mathematics support. A few schools have been able to get some full-time help, but the struggle continues.

In 1995 and 1998, Arlington's Mathematics Advisory Committee, a group of volunteers consisting of Arlington parents and other community members, recommended that all elementary schools have full-time Mathematics Specialists. Unfortunately, the request was denied both times. In 2000, Arlington's Mathematics Advisory Committee's recommendation to place five full-time Mathematics Specialists in the schools with the greatest need was also denied. During the 2001-2002 school year, two elementary school principals made it possible for their schools to use their Lead Teachers as school-based Mathematics Specialists by reconfiguring their staff allocations. In addition to performing their Lead Teacher duties, the elementary school-based Mathematics Specialists were available to work with all classes during the school day modeling lessons and supporting quality instruction. As of October 2002, two more elementary schools received school-based Mathematics Specialists because of the No Child Left Behind legislation. These positions were made possible through reallocation of Title I funds from reading support to math support.

During the school year 2002-2003, the four school-based Mathematics Specialists met monthly with central office staff. All four positions were previous Mathematics Lead Teachers and participants in the *Teaching for Understanding* group. Through their work, a more detailed job description evolved. The four teachers were a resource for each other as they shared what had worked.

In the final budget, approved May 2003, there was another full-time equivalent position for a school-based Mathematics Specialist. For the year 2003-2004, the principal of a new elementary school used creative staffing to accommodate a full-time elementary school-based Mathematics Specialist. Because of the full-time position in the new budget and another .5 position from Title I, three more schools in 2003-2004 had an elementary school-based Mathematics Specialist, bringing the total to seven positions serving eight elementary schools. Two more positions were approved for 2004-2005. Another elementary principal reallocated resources to have a school-based resource position, bringing the new total for 2004-2005 to ten positions serving thirteen elementary schools.

As Mathematics Specialists have been added, a more unified and systematic professional development program has resulted, ensuring that all students receive the same high quality service and that more teachers are properly trained to deliver this service. School-based Mathematics Specialists attend monthly daylong meetings to share ideas, look at the research, and analyze data. They also participate during that time in focused professional development on coaching and mathematics content. Regular communication with the principals of those schools is built into each Specialist's plan. Specialists are required to submit monthly reports. During July 2003, seven of the school-based Mathematics Specialists attended *Investigations* training and two attended *Developing Mathematical Ideas* (*DMI*) training [2,5]. During Summer and Fall 2004, eight Mathematics Specialists, ten elementary teachers, and four middle school teachers participated in a *DMI* class. The opportunity for the *DMI* training was made possible through ExxonMobil grants. The grants also make it possible for these school-based Specialists and the teachers in their schools to work with a mathematics consultant to develop more effective questioning strategies in the classroom.

With an eye toward Mathematics Specialist certification, Arlington has offered three, three-credit math courses since Summer 2003. Though the road to full implementation of a Mathematics Specialist program has been slow and bumpy at times, we feel that addressing mathematics needs in this way is essential to the ultimate success of our goals for teachers and students. With the current No Child Left Behind legislation for reading and mathematics, it is hoped that more mathematics support will be possible.

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[2] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: http://investigations.terc.edu

[3] *Teaching for Understanding*, Harvard Graduate School of Education, 2004, Internet: http://wideworld.pz.harvard.edu

[4] G. Wiggins and J. McTighe, *Understanding by Design*, Association for Supervision and Curriculum Development, Alexandria, VA, 1998.

[5] D. Schifter, V. Bastable, and S.J. Russell (eds.), *Developing Mathematical Ideas*, Dale Seymour Publications, Parsippany, NJ, 1999.

MATHEMATICS TEACHER SPECIALISTS—MAKING A DIFFERENCE FOR STUDENT LEARNING

T. ROWAN
University of Maryland, College Park
College Park, MD 20742

Introduction

Mathematics is generally considered the second most important subject for students to gain competency in, reading and language arts having a solid hold on first place. Having said this, there is also general agreement that many elementary teachers are much less prepared to teach mathematics than they are to teach reading. My experience teaching a mathematics methods course for elementary teachers supports this view, both with respect to content knowledge and confidence about knowing and teaching the subject. However, many elementary schools have Reading/Language Arts Specialists because of the high level importance of reading. Schools generally do not have Mathematics Specialists, though teachers are better prepared and more confident with reading. Reading/Language Arts Specialists are often classroom teachers who have had additional preparation and experience. They often do not have responsibility for a classroom of children, but rather are responsible for supporting their fellow teachers who do have classrooms.

Despite the acknowledged importance of mathematics and less well-prepared teachers, there are relatively few elementary schools that have Specialists for mathematics. While the reason for this is often given as budget constraints, those budget constraints do not prevent the employment of Reading Specialists. It could be argued that, *if* mathematics is important in our society, and *if* Mathematics Specialists can make a difference in student learning, then money or ways of organizing teacher personnel should be found to provide Specialists, just as they are for reading/language arts. This paper is intended to support the view that Mathematics Specialists do make a difference—and this difference can be seen in many ways, including student learning.

Two school systems that have endeavored to provide some level of Mathematics Specialist support will be discussed to informally describe the positive changes that Mathematics Specialists can help to bring about. One of these school systems is in Phoenix, Arizona and the other is near Richmond, Virginia. These districts are similar in size, but dissimilar in other characteristics, including the way in which the Mathematics Specialist positions were implemented.

The Madison District

The Madison School District is located in Phoenix, Arizona which is separated into a number of elementary/middle school districts. It is a small K-8 district with seven schools. The District received two National Science Foundation (NSF) grants. The first (1998-99) was a planning grant. That was followed by a grant for a three-year project (2000-2003) that enabled the District to provide half-time release for two teachers for six of its seven schools and one Teacher Leader for the seventh school. Thirteen teachers were released half-time to serve as mathematics leaders for the 329 teachers in the seven schools. These teachers were selected by a relatively informal process that involved self-nomination, principal nomination, and prior participation in mathematics planning activities that preceded application for NSF support. The District had over 5,200 students in the 2002-2003 school year.

Madison District—Mathematics Teacher Leaders

Prior to receiving NSF support, the District had adopted two reformed mathematics programs, *Investigations in Number, Data, and Space* and *Connected Mathematics* [1,2]. The District curriculum was developed with these two programs as its basis (1995-96). The Mathematics Teacher Leaders (MTL) were initially established (1996-97) and were given half-time release with the support of the planning grant. The progress made during the planning grant led to the funding of the larger grant for the 2000-2003 school years. The MTL participated in extensive professional development through workshops conducted by consultants and college mathematics courses from Arizona State University (ASU) during both NSF grants. Professional development workshops were usually single days used to focus on the concept of reflective teaching—teaching that is based on first gaining a deeper understanding of the background knowledge of the students, then planning instruction that reflects that background knowledge. As might be expected, exploring this instructional concept included some simultaneous exploration of content. The college-level courses focused specifically on content understanding, and developed and extended understanding of algebra and geometry. These courses were designed specifically to develop this content using, to the extent possible, instructional strategies that were supportive of the reflective teaching goal of the project. This was important because of the variation in content background of the MTL and because it was essential for the MTL to have consistent reinforcement of the instructional strategies they were to provide training on and to use. Much of the content of the workshops and the design of the content courses used the ideas of the Cognitively Guided Instruction Project [3]. The college courses were open to both the Mathematics Teacher Leaders and to the other teachers in the District. It was understood that there would be turnover in the MTL program, and teachers who were seen as possible future Teacher Leaders were especially encouraged to take the courses. To enhance their leadership skills, the MTL were sometimes used as instructors' assistants in presenting some parts of the courses.

Each Specialist was released for half of the school day and had a class to teach the other half. The reason for this arrangement was not primarily a budgeting issue, but rather a belief that maintaining close contact with children and teaching would enhance the Specialist's performance and increase credibility with the teachers served by the Specialist.

While the MTL in the Madison District had relatively well-defined responsibilities, as indicated in Table 1, the District administrators recognized that there were many differences among the schools that required a flexible approach to the implementation of the MTL position at the school level. The building principals participated in many of the training sessions for teachers and familiarized themselves with the philosophy and goals of the Mathematics Teacher Leaders program. The principals and the MTL were thus able to work together in very cooperative ways to adjust the implementation process to meet the needs of the local schools. In some cases, the teaching staff was stronger and needed less frequent individual support by the MTL. The MTL worked to establish schoolwide activities to support children, teachers, and parents. In other cases, the dominant role was cooperatively working with teachers.

The NSF grant proposal that led to initial funding of the half-time release of the MTL included an overall plan to provide professional development to all teachers in the District, with the MTL leading workshops for the other teachers, in addition to the opportunity to enroll in the content courses from ASU. Training for classroom teachers was provided primarily through released time or summer workshops paying stipends for attendance. College courses that were offered either paid a stipend or gave teachers who took them college credit without having to pay tuition. The MTL participated in teacher workshops (either as participants or leaders), attended additional workshops once a month, and took the college courses. While the half-day release time was used in a variety of ways, depending on the needs of a particular school, a typical schedule was described in the NSF proposal as shown in Table 1.

The MTL found that the reading/research days and the flexible use days included in the original proposal plan were often taken up with other tasks, such as follow-up meetings with teachers or providing support by organizing and facilitating access to instructional materials, including manipulatives.

Table 1
Typical MTL Two-Week Half-Time Release Schedule

Day 1 – Grade-level meeting	Day 6 – Grade-level meeting
Day 2 – Grade-level meeting	Day 7 – Grade-level meeting and classroom support
Day 3 – Classroom support	Day 8 – Classroom support
Day 4 – Reading and research	Day 9 – Districtwide meetings
Day 5 – Work with partner MTL to strengthen reflective teaching/leadership skills	Day 10 – Flexible use

The MTL were originally selected because of the excellence of their teaching, their interest in mathematics teaching in particular, and their demonstrated leadership qualities at their schools and on District committees. Given that informal selection process, one might expect that the MTL would feel very comfortable with their knowledge of mathematics and pedagogy related to the subject. As a part of data collection during the planning grant, MTL were asked to estimate their comfort level with mathematics content and pedagogy. The results are shown in Table 2.

These self-report data seem to indicate that, even with teachers who had been selected for their leadership roles based upon excellent teaching of mathematics and content backgrounds that exceeded that of their peers, the percentage that indicated a "very comfortable" level with mathematics content was less than half of the group. Only slightly more than half were "very comfortable" with the pedagogy. The need for support and additional training in content **and** pedagogy were supported by the data.

Table 2
Mathematics Teacher Leaders

	Uncomfortable	Somewhat comfortable	Comfortable	Very comfortable
Mathematics content		14%	43%	43%
Teaching mathematics			43%	57%

From my experience as a college methods instructor and district supervisor, I know that teachers of the early elementary grades are often uncomfortable with mathematics content and pedagogy. The Madison District MTL included teachers whose classrooms ranged from first through eighth grade. The survey result can be interpreted as further emphasizing the need to support classroom teachers with mathematics content and pedagogy training. It is simply too much to expect that a classroom teacher who teaches all subjects should be an expert in each of those subjects. The teaching of mathematics is further complicated by the diverse strands that must be addressed (number/operation, geometry/measurement, statistics/probability) and the need to develop the processes of problem solving, reasoning and proof, communication, connections, and representation within those strands [4]. Even though many middle school teachers may teach only mathematics, they too are often uncomfortable at some level with all or part of the content and/or pedagogy that integrates these processes.

Madison District—The Move Toward Reflective Teaching

The goal of the NSF project in the Madison District was to help all teachers in the District move toward *reflective teaching*, the definition of which was adopted from a proposal submitted to the NSF by the Madison School District entitled, "Teaching Reflectively: Extending and Sustaining use of Reforms in Mathematics Classrooms." This goal was chosen based upon research into how children learn mathematics. In our view, to be a reflective teacher means to adopt the following practices and views of teaching.

- A critical part of teaching is observing and listening to students, and then making educated judgments about the understanding that those students have about the mathematics.
- Judgments about the level of understanding of individual students are used to plan instruction that will move students forward in their mathematical understanding.
- An important dimension of teaching is that of constantly refining and improving one's knowledge of how students think and develop mathematically in order to build strong background knowledge by: 1) continually learning more about research into how children learn mathematics; 2) observing students and thinking about what they say and do; 3) sharing ideas with colleagues about each other's observations and the judgments that may apply to them, as well as discussing the interpretation of research; and, 4) refining one's questioning skills—an important element in getting improved feedback

from students about their understanding of mathematics, as well as an important tool in helping students develop strategies for learning mathematics.

- Instructional materials, such as texts, are tools that are to be used as a part of planning and implementing instruction that builds on the background knowledge of students; they should not drive the instructional program.
- Much of mathematics instruction can be based on having students solve challenging problems for which they have the background knowledge to create procedures leading to solutions, then moving students toward more efficient procedures that build on those they created.

This definition focuses on pedagogy and does not explicitly mention content. It is important to note that mathematics content was the substance on which this pedagogical perspective was developed. Content knowledge was embedded in every phase of the project implementation.

Madison District—Student Performance Data

With the goals that were set for the project, the flexible leadership to address local needs, and having the benefit of half-time release for the MTL, how did student learning fare? While the project was not a research project, data routinely collected by the District provide a reasonably good estimate of student achievement over the years following the initiation of MTL. The following charts give an indication of student performance.

The Stanford 9 scores from 1997–2002 for each tested grade level are shown in Figure 1.

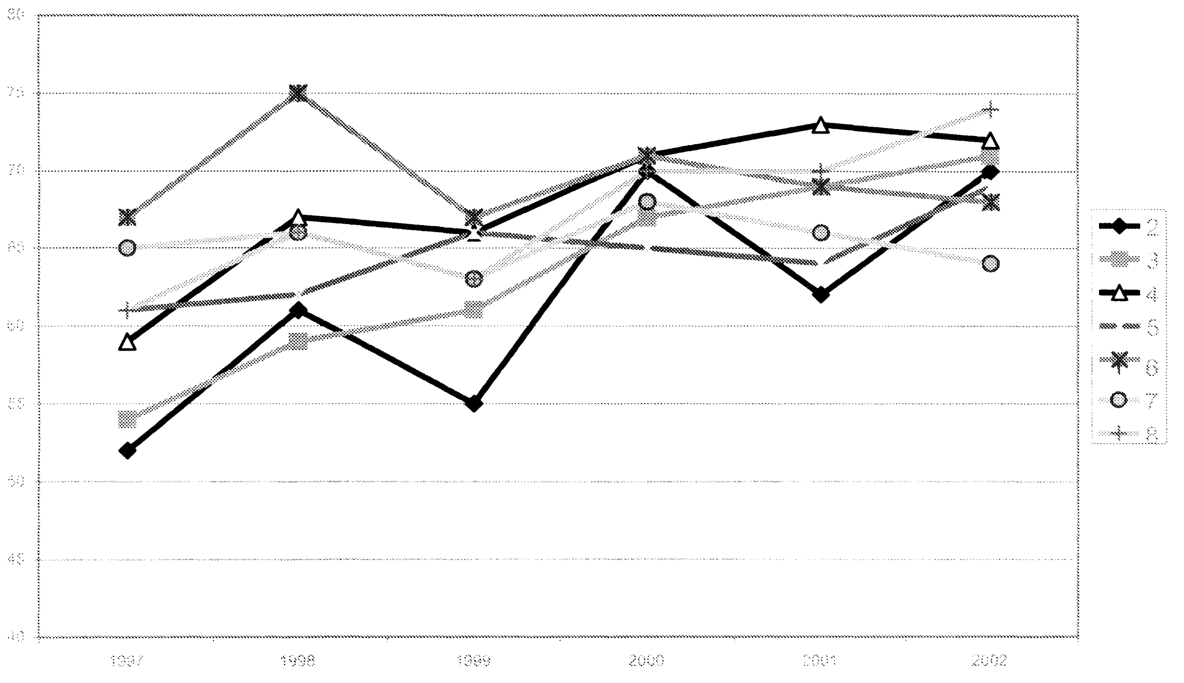


Figure 1. Stanford 9 mathematics scores by grade (1997-2002).

While there are fluctuations of the scores from year to year, Figure 1 shows the overall trend for most grades is in a strong upward direction. The exception is in grade 7, where there was resistance from some teachers to the pedagogical ideas of the project. Also, as indicated by Figure 2, during these same years (1997–2002), the student population became increasingly diverse. While this trend is often accompanied by falling test scores, the Madison District scores trended in an upward direction for most grade levels. Of course, it should be kept in mind that each year's data came from a different group of students.

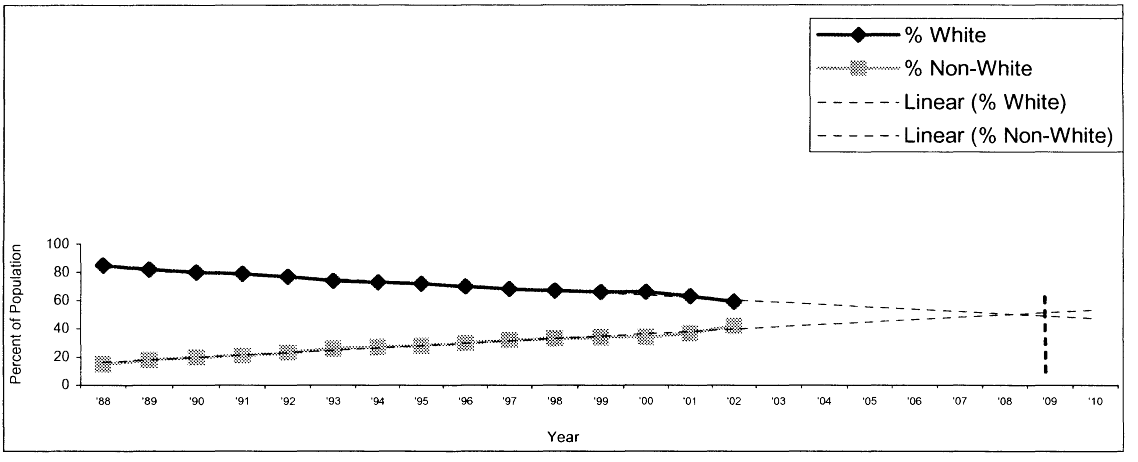


Figure 2. Ethnicity trends (long range).

The results on the Arizona State Mathematics Test (AIMS) also indicated high performance during the project (Figures 3–5).

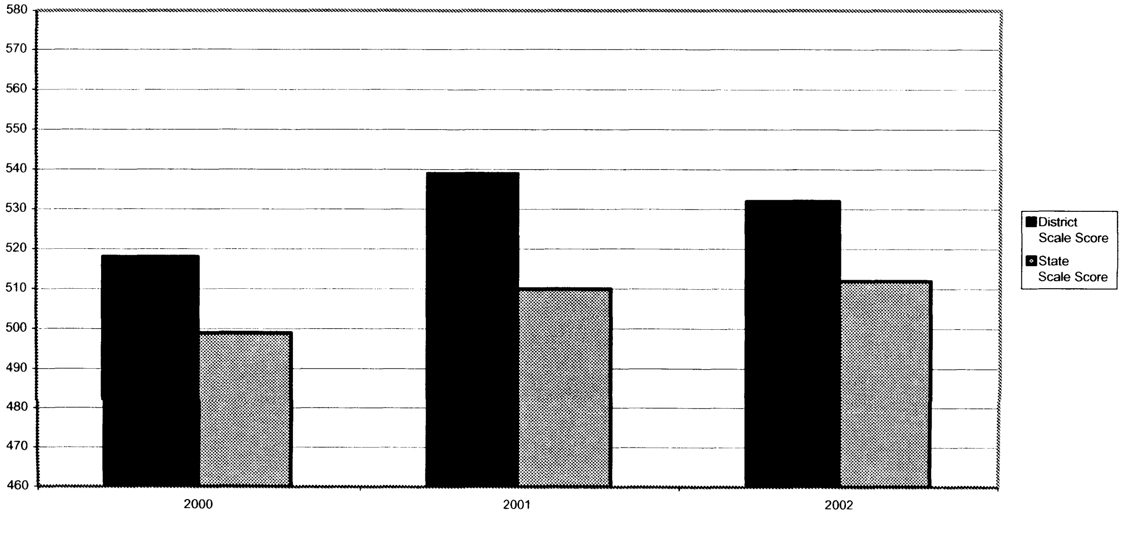


Figure 3. Grade 3 AIMS mathematics scale scores by year.

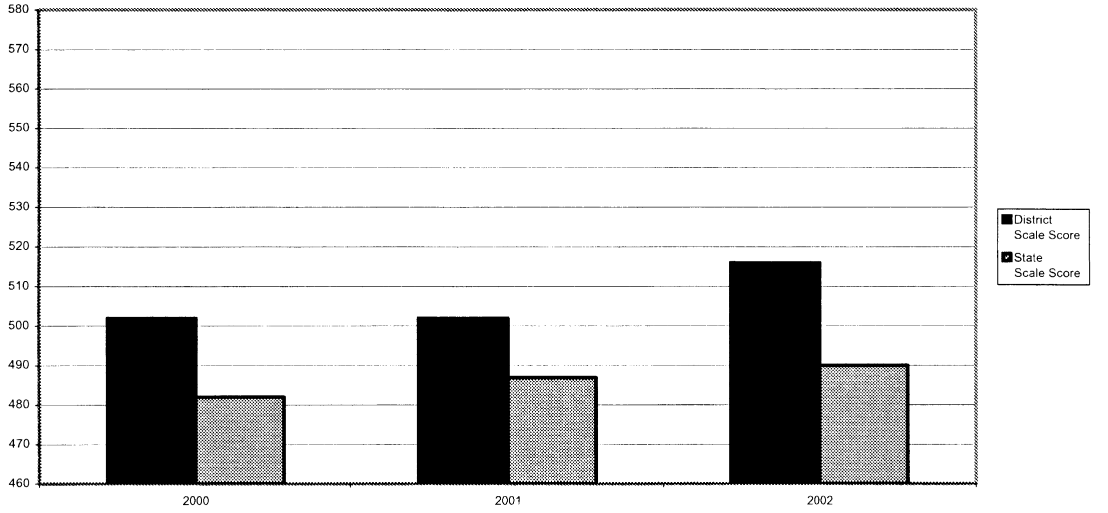


Figure 4. Grade 5 AIMS mathematics scale scores by year.

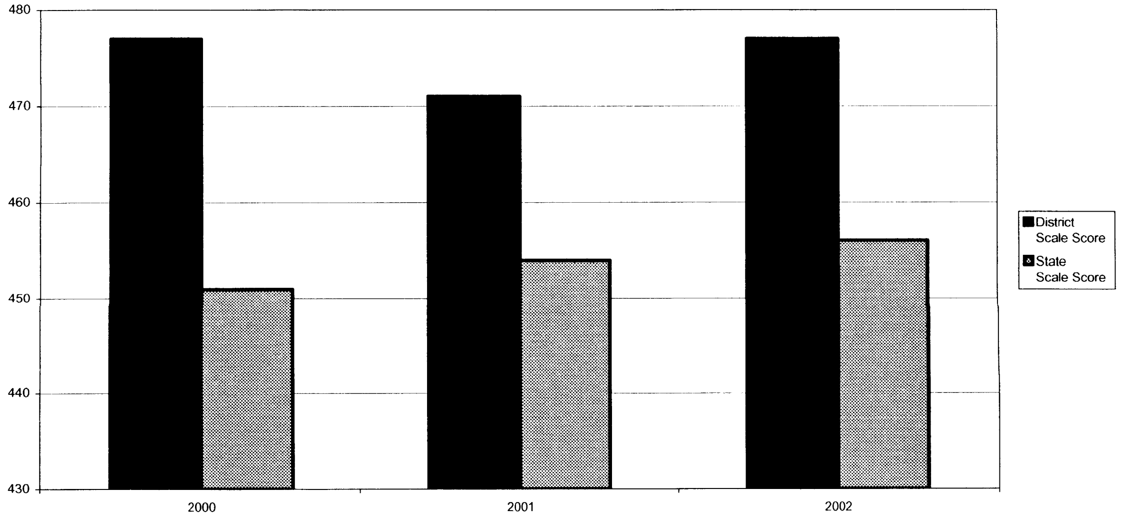


Figure 5. Grade 8 AIMS mathematics scale scores by year.

As another indication of progress, it can be noted that, over the years of the project, the percentage of students going into advanced mathematics classes on entering high school from the Madison District increased dramatically.

Madison District—Summary

While none of the preceding data are presented as a formal analysis, they do seem to indicate that the introduction of Mathematics Teacher Leaders to work with their colleagues and give thoughtful attention to ways of improving mathematics instruction was a positive move on the part of this school district. The emphasis on understanding and using student thinking as a fundamental component of teaching and learning mathematics, as fostered by the MTL, is a difficult change for classroom teachers to make. Their own experience as students, as well as their previous teaching, has almost always been based on a direct instruction model. The use of the MTL to assist teachers in making this transition seems to have been justified by the excellent student test performance, as well as the general feeling among teachers and administrators in the Madison District that students understand mathematics better and enjoy the learning of mathematics more. Mathematics Teacher Leaders, working in close cooperation with building principals who understood the pedagogical goals, seem to have contributed to excellent results for students in the Madison School District of Phoenix, Arizona.

It should be noted also that the Madison School District has elected to continue the Mathematics Specialist positions since NSF funding has ended. It was felt that the MTL program was value added to the instructional program.

The Hanover District

This Hanover district is in a suburb of Richmond, Virginia. It is a K-12 district and has both typical suburban schools and rural schools. Hanover County Public School district (HCPS) is a mixture of rural, small town, and suburban neighborhoods. The population has increased almost 50% over the past ten years and is projected to continue to grow. The HCPS currently has approximately 17,000 students in three high schools, five middle schools, and thirteen elementary schools.

Hanover County has received financial support from the ExxonMobil Foundation to implement a program of mathematics leaders in its elementary schools. Foundation funding began in 1997 and has continued as HCPS has worked to maintain its mathematics leader program by combining local funds with those received from the Foundation. While the outside funds have been relatively low, enabling the ExxonMobil Foundation to provide assistance to more school districts, they still have made a very large difference for Hanover County. Without this support, the program would not likely have been possible. Seed money such as this helped HCPS to initiate and maintain a Teacher Leader program in spite of the budget constraints that accompany relatively rapid growth of the student population. In turn, the Foundation has been able to gather information from HCPS that has been useful to other districts that have received funds.

Hanover District—Teacher Leaders

There are currently fifteen Teacher Leaders (TL) supporting classroom teachers in the Hanover district. Because of the budget limitations, these TL must work with their peers at times other than regular school hours; they do not have release time. Teacher Leaders are released for professional development workshops and meetings, but provide most of their in-school leadership through activities after school, individual contacts with their fellow teachers, and other activities. Teacher Leaders are called on to conduct professional development for other teachers on County professional development days when all teachers are released. The support they provide includes development and implementation of the HCPS curriculum, coordination of instruction and assessment with the Virginia *Standards of Learning* (*SOL*), offering mathematics study groups for their peers after school, heading up preparation and delivery of mathematics programs for parents, and assistance with selection and organization of instructional materials to support the teaching of mathematics at the local school level [5]. The Teacher Leaders have been provided professional development through local workshops funded by ExxonMobil Foundation grants and through attendance at national meetings and workshops. The school district has supplemented grant funds to extend the training opportunities and to utilize the Leaders as curriculum developers during the summer. Several of the TL have entered graduate programs at a nearby university to specialize in elementary mathematics teaching. Some have completed this program while others are currently attending classes.

Professional development for the Hanover County TL has been provided primarily through workshops delivered by consultants. These workshops have generally occurred on six release days each school year. In addition, there has usually been a four-day summer workshop that combined curriculum development work with professional development activities. Mathematics content background and pedagogy have been integrated into the presentations of these workshops. The pedagogical philosophy has been that of reflective teaching and modified constructivist strategies, much the same as that used in the Phoenix project. Teacher Leaders have often taken ideas from the workshops, tried them out with their students, and shared the results with their colleagues during the workshops. Often, the TL have given presentations at annual and regional meetings of the National Council of Teachers of Mathematics, here again sharing the ideas and understanding they have gained as a result of the ExxonMobil funding.

Certainly, this is a much less intense level of implementation and professional development than that described for the Madison District with its NSF funding. However, the goal in HCPS was the same as in the Madison District: to support Teacher Leaders who could encourage peer teachers to use reflective teaching strategies to increase and deepen the mathematical understandings of their students. In Hanover County, the high-stakes nature of the Virginia *SOL* testing program also required emphasis to be placed on enabling teachers to see how this way of teaching would move students to high achievement on the *SOL* tests. While this focus on testing was also an issue in Arizona, it didn't carry with it the same level of urgency. This pressure to succeed on the Virginia *SOL* tests was very significant for the school principals in Hanover County and, to some extent, complicated TL efforts in the early years of implementation. Principals did not have the opportunity to participate in any professional development activities initially. As a result, in some locations, the potential effectiveness of the reformed teaching strategies for producing excellent results on the *SOL* tests was not accepted. The flexibility with which the local schools implemented the mathematics Teacher Leader program was considerable. Partially because the building principals did not initially participate in professional development with the TL, there was more emphasis on teaching directly to the *SOL* tests in some schools. During the 2002-2003 school year, the elementary principals participated in the *Lenses on Learning* program conducted by the district-level mathematics Teacher Leader [6]. This provided the opportunity for greater understanding, acceptance, and implementation of reflective teaching.

The Teacher Leaders in HCPS provide a variety of types of support for their fellow teachers. As indicated above, they conduct district-level workshops on professional development days. These have generally been grade-level specific. Since the members of the TL are representatives from all grade levels except fourth, this has allowed them to comfortably divide the responsibilities for these workshops. At their local schools, many TL conduct after-school mathematics study groups for teachers who are interested in learning more about mathematics content and the reflective teaching of mathematics. These study groups focus on a variety of topics which are often determined by the teachers who participate. Communication with parents is facilitated through family math nights and other meetings for parents. While the current district adopted textbook is traditional, the NSF-supported reform program, *Investigations in Number, Data, and Space*, has been made available to teachers as a supplement [1]. Teacher Leaders support their colleagues who want to implement this program in whole or in part. The TL, working together with fellow teachers, select for school purchase manipulative materials that support the mathematics program. Ideas for the effective use of these materials are shared through workshops and individual interactions. Fellow teachers are sometimes invited to observe in the classrooms of the TL.

Hanover District—TL Activities

Study groups are used by most of the TL. An example of this is the Teacher Leader whose study group decided to explore the teaching of geometry. Five teachers met for six weeks, once each week for two hours after school. They explored the formation of open-ended problems for students to solve in geometry. Some of their activities included:

- Looking at examples of student thinking;
- Audiotaping their own lessons and analyzing the questions they were asking students;
- Sharing ideas and research information about reflective teaching; and,
- Implementing similar lessons in their various classrooms and bringing back student work to share and discuss.

Teacher Leaders reported using a variety of other activities:

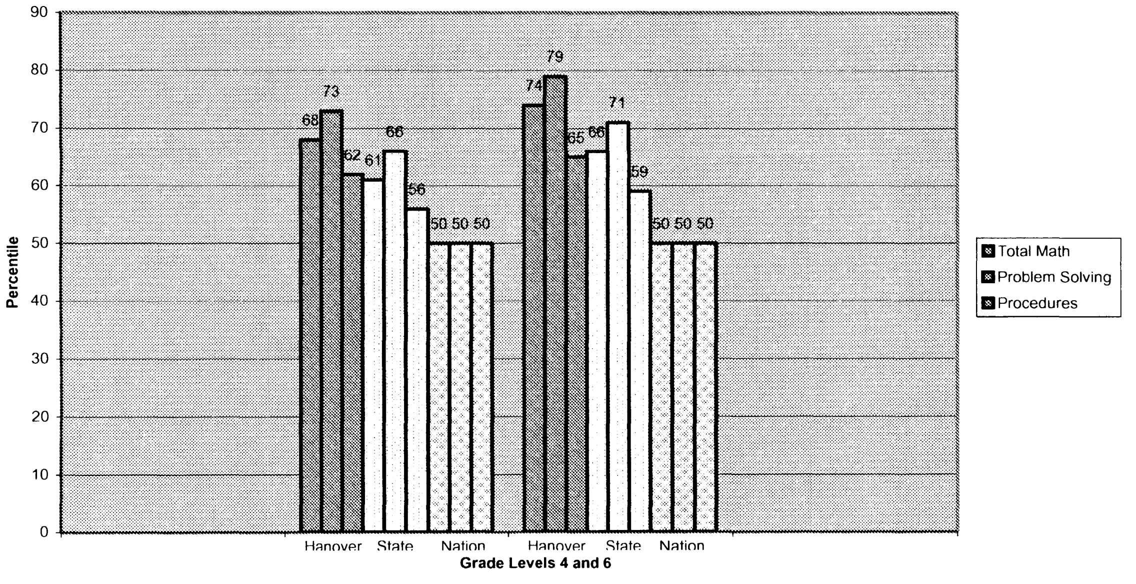
- Formed a math committee with a representative of each grade level for the school;
- With the committee, planned a family math night;
- Provided leadership for a "Math-a-lon" to raise funds from the community for the purchase of manipulative materials;
- Provided information and demonstration lessons for school board members;
- Mentored a new teacher;
- Inventoried and relocated the "math closet" that houses manipulatives;
- Presented at faculty meetings;
- Led in-service sessions for countywide groups of teachers; and,

- Worked in the summer week-long workshop to write instructional guidelines to assist teachers, whether using the traditional text or the reformed text, to be more reflective in their teaching.

Hanover District—Student Performance Data

Given the less intensive implementation of Teacher Leaders for mathematics in the Hanover district, has there been a positive result for students? As with the Madison District, there has been no formal evaluation of student progress that can be directly attributed to the TL program. As mentioned previously, the nature of this district is quite different from the Madison District. The assessment tools used by the district are also quite different. Clearly, the nature and implementation of the TL program is also very different from the MTL program in Madison. It is not really appropriate to compare the informal results between these two districts. However, treating them as completely separate examples with extremely different characteristics may make their separate results even more interesting. The student performance data for grades 4 and 6 from the Hanover system indicate strong performance on mathematics achievement assessments when compared to the statewide results. The chart below shows the scores on the Stanford 9 test for the 2001 school year. The TL professional development program had been in place since 1997. The highest achievement is in the area of problem solving, an area of particular importance and emphasis in the TL professional development activities.

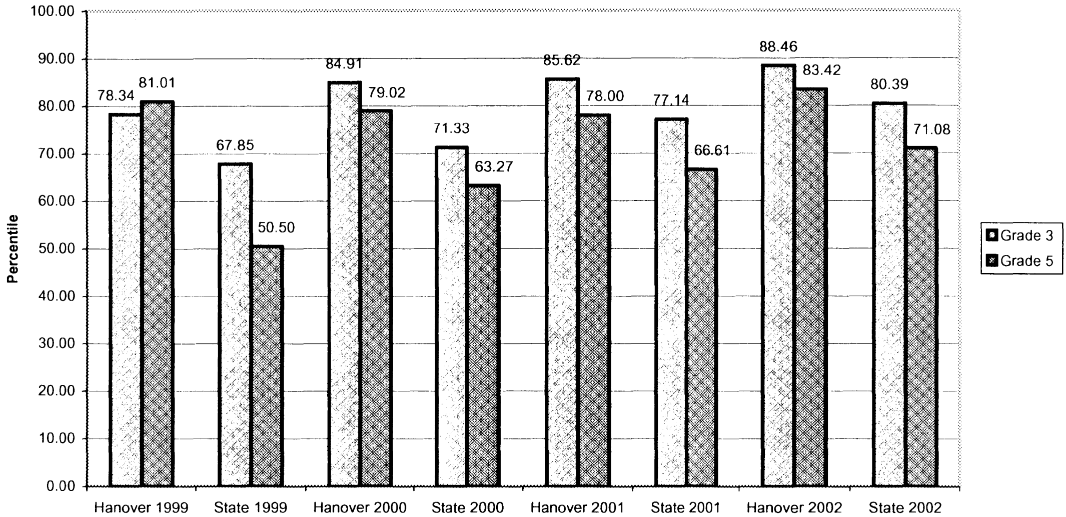
Table 1
Stanford 9 TA 2001



Both the state results and those of the Hanover district exceed the national average for the tested elementary school grade levels, 4 and 6. The Hanover scores are above the statewide performance at both grade levels and in all three of the subscores.

The *SOL* achievement tests are the tests of primary interest in Virginia. Table 2 indicates the performance of the Hanover County district and the statewide results for four school years and two grade levels, 3 and 5. As with the Stanford results, the Hanover district exceeds statewide performance in every school year for each of the grade levels. Note also that the trend for each grade level is upward, both for Hanover and the Commonwealth of Virginia. The results in each of the years represent the performance of a different group of students, so fluctuations would be expected. Each new group can be seen as demonstrating higher scores than the preceding one.

Table 2
Virginia *Standards of Learning* Test



The scores at grade 5 for the year 2001 would represent the performance of many of the same students who were tested in grade 3 during the 1999 school year. While the data indicate a drop of slightly more than 1 percentile from grade 3 to 5 for the state, the Hanover students essentially kept their achievement level, dropping by only about 1/3 of a percentile. Grades 3 through 5 maintained about the same trend as the Commonwealth from 2000 to 2002, the scores in both for those years were very nearly holding steady. Given the high level of the Hanover scores, one might conjecture that they may have been experiencing what is called a "ceiling effect." Given a diverse population, what is the highest performance one might expect on the *SOL* test?

Do the data from these two tests tell anything about the effectiveness of the TL program? There is no basis for claiming that. The scores for both Hanover County and the Commonwealth trended upward over the years displayed for grade 3. For grade 5, Hanover scores stayed relatively level, with a slight upward jump in 2002. Overall state scores had an upward trend for grade 5 across all four years. Hanover scores have stayed considerably above the statewide averages each year. It is generally accepted that improving scores that are low is easier than getting the same improvement in scores that are already high. The TL program may or may not have played a role in the increases and high performance by Hanover County students. However, it can be noted that the problem solving scores stood out well above the other subtests on the Stanford, and seeing this continual high performance on the *SOL* test, accompanied by generally positive responses from students, parents, and administrators provides a combination of results that are supportive.

Because the emphasis in the TL program has been on problem solving and encouraging students to make sense of the mathematics, rather than on focusing only on the *SOL* test, it could be argued that students are gaining a perspective on mathematics that would not be gotten by focusing directly on the content of the tests. The fact that the scores were high and trended upward is a plus. It is often argued that making significant changes in the way a subject is taught will cause an initial decrease in student performance. It would certainly seem that such is not the case in Hanover.

Moving to a nontraditional approach for teaching mathematics is not easy for teachers at any level. For elementary teachers, it is challenging because many of them do not have a great deal of confidence with respect to mathematics and its teaching. Having a Teacher Leader in the building can help make the transition easier and alleviate some of the anxiety about mathematics content. The activities used by the TL in their local buildings have the potential to do that.

Closing Remarks

My experiences in working with these two school districts as they designed and implemented the MTL and the TL programs have convinced me that Teacher Leaders are virtually essential to maximizing the potential of classroom teachers for getting the best from their students. Schools and school districts should find ways, either through budget additions or resource allotments, to implement such programs. The gains are more valuable than the costs. This is particularly important in the typical school setting where classroom teachers often lack strong mathematics backgrounds. The structure of our schools is such that the classroom teacher is isolated and has sole control over the content and pedagogy that is experienced by the students. There are those who would argue that imposing particular assessments takes away that control, but it really doesn't. What each teacher does to move students to achieve on the assessments is governed by the teacher. If "drill and kill" is the only thing that seems available to a teacher, then that is what will happen. A Teacher Leader can help teachers see better options. Many school administrators have as little background in mathematics content and pedagogy as their teachers. At best, they cannot provide the support that would be provided by a Teacher Leader. At worst, they may actually promote rote learning of test items. If we are to have mathematics programs that help students achieve good results in today's atmosphere of heavy emphasis on tests, **and** make sense of the mathematics they are learning so that they can use that mathematics effectively in future mathematics courses and daily life, then we need to provide the kind of support that Teacher Leaders can provide.

What are some things that seem to be essential for an effective Teacher Leader program? A few suggestions are outlined below.

- Provide a professional development program for Teacher Leaders and classroom teachers that integrates content knowledge with pedagogy that enables students to make sense of mathematics.
- Help building administrators gain enough understanding of the pedagogy to effectively support the program implementation as they observe and evaluate teachers.
- Recognize that getting teachers to make significant changes in their pedagogical approaches is a long-term task.
- Provide support in the way of release time and resources so that leaders and teachers will not be frustrated. This includes manipulative materials, but these need not be unreasonably extensive or expensive. Once teachers focus on the "big ideas" of mathematics and see that the manipulatives are only one of the possible ways to represent those ideas, this expense can be controlled and/or spread out over a reasonable time frame.
- If at all possible, provide time during the school day for the Teacher Leaders to carry out their responsibilities. This can shorten the time for successful implementation and minimize the resistance of teachers who are reluctant to make changes in practices they have used for years.
- Recognize that high achievement on the part of some students using current traditional methods does not necessarily indicate that those methods are truly effective. Such achievement may occur *in spite* of those practices. In my experience, many high achievers who got there because they memorized what the teacher or text said, later dropped out of mathematics when they could not succeed in higher mathematics courses through that strategy. All students, high and low achievers, can benefit from mathematics

classes that emphasize the fact that what is done with mathematics should make sense, rather than just getting an answer that pleases a teacher or test developer.

References

[1] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: http://investigations.terc.edu.

[2] *Connected Mathematics*, TERC, Cambridge, MA, 1998, Internet: http://investigations.terc.edu.

[3] T.P. Carpenter, E. Fennema, P.L. Peterson, C.P. Chiang, and M. Loef, "Using Children's Mathematics Thinking in Classroom Teaching: An Experimental Study," *American Educational Research Journal*, **26**(4) (1989) 499-531.

[4] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[5] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[6] C.M. Grant, B.S. Nelson, E. Davidson, A. Sassi, A.S. Weinberg, and J. Bleiman, *Lenses on Learning: A New Focus on Mathematics and School Leadership*, Dale Seymour Publications, Parsippany, NJ, 2002.

HOPEWELL, VIRGINIA: HOW DO YOU "HOOK" ELEMENTARY TEACHERS INTO ENJOYING AND SEEING THE BEAUTY OF MATHEMATICS?

Y. SMITH-JONES
Hopewell Public Schools
Hopewell, VA 23860

Elementary classrooms are the genesis of learning. Excitement, curiosity, and inquiry-based learning are essential elements in the classroom. As readers, elementary teachers experience success early on and do not fear teaching reading because many of the skills are repetitive and recursive. However, mathematics has often been perceived as an additional component to teach if the reading schedule allows time. It is painful for so many elementary teachers because it was a subject that many of the teachers struggled with as students. They do not feel equipped with the prior knowledge needed to understand mathematics.

Teachers (especially elementary teachers) have mathematics backgrounds that are typically weak and often dismal, and math expertise in elementary school is generally minimal [1]. Therefore, the preparation to teach mathematics becomes a laborious, time consuming task. Not being able to teach elementary mathematics is one of the most infuriating problems afflicting teachers. The cure to this challenge is to debunk the myths and fallacies associated with not being comfortable and confident in teaching elementary mathematics. So, how does one begin to "hook" elementary teachers on mathematics?

Initially, elementary teachers need a something to capture their interest and motivate their learning that isn't intimidating. The learning atmosphere should be an inviting, stress-free place in which to take risks as well as experience failures. Hopewell Public Schools decided to become proactive and accept this problem as a challenge. An action plan was developed to partner mathematics with reading, thus valuing both subjects as the focal point of the academic day. The birthing of a sustained, continuous staff development plan emerged.

The plan involved learning teaching models, practicing effective teaching strategies, and understanding mathematics. Graduate classes were offered for all elementary teachers in the area of mathematics from Virginia Commonwealth University with Dr. John Van de Walle as the key instructor. Clusters of classes were offered: grades K-2, 3-5, and 6-8. Emphasis was placed on understanding mathematics from a constructivist perspective with the *Principles and Standards* (National Council of Teachers of Mathematics) providing the overarching frame [2]. These courses unveiled the power of the communication strand. Teachers were encouraged to think and

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 63 - 65

experiment as individuals and teams. Thus, the teaching environment was busy with chatter as teachers began to verify and justify answers. Many of the assignments were activities directly associated with curriculum. Teachers were afforded the opportunity to try the strategies and discuss their findings during class.

In conjunction with this preparation, another selected group of teachers was studying at the university level to obtain degrees in curriculum and instruction with emphasis in elementary and middle school mathematics. These teachers were given the opportunity to interview for Lead Mathematics Teacher at the elementary level. In the beginning, Lead Mathematics Teachers were classroom teachers with additional assignments and a stipend. From this pool of candidates, lead classroom teachers were given additional responsibilities and became full-time Lead Mathematics Teachers. This change from classroom to Lead Mathematics Teacher was made possible by the school district creatively using various funding sources, such as Title I funds, grants, and the local budget, to transform these positions elementary school by school. A stipend is given for preparation and staff development after contract hours. These Lead Teachers attend conferences, participate in study groups, work with analyzing data, create and dissect assessment items, and provide staff development for their school and the division. The move toward Lead Mathematics Teachers was supported by recent research which acknowledges that the best instructional leaders are teachers with an abundant source of content leadership, and that schools need to restructure to allow this transformation to occur [3]. This type of leadership role is multidimensional.

After previewing data and need assessments, the Lead Mathematics Teachers began to plan, schedule, and teach lessons based on areas in need of improvement. Curriculum areas were developed from weekly team planning sessions with various grade levels. Lessons were correlated with each team's weekly lesson. This model lesson is based on best practices with heavy emphasis on using concrete items to model concepts by using word problems to motivate students into tuning into the lesson. The classroom teacher assists with the lesson being taught by the Lead Mathematics Teacher and extends the lesson throughout the week.

Today, Lead Mathematics Teachers in Hopewell have paved the way in charting the course for elementary mathematics. Lead Mathematics Teachers, building-level administrators and the division level director of mathematics have worked not only to ensure that resources are allocated, data is disaggregated, and strengths and weaknesses are identified, but have also developed coherent action plans to improve instruction. The preparation and experiences of

Hopewell's Lead Teachers have afforded them the confidence and respect of the administration, colleagues, students, parents, and community. This has been transformed into schoolwide efforts with well-prepared and trained classroom teachers and Lead Teachers working toward the same goal of improving the performance of all students. The essential ingredients are to leave no child behind and recognize the pivotal importance and long range impact of understanding mathematics. Having full-time Lead Teachers with the credentials to address the challenges, complexities, and joys of teaching mathematics is imperative. Lead Mathematics Teachers are vital to our strong elementary mathematics program. Lead Mathematics Teachers at each elementary school became the hook that brought the joy and beauty of mathematics back into the elementary school classroom.

What does the data show concerning the success of this program? In 2001-2002, the first elementary school to use a full-time Mathematics Lead Teacher Specialist was fully accredited by the Commonwealth of Virginia. The following school year, 2002-2003, the other elementary schools added full-time Mathematics Lead Teacher Specialists and received full accreditation from the Commonwealth. Perhaps the best answer is contained in a recent news item. At the Virginia School Board meeting on February 23, 2005, Hopewell Public Schools was recognized as the **only division** in the Commonwealth of Virginia to receive the honor of being a "Highly Distinguished Title I School Division." As a K-12 school division, Hopewell made adequate yearly progress (AYP) for two consecutive years by exceeding all annual measurable objectives. Hopewell also closed the achievement gap by maintaining or increasing the performance of all students and by increasing the performance of each subgroup in both reading/language arts and mathematics.

References

[1] M. Burns, *Leading the Way: Principals and Superintendents Look at Math Instruction*, Math Solutions Publications, Sausalito, CA, 1999.

[2] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[3] L.O. Pellicer, and L.W. Anderson, "Teacher Leadership: A Promising Paradigm for Improving Instruction in Science and Mathematics," in C.R. Nesbit, J.D. Wallace, D.K. Pugalee, A.C. Miller, and W.J. DiBiase (eds.), *Developing Teacher Leaders: Professional Development in Science and Mathematics*, Columbus, OH, 2001, ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

MATHEMATICS SPECIALISTS IN NORFOLK PUBLIC SCHOOLS

D. WALSTON
Norfolk City Public Schools
Norfolk, VA 23510

Abstract

In a dramatic move in Summer 2004, the Norfolk City Public Schools (NCPS) allocated funds to place a full-time mathematics resource person in 33 of the district's 35 elementary schools. These teachers function in support of mathematics instruction by: building a presence for mathematics; working collaboratively with individual teachers and/or grade levels; supporting the administration in terms of improving the mathematics program at the building level; and, working with small groups of students on a regular basis. These are not "pullout" programs. The goal for this Teacher Leader program is to positively impact mathematics teaching and learning in the entire school. This step was the culmination of a evolutionary journey that began in 1990-91with a Mathematics Lead Teacher program, Project Math Lead. In this article, we tell the story of the process and the vision behind it.

The Vision

The vision behind Mathematics Lead Teachers and Mathematics Resource Teachers in Norfolk City Public Schools (NCPS) is simply that a teacher's motivation, knowledge of content, and commitment to continued professional growth are critical to what happens in the classroom, and largely determine the degree to which new instructional practices filter into the classroom. Lack of content expertise and confidence, especially when coupled with inadequate teaching methods, strongly limit the quality of mathematics instruction. There is a need for programs that provide on-site leadership through a peer group of teachers with training in content, a knowledge of how children learn mathematics, and a focus on effective pedagogy.

This view is grounded in recent results in mathematics both from the Virginia *Standards of Learning* (*SOL*) tests and national measures, such as the 2000 National Assessment of Educational Progress (NAEP) [1]. These test results cite gains in student performance; and on the national level, achievement in mathematics among U.S. fourth and eighth graders is improving. For example, the percentage of fourth grade students performing at or above the proficient level has doubled since 1990; and Caucasian, African-American, and Hispanic fourth and eighth graders had higher average scores in 2000 as compared to 1990. Unfortunately, the achievement gap between Caucasian and African-American students, and between Caucasian and Hispanic students remained large at all grade levels.

Reviewing this data, one must ask what is needed to significantly increase the performance of all students on multiple measures of student achievement? One compelling argument that led to Mathematics Resource Teachers in Norfolk is found in *Closing the*

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 67 - 72

Achievement Gap: A Vision for Changing Beliefs and Practices [2]. It is that the four critical variables—Content Coverage, Content Exposure, Content Emphasis, and the Quality of Instructional Delivery—are key to providing students with effective opportunities to learn. While numerous external factors that are beyond educators' control are also important, these four variables are within a school's purview as a means for increasing student achievement. The quality of the teachers' instructional delivery affects both what and whether a student learns, and the teacher is the most important change agent in the classroom. Impacting these variables and school culture are the most apparent pressure points for affecting school change and student learning.

Norfolk's Mathematics Lead Teacher Program

Against that backdrop, Norfolk's Mathematics Lead Teacher Program began in 1990-91 with Project Math Lead. Using Eisenhower funds and district professional development funds, principals were asked to identify a teacher within their building willing to commit to extensive training in mathematics and pedagogy. These teachers were to act as resources for the school mathematics staff and as liaisons between the school and the mathematics office. The Mathematics Lead Teachers were willing to take nine hours of graduate work in instructional strategies and mathematics content, and attend at least one intensive workshop per year. They were interested in assuming a leadership role at the school, division, and area levels. As a result, these teachers took six to nine hours of mathematics focused on:

- The teaching and learning of geometry;
- The teaching and learning of number sense;
- The teaching and learning of probability and statistics; and,
- Their role in working with adult learners.

Sessions were facilitated by a number of local mathematicians and mathematics educators. While the majority of the sessions were held on Saturdays, teachers were involved in extensive training during the summer as well. Principals supported the Program by encouraging and monitoring teacher participation. The district's mathematics office committed to fully funding the cost of training and the cost of substitutes for release time provided to the Lead Teacher.

A network of support was provided by Lead Teacher meetings held after school on a quarterly basis. Mathematics Lead Teachers also received release time during the school year (no *more than two* days) to conduct professional development within their buildings. This release time was typically spent working with teachers during planning and providing demonstration lessons.

At the end of the first year, 33 out of 35 schools had fully participating Mathematics Lead Teachers. A yearly application process was begun in which the school principal would identify the teacher that would work as a Lead Teacher, as well as indicate their specific in-building needs and rationale for their selection. Each principal received a copy of the rationale in addition to identified responsibilities for the Mathematics Lead Teacher.

For example, the Mathematics Lead Teacher will:

- Provide information for staff within their building about workshops, in-service opportunities, conferences, and information from Lead Teacher meetings;
- Offer suggestions or strategies for implementing lessons, teaching activities, and assist the principal with the ordering of the needed instructional materials in mathematics;
- Provide guidance or present brief in-service experiences for school staff and parents; and,
- Support the enhancement of instruction in mathematics by contributing ideas at faculty, grade-level, and Lead Teacher meetings.

This process generated greater "buy-in" between principal, teacher, and the district mathematics coordinator. Principals were surveyed at the end of each school year to assess the effectiveness of the Mathematics Lead Teacher Program. Principals were overwhelmingly supportive of the Program. At the end of 1993-94, 34 of 35 schools had identified Mathematics Lead Teachers. The Program characteristics and focus remained in effect in 2004; 34 of 35 schools have an effective Mathematics Lead Teacher Program.

The Program's major drawback was that Lead Teachers were unable to provide consistent daily support to the entire faculty. Mathematics Lead Teachers are full-time classroom teachers who share their expertise. They are as busy as other teachers and they receive no additional financial awards. They are supported by the mathematics office which covers costs to attend local, state, regional, or national mathematics conferences, and they receive extensive specific Lead Teacher training during the school year and summer.

Title 1 Mathematics Resource Teachers

The Mathematics Lead Teacher Program, while viable, was recognized as limited in its impact on schools, especially schools with greatest need. Working collaboratively with the office of Compensatory Programs, the mathematics office began requesting resource personnel with daily release time in schools of highest need. As a result, federal funds were used to support the cost of a Title I Mathematics Resource Teacher in each Norfolk Public School that is identified as a Title I School. When this process began, there was concern about the impact that these Resource Teachers would have within the building. It was the intent of the mathematics office that the current traditional roles of the Title I Mathematics Teacher change to dramatically impact instructional delivery within the schools. As a result, the Title I Mathematics Resource Teachers are asked to work cooperatively with classroom teachers and principals in providing mathematics instruction (i.e., small group, one-to-one).

These teachers were expected to: work with teachers during grade-level planning in addressing the instructional program based upon identified needs; provide demonstration lessons in mathematics (in the classroom with the teacher present), including those strategies related to the teaching of mathematics; and, provide building-level professional development in the teaching of mathematics. No longer were teachers merely giving demonstration lessons. Rather, they served as both mentor and coach for individual teachers or groups of teachers; i.e., the Mathematics Resource Teacher plans with the individual teacher or group and then they team teach. These responsibilities comprise at least 60% of the Title I Mathematics Resource Teachers' weekly schedule. At the end of 1997-1998, there were nine teachers identified as Title I Mathematics Resource Teachers. All of these teachers were original members of Norfolk Public Schools Mathematics Lead Teacher Program. The number of Title I Mathematics Resource Teachers grew to more than fourteen teachers during the 2000-01 school year.

Funding for the Title I Mathematics Resource Teacher Program is still provided through the office of Compensatory Education. However, these teachers work collaboratively with the mathematics office and Compensatory Education. The Title I Mathematics Resource Teachers attend monthly meetings facilitated by the mathematics office as a vehicle for providing a network of support. These teachers also attend quarterly Mathematics Lead Teacher meetings.

It is through these meetings that ideas are shared and cultivated. Book talks are held so that the Mathematics Lead Teachers may discuss current literature reflecting effective practices, as well as research on teaching and learning mathematics. The Title I Mathematics Resource Teachers also have eliminated walls within the district. For example, if one Title I Mathematics Resource Teacher needs assistance with the implementation of "Math Menus" in their school, the support system is so strong that they can call upon the expertise of another Title I Mathematics Resource Teacher to assist them.

Because of the success (in terms of student performance of these Title I Mathematics Teachers), the district funded four additional positions in non-Title I schools during the 2002-2003 school year. As a result, the title of the group changed to Mathematics Resource Specialists.

Conclusion

The Mathematics Lead Teacher Program, the Title I Mathematics Resource Teachers, and now the Mathematics Resource Specialists are seen to have contributed enormously in improved student achievement within the NCPS. Their enthusiasm is contagious and they have impacted student achievement by changing the culture of elementary classrooms in terms of mathematics teaching and learning. As a result, in the Norfolk City Public Schools, there are now no elementary schools accredited with warning in mathematics based upon *SOL* scores.

Because of the impact of the work of our Mathematics Lead/Resource Teachers, building-level and district administrators were supportive of funding these positions. Principals and other administrators touted the academic benefits of such positions. As a result, the district allocated funds at the end of the 2003-04 school year for the position of either a Mathematics or Science Resource Specialist for all elementary schools. The primary beneficiaries were schools that did not have a mathematics position funded through the Title I program. As a result, a total of 33 out of 35 of the elementary schools have a "mathematics resource person."

The newly enlarged group still has monthly half-day meetings. The Mathematics Leaders are supporting the mathematics office by facilitating professional development sessions in the district. A tiered system has been put in place, in which the Level 2 Mathematics Leaders (those with extensive experience) mentor/coach the Level 1 Leaders (those with limited experience). The mentoring/coaching occurs during the school day, and these sessions are regularly scheduled. In addition, ten of the current Mathematics Resource Teachers are completing the requirements for the Mathematics Specialist licensure.

Improvements are still needed, but because of the commitment and attention of this group, we continue to improve in a dramatic manner.

—And still we rise.

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[2] B. Williams (ed.), *Closing the Achievement Gap: A Vision for Changing Beliefs and Practices*, Association for Supervision and Curriculum Development, Alexandria, VA, 1996.

LEADERSHIP PROGRESS IN STAFFORD COUNTY SCHOOLS

V. INGE
Stafford County Public Schools
Stafford, VA 22554

Stafford County Public Schools is the recipient of an ExxonMobil Leadership Grant, and introduced Mathematics Specialists in five of their elementary schools in Fall 2003 and in a sixth school in 2004. This article is a slight modification of a report on progress that appeared in the ExxonMobil newsletter, *Intersection*, in Fall 2004.

Important components of our Mathematics Specialist Program continue to provide opportunities for our Lead Teachers and Specialists to deepen their own understanding of mathematics, to increase their understanding of how children come to make sense of mathematics, and to further develop their own leadership skills. There are many ways to substantiate the positive impact that has resulted from the learning opportunities that the fifteen Stafford County Mathematics Specialists and Mathematics Lead Teachers have received as a result of our ExxonMobil Leadership Grants.

Has the grant-supported professional development for our Lead Teachers and Mathematics Specialists been an effective lever for improving student performance? It is not easy to make a direct correlation between staff development and student achievement. To add to this complexity, the Lead Teachers and Mathematics Specialists use their own learning to provide learning opportunities for the teachers in their buildings. We measure the broad strokes of our success by looking at the achievement of all students on the Virginia *Standards of Learning* (*SOL*) tests [1]. Over the past two years, we have seen a steady increase in student achievement on the *SOL* tests at grades 3 and 5. Not only have the overall pass rates increased, but the percentage of students passing advanced has also increased. Our six lowest socioeconomic schools, assigned a full-time Mathematics Specialist, are improving at a greater rate than the nine schools that do not have a full-time Specialist.

In the October 29, 2004 article in Fredericksburg's Free Lance-Star, Peter Vernimb, the Executive Director of Instruction in Stafford County, highlighted two schools—Rocky Run Elementary and Stafford Elementary. Rocky Run fifth graders had a 71% pass rate on the mathematics exam, an 11% jump from last year. At Stafford Elementary, 80% of fifth graders passed the mathematics exam, up from 60% last year. Vernimb said hiring Mathematics Specialists at those schools made the difference.

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 73 - 76

The additional learning opportunities in mathematics content, problem-centered learning, and mathematics pedagogy afforded our Mathematics Specialists and Mathematics Lead Teachers through the ExxonMobil Leadership Grant is reflected in the staff development and teacher support that these Teacher Leaders are facilitating in their schools. In 2003-2004, the Mathematics Specialists conducted an average of 65 hours of staff development and the Mathematics Lead Teachers conducted an average of 32 hours of staff development for staff and parents. In addition to the site-based staff development, these Teacher Leaders assist delivering divisionwide staff development opportunities.

We are moving strongly toward meeting our goal to build a critical mass of teachers who will be ready to adopt a reform curriculum during the textbook adoption process in 2004-2005. Due to the work of our Specialists and Lead Teachers, over 50% of our elementary teachers are currently using *Investigations in Number, Data, and Space* as a substantial part of their curriculum [2]. We have both special education teachers and gifted resource teachers who are proponents of this curriculum. One of our strongest advocates for the Program is a special education teacher who reported the following to me during an interview in May 2004.

> My children don't know that they are different from the other students in my collaborative class when we are using *Investigations*; in fact, they often see things that other (regular ed.) students don't see when we are doing an investigation. They are more willing to take a risk and try something. My collaborative teacher was shocked at what some of my (special ed.) students came up with. She is even treating them differently now and calls on them just like everyone else. The kids feel better about themselves and are willing to try things more than before.

Moreover, I have heard similar comments from other teachers who realize that problem-centered learning focused on developing students' understanding, and mathematics proficiency has multiple entry points to meet the needs of our diverse learners.

A survey of administrators in June 2004 revealed that thirteen of the fifteen elementary school principals found the *Lenses on Learning* (*LOL*) class to be a highly beneficial learning opportunity while the remaining two administrators found the class to be somewhat beneficial [3].

Interviews with the Mathematics Specialists indicate that their principals came to them after each *LOL* class to discuss what they had learned and, on several occasions, the principals used staff meetings to share some of the video and mathematics with the entire staff. The exit cards from the *LOL* class informed me that principals without a Specialist came to realize the value of having a Specialist in the building to work with teachers in order to move the faculty to a more standards-based mathematics program.

Principals in buildings with a Specialist reported to Dr. Marie Sheckels in her study of Stafford's Specialist Program that placing a Mathematics Specialist in a building was one of the most cost effective moves the division has made. They also noted that Specialists were a necessary change agent to support teachers in transforming their practice and in improving student learning.

Our Mathematics Specialists are gaining great respect from teachers, administrators, and community members throughout the school division for their strong leadership skills, their exemplary professionalism, and their deep understanding of how children learn. Furthermore, they are being recognized for their ability to design and implement effective staff development opportunities in content, assessment, and instruction. In fact, they are being called upon by so many agents outside of mathematics that we are now having discussions about how to replicate the professional development model to prepare Teacher Leaders in the other core disciplines.

Stafford County is excited to be a part of Virginia Commonwealth University's National Science Foundation Teacher Professional Continuum research grant to study the impact of Mathematics Specialists on teaching and learning. Over the next four years, we will deploy Mathematics Specialists into six more of our elementary schools. Our long-range goal is to have a dedicated Mathematics Specialist in each of our elementary and middle schools. During the 2005-2006 school year, we will establish a Middle School Mathematics Task Force to define the Middle School Mathematics Specialist Program for Stafford County.

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[2] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: http://investigations.terc.edu.

[3] C.M. Grant, B.S. Nelson, E. Davidson, A. Sassi, A.S. Weinberg, and J. Bleiman, *Lenses on Learning: A New Focus on Mathematics and School Leadership*, Dale Seymour Publications, Parsippany, NJ, 2002.

PART III: PROFESSIONAL DEVELOPMENT

This section describes the design of professional development programs for Mathematics Specialists. Articles by national experts address the issues relating to what Mathematics Specialists need to know and how to train them to acquire the content, pedagogical, and leadership skills necessary for their roles in the schools.

DESIGNING PROFESSIONAL DEVELOPMENT ACTIVITIES FOR MATHEMATICS SPECIALISTS

V. BASTABLE
Mt Holyoke College
South Hadley, MA 01075

L. MENSTER
Houston Independent School District
Houston, TX 77027

Introduction

In response to calls for the improvement of mathematics instruction on national, state, and local levels, many school systems have begun to develop programs in which a key player is a mathematics specialist, mathematics teacher leader, or mathematics coach. While each system defines the work of these educators in slightly different ways, these terms generally indicate an educator who has been given the responsibility for supporting other teachers as they seek to improve their mathematics instruction. For the purpose of this paper, we will use the term Mathematics Specialist to refer to these educators. The work of Mathematics Specialists may include conducting professional development activities, working with teachers in their classrooms, interpreting local curriculum goals in the light of national standards and published curriculum, and communicating with parents and the general public about the purposes and accomplishments of the school's mathematics program.

Mathematics Specialists and Professional Development

Given this description of the work of Mathematics Specialists, questions arise. What do Mathematics Specialists need to learn to take on these responsibilities? What kinds of learning opportunities should be provided on an ongoing basis as they do their work? What areas of interest should be studied?

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 77 - 96

Much has been written about the professional development needs of both pre-service and in-service teachers [1-5]. In our work, we examine the connections between designing professional development for teachers and for Mathematics Specialists. What is it that Mathematics Specialists should learn in their professional development experiences and how might that learning take place?

The following journal responses provide a glimpse into the learning of two Mathematics Specialists, Beth and Jolene, who are reflecting upon questions posed to them in the context of their professional development: How would you describe an effective mathematics class? How has this vision changed since you began this work?

> My vision of an ideal classroom has changed considerably. Before, I did not focus on children's thinking as much. If the right answer came up, most of the time I moved on to the next thing at hand. We did not take much time to explore other ways to solve problems or express other ideas. I still find myself doing that from time to time—not allowing for other ideas to surface. I realize it will take some time to break old habits. ... I had been a procedural type of teacher, now in my teaching I try to create meaning. This has been the biggest change of all.
>
> Beth, November 2001

> It [my vision] is still changing. Before, a math classroom that had manipulatives and centers would have been enough. Now I see planning important questions ahead of time is needed. What is the math concept we will work on? What do I want the children to know? Where do I want them to go with this idea?
>
> Jolene, November 2001

These responses indicate the changes Beth and Jolene are in the process of making. These include changes in their views of what mathematics is, how children come to understand it, and how a classroom might be organized to support and develop children's mathematical ideas. These shifts are consistent with the goals of their professional development work. Now consider one more journal response:

> I always had the personal belief that you just can't hand somebody knowledge. They need to have experiences to work through something themselves. I have always believed this about students. Now I have the same belief when working with teachers.
>
> Marie, November 2001

Marie's response indicates that her ideas about how to work with teachers are changing. She now sees that the same principles of learning that she considers for students should also ground her work with teachers.

These journal responses provide a glimpse into the shifts of thinking of three Mathematics Specialists as a result of their professional development experiences. Some of these shifts are similar to what teachers might learn in professional development work and some are appropriate for Mathematics Specialists.

This raises a set of interesting questions. What is the connection between the kind of professional development designed for teachers and the kind of professional development that Mathematics Specialists might need? How are the goals for professional development for teachers and Mathematics Specialists the same or different? What additional goals should be considered in designing professional development for Mathematics Specialists?

We will examine this set of questions based on our experiences working with the Houston Mathematics Initiative, a collaboration between the Southwest District of the Houston Independent School District, the Houston A+ Challenge, and the ExxonMobil Foundation. The Houston Mathematics Initiative currently involves thirteen schools and fifteen Mathematics Specialists. The Mathematics Specialists work in project schools Monday through Thursday. On Fridays, they meet for professional development work.

Although there are many components built into the Friday professional development work, we will focus only on a subset of those activities. In this paper, we are particularly interested in examining how goals for the professional development of teachers and Mathematics Specialists intersect and how materials originally designed for classroom teachers can serve as a resource for the professional development of Mathematics Specialists.

Goals of Professional Development for Classroom Teachers

The *Developing Mathematical Ideas* (*DMI*) professional development curriculum serves as the basis for this work [6-7]. The *DMI* curriculum currently consists of five modules, each focused on a specific set of related mathematical ideas: *Building a System of Tens*, *Making Meaning for Operations*, *Examining Features of Shape*, *Measuring Space in One, Two, and Three Dimensions*, and *Working with Data*. Each module includes a casebook, facilitator's guide, and a set of video cases. The casebook consists of eight chapters. The first seven contain narratives written by teachers in which they describe and analyze the mathematical thinking of their K-6 students. The eighth chapter is an essay, "Highlights of Related Research," which connects the mathematics examined in the cases with educational research.

The facilitator's guide includes discussion questions focused on the print and video cases, mathematics activities at an adult level related to the mathematics topics in the cases, and reflective writing assignments. The guide also includes components designed to support facilitators in their use of the *DMI* materials. One such support is called "Maxine's Journal," a reflective journal written from the viewpoint of a seminar facilitator. In the same way that the *DMI* cases offer seminar participants the opportunity to experience a classroom through the thoughts, questions and reflections of the classroom teacher, "Maxine's Journal" provides seminar facilitators with the opportunity to view a seminar in action through the thought processes of the facilitator.

Much professional development in the past has been based on an "expert" model in which an individual who is particularly knowledgeable about a certain subject presents his/her ideas to the participants. The *DMI* seminars embody a different vision of professional development with the following set of goals for participants:

- Understand that mathematics is about thinking and that they themselves are capable of thinking mathematically;
- Recognize their students as mathematical thinkers with ideas worth listening to and thinking about;
- Learn how to make sense of their students' ideas and then connect these ideas to their instructional and curricula goals;
- Engage students in discussions in which their ideas about mathematics are analyzed and refined; and,

- Experience these goals for themselves in a supportive learning community.

The *DMI* curriculum is designed with the idea that individuals learn when they articulate their own ideas, compare them with the ideas of others and then refine those ideas to take into account these new experiences. Discussions among participants are valued and encouraged whether the topic at hand is mathematics or pedagogy. Negotiating these discussions by providing both support for and challenge to participant ideas is an integral part of the work of any *DMI* facilitator. Components of the facilitator's guide such as "Maxine's Journal" are designed to support *DMI* facilitators as they take on this role. For a more detailed analysis of the work of a *DMI* facilitator, refer to "Active Facilitation: What Do Facilitators Need to Know and How Might They Learn It?" [8].

Principles Underlying Professional Development for Mathematics Specialists

Our work designing professional development for the Mathematics Specialists began with the goals that *DMI* establishes for teachers. However, as we considered the additional demands of the work of Mathematics Specialists, we expanded on these goals. Four principles guided our work as we designed professional development activities for Mathematics Specialists using the *DMI* materials as a resource.

<u>Mathematics Specialist Is a Teacher in the Process of Changing His/Her Teaching Practice</u> — The Mathematics Specialist is first and foremost a teacher in the process of changing his/her own teaching practice. Even though the Mathematics Specialist has additional responsibilities, a key part of the work remains teaching. In general, teachers currently serving as Mathematics Specialists have not had the opportunity to learn mathematics by considering their own ideas and developing their own approaches to mathematics problems. Yet, they are expected to establish classroom practices so that students may learn this way. The Specialists need opportunities to consider what it means to organize instruction around student ideas and also to come to see mathematics as a set of coherent ideas which students are capable of developing. In addition, the work of creating a classroom culture that both supports and challenges students' thinking requires roles for both teachers and students that are different from past practices in schools.

This work involves both mathematical and pedagogical challenges. For instance, teachers must be able to follow the logic in students' mathematical thinking and to link their students' ideas to the mathematical goals of the curriculum. This requires mathematical knowledge deep enough to enable teachers to make connections between related mathematical ideas. At the same time, there are also new pedagogical tasks. For instance, teachers must help students learn how to participate in discussions; students need to see discussion involves both offering their ideas and analyzing the ideas of others. Since Mathematics Specialists must also take on this work of refining their teaching, the first four goals listed for the professional development for classroom teachers which address these needs are necessary and appropriate when planning professional development for Specialists.

Mathematics Specialists Need to Have a Deep Understanding of How Mathematical Ideas Develop Over Grade Levels — Before taking on the role of Mathematics Specialists, teachers may have had experience teaching one or two grade levels. However, their new work requires they develop knowledge of the mathematics of the entire K-5 curriculum. They need to know the connections among the pattern block work in the first grade, the geometry activities in the third grade, and area work in the fifth grade. This is essential as Mathematics Specialists are called upon to help teachers move from looking at mathematics as a series of activities students do, to a set of ideas students think about. While their own work as classroom teachers provides one resource for this work, they also need to be able to envision the interaction between student ideas and the district curriculum for every grade level and to see how mathematical ideas relate to the work at various grade levels. Their professional development must offer opportunities for them to deepen their mathematics knowledge, to understand the ways children encounter and develop mathematical ideas over time, and to connect children's ideas with the district K-5 curriculum. This need represents an expansion of the third goal listed for classroom teachers.

Mathematics Specialists Need to Be Able to Create Learning Communities — Mathematics Specialists need to be able to create learning communities for the various groups with whom they work. Most educators have not had opportunities to participate in a community of learning, a setting where inquiry into ideas is the norm. In a learning community, discussion and analysis of each person's ideas is the mechanism for learning. One of the goals listed for teachers states that they need to have the experience of participating in a learning community; this goal remains appropriate for Mathematics Specialists as well. However, the work of Mathematics Specialists requires even more; they must learn how to establish and cultivate such communities, not only with students, but also with adults. Working on their own teaching practice and learning to facilitate *DMI* seminars are two contexts in which Mathematics Specialists can work on developing learning communities. In these two formal settings, it is a part of the work to create a supportive environment in which each person's ideas are to be articulated and also challenged.

However, these formal settings are only part of the work of a Mathematics Specialist. Mathematics Specialists also work with teachers as a classroom coach or as a leader of grade-level meetings. They work with principals; for instance, in considering how district curriculum connects with student thinking or how the principal can support teachers as they work to develop classroom practices built on analyzing student ideas. Mathematics Specialists need to learn how to approach these kinds of interactions with the same focus they bring to the formal settings, that of an active facilitator responsible for the learning of others. For example, in a *DMI* seminar, participant's questions are seen as starting points for discussion rather than demands for the facilitator's answer. Mathematics Specialists need to learn how to adopt a similar stance toward inquiry as a basis for their work when coaching or leading grade-level meetings or in conversations with their principals. Their professional development work must include opportunities to examine what it means to create a school culture that is a community of learning and to consider possible ways of responding to teachers and principals that are compatible with such a community.

Mathematics Specialists Must Have a Stance of Inquiry Toward Their Own Work — They need to see themselves as learners, to see each other as a support, and to see that together as a group they are also a learning community. Mathematics Specialists need to experience their professional development as a community of learners. They must have the opportunity to learn mathematics, to examine children's mathematical thinking, and to consider district curriculum goals in terms of children's ideas. Then, they need to examine and analyze the conditions under which their learning took place so that they can create similar environments for students, teachers, and principals. In addition, the professional development should also provide opportunities for the Specialists to recognize that they can serve as a resource for each other.

Just as a *DMI* seminar participant's question is seen as a springboard for discussion, so too, the questions that Mathematics Specialists pose should be seen as the starting point for inquiry for the whole group. The professional development work should provide the context for the Mathematics Specialists to develop this sense that they, as a group, are a part of a systemwide program working in concert for the improvement of mathematics instruction. The work must include opportunities to develop this shared vision.

Examples of Professional Development for Mathematics Specialists

In this section of the paper, we provide four examples of professional development activities used in the Houston Math Initiative. Each example is also an instance of designing professional development for Mathematics Specialists using the *DMI* materials as a resource. The description of each activity includes:

- the primary goals of the activity
- the *DMI* excerpt that was used as a resource
- the structure of the activity
- the assignment sheet
- a brief analysis of how the activity addresses the professional development needs of the Mathematics Specialist

These professional development activities describe learning opportunities that embody the four principles we have established. By participating in these activities, the Mathematics Specialists will: 1) develop images and practices to support their teaching; 2) work on their own mathematical ideas; 3) consider how to engage with teachers and principals; and, 4) create a learning community and analyze how that community operates to support learning.

Examining the Work of Facilitating *DMI*

Since part of the work of a Houston Mathematics Specialist is to facilitate *DMI* seminars, one component of their professional development work is focused on supporting the Specialists as they take on the role of becoming a teacher of teachers. There are three specific ongoing activities devoted to *DMI* facilitation: *DMI* Leadership Institutes, practice facilitation sessions, and shared debriefing discussions. The *DMI* Leadership institutes take place in the summer while the facilitation sessions and debriefing discussions are incorporated into the Friday professional development work.

In practice facilitation sessions, pairs of Mathematics Specialists conduct a *DMI* session with the rest of the group as participants and then the entire group holds a feedback discussion that includes comments both about the mathematics content of the session and the facilitation process. In shared debriefing sessions, the Specialists discuss the *DMI* seminars they are offering to system teachers to bring facilitation concerns to the group. The discussions might be focused on working to understand participant ideas, responding to teachers' journal writing, the mathematical content of sessions, issues about connecting the *DMI* work with local curriculum goals, or questions individual Specialists bring about their facilitation work. Thus, the professional development work provides an ongoing support structure to help the Mathematics Specialists offer the *DMI* seminars. Example one builds on this background of working on facilitating *DMI* seminars.

Example One—Primary Goals of the Activity

- To consider the connections between one's personal beliefs about teaching and learning and one's actions as a facilitator of other teachers' learning.
- To examine the underlying mathematical ideas of a variety of approaches to computing multi-digit subtraction problems and to examine the pedagogical value of exploring those strategies with students.

Example One—*DMI* Excerpt Used as a Resource

A passage from "Maxine's Journal" is described and incorporated into the assignment sheet, "Examining Multiple Strategies."

Example One—Structure of the Activity and Assignment Sheet

Mathematics Specialists read and discuss the assignment sheet questions first in small groups, and then as a whole group.

Examining Multiple Strategies

Consider this situation as described in "Maxine's Journal" for session two. The seminar participants are discussing the video clip in which several children explain their ways for calculating 40 - 26 or 35 - 16. At this point in the seminar, participants have read the print cases, which also show children sharing a variety of strategies for two-digit subtraction problems. In the journal, Maxine reflects on a comment by one participant, "I thought we would spend a few minutes talking about Becky's logic, but Sheila [a seminar participant] blurted out, 'I don't see why those teachers are teaching so many different ways to subtract. Why don't they just do one way, and then they can all do it?'"

There are three points of discussion about this passage.

One has to do with Sheila's interpretation of the print and video cases.

What are your reactions to Sheila's comments?
What does her comment suggest about her ideas of teaching and learning?
What is it you, as her facilitator, would like Sheila to understand about the strategies in the cases? How might you bring that into the conversation?

Another has to do with your role as a *DMI* facilitator or as a Mathematics Specialist.
What is the difference between your personal answer to questions such as those about the value of multiple strategies and how you might respond in a *DMI* seminar when this issue comes up?
In general, what is the interaction between your own beliefs and your responsibility for supporting the learning of the teachers with whom you work?

The third has to do with the role of multiple strategies.
What are your answers to the following questions:
Why should teachers encourage a variety of solution strategies?
What does sharing multiple strategies offer within a classroom setting?
Is it your expectation that all children will understand all of the strategies? If not, what is it you do expect to happen as a result of sharing? If so, what do you need to do, as a teacher, to accomplish that?

Example One—Addressing the Professional Development Needs of Mathematics Specialists

This activity addresses the professional development needs of the Mathematics Specialists on several levels simultaneously. The first two discussion points focus on the role of a *DMI* facilitator. As the Mathematics Specialists participate in the discussion about Sheila's ideas and how to work with them, they can refine their ideas about what it means to take on responsibility for the learning of teachers and how to create a community of learners. Just as learning to listen and analyze student ideas is a practice classroom teachers need to develop, so is learning to listen and analyze teachers' ideas a practice that Specialists need to develop. The second set of discussion points continues this focus on the role of a facilitator. In this discussion, the Mathematics Specialists can explore the relationship between their own ideas and the ideas of the *DMI* participants, thus considering what it means to provide a learning opportunity for the teachers with whom they work. This addresses a shift Specialists must take on, they must move from thinking of themselves as simply colleagues sharing their ideas to considering themselves responsible for the learning of teachers.

The third set of discussion points, about the value of multiple strategies, provides a context for the Mathematics Specialists to examine both their mathematics and their teaching practice. As they work to explain the math ideas that underlie the subtraction approaches, they can develop deeper understandings of that math topic. As they discuss how they can organize class discussions based on sharing multiple strategies to support the development of these mathematical ideas, they can articulate and refine their instructional methods.

Finally, since these points are explored through a process of small- and whole-group discussion with the Mathematics Specialists voicing their own ideas and then listening to the ideas of each other, the activity itself provides the means for the Mathematics Specialists to work together as a learning community.

Example Two—Primary Goals of the Activity

- To examine the mathematical ideas involved in division of fractions and to consider how those ideas are developed in various grade levels.
- To consider how to analyze and use the thinking of teachers as a basis for classroom coaching.

Example Two—*DMI* Excerpt Used as a Resource

Case #27 is taken from *Making Meaning for Operations*: "Who says that's not the right equation? My own experience vs. students' thinking." [7] In this case, the classroom teacher, Sarita, describes a class working on the following problem. "You are giving a birthday party. From Ben and Jerry's™ ice cream factory, you order 6 pints of ice cream. If you serve 3/4 of a pint of ice cream to each guest, how many guests can be served?" In this case, Sarita analyzes the students' number sentences and written explanations. She states she is confused because her students did not write division sentences to express their solutions, but rather wrote equations which used addition, subtraction, and multiplication. She groups the student responses into two categories: those that seem to match the situation and those for which she could not follow their logic. The following are examples of students' work which Sarita thought "had impressive reasoning to justify their thinking."

24 ÷ 3 = 8	There are 24 pieces, 3 pieces to a serving, 8 people can be served.
8 x 3/4 = 6	8 servings of 3/4 of a pint each gives you 6 whole pints
3/4 + 3/4 + 3/4 + 3/4 + 3/4 + 3/4 + 3/4 + 3/4 = 6	3/4 each gives you 6 whole pints

The following are examples of students' work about which Sarita said, "I could not follow their logic."

24 ÷ 3/4 = 6 or 8	There are 24 pieces altogether, and each serving is 3/4 of a pint, so there are 6 pints or 8 servings (depending on what you are looking for.)
3/4 ÷ 8 = 6	3/4 pint is the serving; there are 6 pints of ice cream, so 8 servings.

Example Two—Structure of the Activity and Assignment Sheet

The Mathematics Specialists read the full case and participate in small- and whole-group discussions, focusing on questions posed on the following assignment sheet.

> Sarita's Division of Fractions Dilemma
> What mathematical issues does this case bring up for you? Do you agree with Sarita's opinions of her students' work? Consider each student's response.
>
> What is the mathematics in this case that you would want to explore with *your students*? How would you go about bringing out those ideas? What questions would you ask? How might you structure the work?
>
> Suppose you were working with this teacher. How would you engage the teacher about this set of mathematical ideas and how to work with students? Why do you see that as a next step for this teacher?

Example Two—Addressing the Professional Development of Mathematics Specialists

In this activity, Mathematics Specialists are working on a particular skill essential to teaching mathematics; that is, how to analyze student work to determine what it is that the students understand and to determine what next steps would be good for each student. As they work through the mathematics problem for themselves and then analyze each of the student responses, the Specialists are also increasing their own ability to make sense of fractions, of operations with fractions, and what it means to represent a story situation with a diagram or arithmetic expression.

In addition, the Mathematics Specialists also examine the way mathematics ideas develop over time. In the small-group conversations, the Specialists consider the mathematics in the grade they teach to identify the connections between the mathematics at that grade level and the mathematical ideas they detailed in the case discussion. In whole-group discussion, the mathematical ideas about fractions are collected in grade-level order, allowing the group to generate a map of fraction ideas as they are addressed across the K-5 curriculum.

This activity also engages the Mathematics Specialists in considering their role working with teachers as classroom coaches. As they discuss possible goals and approaches for conversations with Sarita, they articulate and analyze their own ideas about coaching and then compare them with the thoughts of their colleagues. They are able to consider a variety of possible actions and to discuss the potential impact of various interventions. In this way, they are examining which actions will support the learning of the teachers with whom they work and so are able to develop strategies that are both supportive and challenging. Finally, this work is an example of a group of Mathematics Specialists serving as resources for each other, and so is an example of working as a community of learners.

Example Three—Primary Goals of the Activity

- To explore the mathematics of division.
- To examine a mathematical discussion among students.

- To examine the links between project structures and goals, and consider how project structures can be used to support work with students and teachers.

Example Three—*DMI* Excerpt Used as a Resource

This activity uses both print and video cases: the print cases of chapter four of *Making Meaning for Operations*, "When Dividing Gives an Answer Less than One"; and the video case from session six of *Building a System of Tens*.

Example Three—Structure of the Activity and Assignment Sheet

The activity has five components: an introduction in which the framing questions are posed, a mathematics activity in which the Specialists analyze each other's mental mathematical strategies for the problem $159 \div 13$, a video analysis of students' approaches to solving $159 \div 13$, a case discussion, and a concluding whole-group discussion based on the framing questions.

A Discussion about Discussion

> The work today will have two components. One part will be focused on a set of mathematical ideas and cases. This will allow us to expand our own mathematical thinking and to consider our own teaching. Another part of the work is designed to allow us to consider those ideas in light of the larger project work. The following framing questions will guide our final discussion. Keep these framing questions in mind as you work today.

Framing questions:

- What does it mean to explore, develop, and use students' mathematical thinking?
- How does today's work help you think about what you want for the students in your classroom?
- How does today's work help you think about what you want the teachers in your school to understand?
- What are ways this project can help you reach these goals?

Focus questions for the case discussion:

- Talk through the mathematical ideas about division that you see in these cases.
- How do the cases help you see what a mathematical discussion might look like?
- How does the teacher use the children's ideas?

- How do the children use each other's ideas?
- What questions does this raise for you?

Example Three—Addressing the Professional Development of Mathematics Specialists

This activity is designed to engage the Mathematics Specialists on many levels, both as teachers and as teachers of teachers. There is an opportunity to deepen their own mathematics as they examine the mathematical principles that underlie computation methods in division, both as adults might view them and as children develop them. The video focuses on strategies for division computation while the case focuses on what the operation of division entails. Discussion of both the video and the case provides the means for making connections between computation strategies and conceptual understanding of division.

The focus questions are designed to support the Specialists in analyzing the mathematical conversation in the cases and to examine the role that both teachers and students play in the development of the mathematical discussion. This leads to two potential learning opportunities for the Specialists. One is their continued learning on how to support and encourage such mathematical discussions in their own classrooms. The other is related to their ways of working with teachers in classroom coaching situations. The conversations analyzing the student thinking in the cases provide a model for the kinds of debriefing conversations they want to develop with the classroom teachers they are coaching.

Finally, the framing questions include the opportunity to examine how the Specialists' individual goals—both for their students and for the teachers with whom they work—can be seen in the context of the projectwide work. The framing questions begin with an examination of the Specialists' own ideas about how teaching and learning takes place, then move to a consideration of how to implement those ideas in their own classroom, and finally, support a projectwide perspective. This allows the Mathematics Specialists to consider how they can use project structures such as mathematics leadership teams or grade-level meetings to further their work. The activity also supports the development of a shared vision for the project as the Specialists' work together to describe classroom practice that is built on students' ideas.

Example Four—Primary Goals of the Activity

- To discuss issues that arise from working as a Mathematics Specialist.
- To provide opportunities for the Mathematics Specialists to provide suggestions, comments, and support to each other in the context of their work.

Example Four—*DMI* Excerpt Used as a Resource

The *DMI* structure of writing cases.

Example Four—Structure of the Activity and Assignment Sheet

A week before the session, Mathematics Specialists receive the assignment sheet describing the writing assignment. In the session, there are two sets of small-group discussions and two whole-group discussions. In the small groups, Specialists read and discuss each other's papers. The first whole-group discussion is based on the content of the papers: What did you see as common in the papers? What struck you as different? What are the issues that came up for individuals and for the whole group? What are ways of working on those issues? The second whole-group discussion is focused on the process of writing and discussing the papers: What was it like to write this paper? How did you feel about having others read and discuss what you had written? What would you do differently the next time we have this kind of assignment?

Writing a Case of Your Own

For the next meeting, we'd like you to write about your work with teachers. It might be about working with your co-teacher or with other teachers in your school or within the *DMI* seminar. This writing doesn't have to be long—3 to 5 pages is fine—and it doesn't have to be polished, but it should be detailed enough that readers can interact with the ideas about which you write. It should also be reflective enough so that readers understand your thinking and the questions you are raising. The specific subject of the writing is up to you, but it should be about interacting with teachers. This writing will be most useful to you if you write about something that puzzles you. Here are some examples:

- Perhaps there was a point in a class discussion or in a conversation with a small group of students or teachers when it wasn't clear what they understood and what would be a good next step.
- Perhaps there are examples of student work or teachers' writing that you find confusing when you try to determine what is it that they understand.

- Perhaps there were moments in a conversation with a co-teacher when you each had a different reaction to a given situation, student comment, or work.
- Perhaps you made a decision in a class or in a conversation with a teacher to say or do a particular thing, and now you wonder what else you could have done or said in that situation.
- Perhaps there was something in the mathematics of a lesson that you are curious about. You might consider the mathematics either for yourself or in terms of how the students or teachers approached it.

Of course, you can't describe everything that happened. You will need to make a choice about what particular aspects of the class, student dialogue, student work, or teacher interaction you will share. Think about what information your reader will need in order to talk with you about the situation you have described.

Please bring eight copies of your writing. We will meet in groups of four to read and discuss what each participant wrote. We'll do this twice so you'll have a chance to participate in two different groups.

Example Four—Addressing the Professional Development of Mathematics Specialists

This activity was designed to encourage the Mathematics Specialists to present their questions, issues, confusions, and dilemmas with one another, and to gather suggestions and comments from each other as colleagues. Sharing difficulties, seeking advice, and brainstorming possible solutions becomes a part of working in a learning community. This kind of activity also serves the goal of helping the cohort of Mathematics Specialists develop a sense of being part of the project as a whole. The issues in the papers might range from mathematics questions, to questions about interacting with teachers and principals, to questions about teaching or students. The discussion of the process of writing and discussing the papers provides the opportunity for continued reflection and learning and sets the stage for writing reflection papers as a source for professional development work in the future.

Summary

These examples illustrate the way we used the *DMI* materials to design four kinds of professional development activities for Mathematics Specialists. One method was to use passages from “Maxine’s Journal” as a source for discussion. The discussions include both mathematical ideas and also issues that arise in facilitating *DMI* seminars. A second approach was to revisit cases, first to examine the mathematics more deeply and then to consider possible approaches to working with the teacher in the case. These activities provided support for the Specialists in developing strategies for classroom coaching and holding classroom-debriefing conversations based on examining student thinking. A third method was to use *DMI* material as a means to highlight a project goal. This provided support for the Specialists in developing a shared vision of mathematics instruction and in determining how project structures can be called upon to serve that vision. Fourth, the case writing structure of *DMI* was used as a basis for reflective writing and discussions of issues that the Mathematics Specialists brought to be examined by the group.

Each activity provides the opportunity for the Mathematics Specialists to continue to explore mathematical ideas and to consider how those ideas develop over time. Each provides the opportunity for the Mathematics Specialists to continue to develop his/her own teaching practice; that is, how to organize classroom instruction so that it supports and develops students’ ideas and links those ideas to the system curriculum. Each provides the opportunity to consider how to work with teachers to help them develop a similar interest and desire to learn how to understand and use their students’ mathematical thinking as a basis for their mathematics instruction. Each provides the opportunity to connect their own ideas about teaching and learning to the larger project goals and structures, and to come to see each other as support for that work.

In this paper, we have laid out the principles we consider as we design professional development work for Mathematics Specialists. We also detailed some specific activities and what it is that Mathematics Specialists might learn by participating in them. However, it is important to note that the activities, like any curriculum, do not contain the ideas; they provide a structure in which ideas may be examined. It is the work of a teacher to engage his/her students with the ideas embedded in the curriculum; and so, it is the work of those of us that use these activities to keep the goals for the activity in mind. As we facilitate, we must listen to the thinking of our students who are the Mathematics Specialists and use their ideas to reach the goals we have set for their learning. The activities provide an opportunity, but the learning comes from the interaction between the Mathematics Specialists' ideas and the facilitator's goals.

Concluding Comments

It has been an interesting journey to move from designing professional development for teachers to designing professional development for those whom we might think of as teachers of teachers. One common thread is that of a learning community. This concept has meaning at every level of the work: in an individual classroom, within a *DMI* seminar, among the staff in a school or district and among a cohort of Mathematics Specialists. It also applies to those of us who design and offer professional development at this level. In the spirit of a learning community, we offer the ideas of this paper to educators who are engaged in similar work and look forward to engaging with you.

References

[1] D. L. Ball, and D.K. Cohen, "Developing Practice, Developing Practitioners," in L. Darling-Hammond and G. Sykes (eds.), *Teaching as the Learning Profession: Handbook of Policy and Practice*, Jossey-Bass, San Francisco, CA, 1999.

[2] S. Loucks-Horsley, P. Hewson, N. Love, and N. Stiles, *Designing Professional Development for Teachers of Science and Mathematics*, Corwin Press, Thousand Oaks, CA, 1998.

[3] D. McIntyre and D. Byrd (eds.), *Strategies for Career-Long Teacher Education*, Association of Teacher Educators, Corwin Press, Thousand Oaks, CA, 1998.

[4] M. Solomon (ed.), *The Diagnostic Teacher: Constructing New Approaches to Professional Development*, Teachers College Press, New York, NY, 1999.

[5] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[6] D. Schifter, V. Bastable, and S. Russell (eds.), *Developing Mathematical Ideas: Number and Operations Part One: Building a System of Tens, Casebook and Facilitator's Guide*, Dale Seymour Publications, Parsippany, NJ, 1999.

[7] D. Schifter, V. Bastable, S. Russell (eds.), *Developing Mathematical Ideas: Number and Operations Part Two: Making Meaning for Operations, Casebook and Facilitator's Guide*, Dale Seymour

Publications, Parsippany, NJ, 1999.

[8] D. Schifter and J.B. Lester, "Active Facilitation: What Do Specialists Need to Know and How Might They Learn It?" *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 97 - 118.

ACTIVE FACILITATION: WHAT DO SPECIALISTS NEED TO KNOW AND HOW MIGHT THEY LEARN IT?

D. SCHIFTER
Education Development Center
Newton, MA 02458

J.B. LESTER
Mount Holyoke College
South Hadley, MA 01075

Abstract

Sustained, innovative professional development is now widely acknowledged as essential to the improvement of mathematics instruction in the nation's schools. In recent years, this recognition has prompted the production of a variety of materials designed to support new teacher development programs. However, with the availability of such materials, serious concerns arise as to the kinds of knowledge required of professional development providers, often teachers who have been assigned Mathematics Specialist roles, and the means by which this knowledge is to be acquired. The authors of this paper address such questions in the context of one professional development seminar, *Developing Mathematical Ideas* [1]. Our paper builds on the research of Remillard and Geist who identify the potential for learning in those moments of discontinuity—"openings in the curriculum"—in which the beliefs, knowledge, and commitments of seminar participants diverge from those of facilitators or materials developers [2]. By looking closely at several such moments, we establish how successful facilitation entails deep content knowledge, awareness of seminar goals, and appreciation of the beliefs and understandings of seminar participants. We then describe the kinds of supports available to *DMI* facilitators to help them cultivate the skills and knowledge needed to exploit these openings productively. While the paper focuses particularly on professional development seminars, we suggest that our conclusions apply to Mathematics Specialists' tasks more generally.

Introduction

One considerable obstacle to improved mathematics instruction in the United States is that many teachers simply do not have the necessary understanding of mathematics, of the process of learning mathematics, or of children's mathematical thinking [3,4]. Themselves the products of traditional mathematics education, these teachers doubt their own abilities to think mathematically and view mathematics as no more than a given sequence of facts, definitions, and rule-governed procedures [5,6]. Without having had opportunities to construct new visions of mathematics, mathematics learning, and the mathematics classroom, many teachers may adopt mathematically ambitious curricula, but use them in ways that subvert the intentions of their developers. Furthermore, some may never even *try* to use such materials in their classrooms because they cannot picture how their students might work with them.

If America's students are to leave school as developed mathematical thinkers, continuing teacher education is critical. However, the staff development crucial to improved mathematics instruction may be blocked for lack of necessary resources. Mathematics educators at all levels are thus challenged to build the capacity for supporting teacher change in resource efficient ways.

One option for support of large-scale staff development is the design of tools—professional development materials—that provide structure and content for in-service programs, and that can be used by a wide range of teacher educators, including teachers who become Mathematics Specialists. Further, these tools must underwrite systemwide, long-term, and ongoing staff development.

However, if school systems are to assign Specialist roles to teachers who, in turn, provide professional development to their colleagues, the next question involves the kinds of knowledge required of those Specialists. What must such Specialists know and understand in order to provide effective professional development and how might they acquire it? These are the questions addressed in this paper.

We explore these issues in the context of a professional development curriculum called *Developing Mathematical Ideas* (*DMI*) [1]. These materials were designed in response to the widely recognized need of elementary and middle school teachers to understand more deeply the subject-matter content they teach. However, rather than offer that content "cleansed" of reference to classroom context, these materials present the mathematics as embedded within those tasks of teaching which require teachers daily to call upon their own mathematical understandings [7,8]. Thus, seminars are designed around a set of print and video cases that particularly focus on children's articulation of their mathematical thinking and ways of solving problems. Along with these cases, the materials offer mathematical explorations, analyses of mathematical activities from K-5 curricula, assignments for teachers to conduct with their own students and classes, and readings about related research.

The *DMI* materials were produced in the context of the teacher enhancement project, Teaching to the Big Ideas, co-directed by Deborah Schifter, Virginia Bastable, and Susan Jo Russell. The five modules published thus far are: *Building a System of Tens*; *Making Meaning for Operations*; *Examining Features of Shape*; *Measuring Space in One, Two, and Three Dimensions*; and, *Working with Data*. We intend to produce two modules on early algebraic thinking: 1) functions and the mathematics of number systems; and, 2) generalization and justification about number systems. Each module, containing a casebook, a facilitator's guide, and a video cassette, is designed for eight three-hour sessions.

The Questions

To frame our approach to issues of facilitation in professional development settings, let us start with this scene: Having read a set of cases involving kindergarten and first grade children who solve various problems by counting, a group of teachers now comes together to discuss what they see in these cases. Their facilitator describes what happens next.

> I began, "What did you find interesting in [the case,] 'Insects and Spiders'?"
>
> Tomi offered the first response: "I have kindergarteners and this is first grade. I was looking at how, if they were given 5 spiders and they had 9 more to count, they were able to start counting on from 6. My children aren't at that level yet. I've tried to get them to do it on their own, but they don't. I even try to do it with them, but they still don't do it."
>
> As Tomi was talking, I had the sense this wasn't a complaint; she didn't seem to be reporting a problem. Rather, this was something she had noticed about the way people learn.
>
> Carla commented, in support of Tomi, "I think the issue is developmental. I have third graders who still start from 1."
>
> Even though, on the face of it, Carla's comment is valid and a worthwhile contribution to the discussion, I get a little nervous when I start hearing teachers say, "That's developmental." Too often, I've seen people use that label to get themselves off the hook. If "it" is developmental, there isn't anything the teacher can do. The child just has to grow into "it." The word *developmental* can mark the end of discussion and the end of thought. But at the same time, I think there *is* something developmental about the issue Tomi and Carla were talking about.
>
> I chose to steer the conversation toward the mathematics of counting on.

> "Whether this is developmental or not, what is 'it'? Can you put into words what the math is we're talking about? What ideas are in here, what mathematics has Tomi been working on with her kindergarteners?" [9]

In this short scene, the facilitator begins with a general question—"What did you find interesting?"—but from there, she works to shape the discussion. Choosing to steer it away from talk about whether a particular skill is "developmental," she asks instead that the group think about the mathematical ideas children must put together in order to move from "counting all" to "counting on."

In this paper, we will examine this and other episodes drawn from our professional development work to consider these questions: Does facilitation necessarily entail an active role? If so (and our answer is yes), what are the facilitators' interventions aimed to do? What must a facilitator know or understand in order to select appropriate interventions? What, in our project, do we offer facilitators to help them develop such knowledge and understanding?

Facilitation Is an Active Role

A first question to consider is whether a group of adults coming together to study the mathematics in tasks of teaching requires active facilitation at all. Might they not simply gather as a study group, each member offering ideas to stimulate the thinking of others? Of course, there may be the rare group of teachers prepared to learn together in this way. However, where the nature of the activity being aimed for sharply departs from current practice, most groups will not find their way without determined and knowledgeable leadership. For example, in scenes like the one illustrated above, if teachers were to be satisfied with the comment "that's developmental," and in the absence of skilled facilitation, would they be likely to press on to examine the mathematical ideas raised in Tomi's observation? Or more generally, will a group of teachers seriously interrogate children's mathematical ideas if they are used to thinking of mathematics in terms of computational routines?

Evidence for our initial proposition, that teacher professional development requires active facilitation, is provided by a research study conducted in 1996-97, the first year of *DMI* field tests. In "A Case of Classroom Teachers Becoming Teacher Educators," an unpublished manuscript (1997), Susan Jo Russell traced the issues faced by a group of teachers who were stepping into their first teacher leadership roles, facilitating *DMI* seminars for their colleagues.

Granted, Russell's subjects were not typical teachers. They had spent three years studying mathematics and student thinking in a program led by the *DMI* developers. Indeed, these same teachers had written the cases that form the basis of *DMI.* Yet, although their knowledge of the content of *DMI* was considerable, they were very apprehensive about becoming their colleagues' teachers. In order to cope with this anxiety, many of these neophytes started out by telling themselves that their role was "merely" to facilitate. As they explained it, their task was to bring teachers together, set up the activities, and then let discussion go where it would.

The thrust of Russell's findings was that once the seminars got underway, this stance of "mere" facilitation could not long be sustained. Having studied mathematics and student thinking for three years, these Teacher Leaders had a vision of the potential for learning the *DMI* materials offered, but their colleagues were not taking up the important questions on their own. These fledgling facilitators realized that seminar discussions would not move in what they knew to be fruitful directions without active intervention. After the first session, which included playing a mathematics game, one facilitator wrote,

> Most ... teachers thought that this was a fun game. . . . I was disappointed with that. I wanted them to think more about their strategies and relate their strategies to the work of the students in the cases. I still look back and wonder how (or if) I could have pushed the teachers' thinking along.

Later in the seminar, a team of facilitators who had been afraid to take strong leadership in discussions realized that participants had also become frustrated. The team had opted for a passive role in order not to anger their colleagues, but now that those colleagues were angry anyway, they decided they might as well take a different tack.

> I made a resolution that if they were going to be mad at me I wanted them to be mad for a good reason. By this I mean that all fall we never really got the questions about 'Where's the math?' . . . [Now my partner and I were] absolutely resolved to continually bring the discussion back to that question, "So what are the mathematical ideas here that this child is pushing on or bumping into?"

At that point, the entire tenor of the seminar began to shift. A few weeks later, one of these facilitators wrote:

> I could see layers and layers of complexity and that is what I was trying to add to the discussion....complexify it up! and that . . . felt right and legitimate and interconnected and important.

While Russell's study illustrates the need for active facilitation, a second study, conducted that same year, characterizes the situations that require determined intervention. Janine Remillard and Pamela Geist observed three *DMI* seminars facilitated by a Teacher Leader, a university faculty member, and a staff developer who worked for a school district, respectively [2]. In these three settings, the researchers were particularly drawn to examine the instances, prompted by participants' questions, observations, challenges, or resistant stands, that required facilitators to make judgments about how to guide the discourse. These moments, they argued, arose from conflicts among the goals and commitments of the facilitators, the expectations of the participants, and the agenda of the curriculum. Initially struck by the awkwardness occasioned by such moments, the researchers ultimately came to refer to them as "openings in the curriculum"; "openings" because they held significant potential for inquiry and learning.

Often initiated by the concerns and observations of participants, including the facilitator, these openings invite opportunities for facilitators to structure conversations and explorations that can extend or challenge participants' knowledge and beliefs.

The "counting all/counting on" case illustrates just such an opening: the facilitator sees that discussion of Carla's observation that her students' difficulties are developmentally determined could interfere with a goal for the session—examining the mathematics of children's counting strategies. Aware that many teachers use the phrase, "that's developmental" to put an end to deeper inquiry, the facilitator navigates around that language—"Whether this is developmental or not, what is 'it'?"—to bring the group's attention to the mathematics. Similarly, the teachers in Russell's study learned to ask their participants, "So what are the mathematical ideas here that this child is pushing on or bumping into?"—a question these participants were not conscious needed investigation.

Remillard and Geist identify a set of skills required of facilitators in order to take advantage of the potential for learning offered by such openings in the curriculum: to recognize openings as they occur, to interpret the tensions that underlie them, to consider responses and possible consequences, and to take action. They further comment:

> Well-navigated openings allow facilitators to take deliberate action to foster the kind of learning intended by DMI developers even when doing so involves "veering" from the plans suggested in the curriculum. In a sense, openings may be signals that the curriculum is working [2].

What Knowledge is Required to Navigate "Openings"?

Russell's research has provided support for the principle that facilitation is necessarily active. Remillard and Geist have characterized those moments that require a facilitator to respond with determined action as "openings"—moments that "invite facilitators to structure conversations and explorations that can extend or challenge participants' knowledge and beliefs" [2] . This then invites the question, What is it that a facilitator must know and understand in order to identify an opening, unpack the tensions that underlie it, and choose a response?

Our own analyses point to three areas in which facilitator understanding is called upon in order to navigate openings: seminar content, learning goals for teachers, and participants' perspectives. In this section of the paper, we present examples to illustrate how facilitators mobilize their understandings in each of these areas. Of course, in any seminar event, a facilitator is likely to be calling upon all three strengths. However, we have chosen occasions that particularly highlight each in turn.

Facilitators Must Understand Seminar Content — Just as classroom teachers must understand the mathematics they are responsible for teaching, so too, must teachers of teachers. As in the classroom, so too in the professional development setting, the form that such mathematical knowledge must take in order to be useful differs from the manner in which it is conveyed in the typical mathematics class. Certainly, to understand an idea as presented in a conventional textbook may be helpful. However, in addition and more to the point, a facilitator must be able to recognize that mathematical idea as it is situated in a classroom case, or how it plays out in a variety of mathematical activities. As shown in the example below, a facilitator must also recognize when an important idea is being broached by a participant—and be able to respond with questions or suggestions that help move the seminar into that idea.

One issue explored in the seminar *Measuring Space in One, Two, and Three Dimensions* (*MS123*) is the effect of scaling the sides or edges of two- and three-dimensional objects: double the sides of a rectangle, say, and the perimeter also doubles, but the area quadruples; double the edges of a rectangular solid, and the surface area quadruples, but the volume multiplies by eight [10]. These ideas are new to most of the teachers who participate in *MS123*. Indeed, we suspect that few teachers anywhere in the United States have had much experience envisioning spatial relationships. Thus, a seminar facilitator is frequently called upon to help sort out such matters.

In one homework assignment, teachers solve the following problem: *How much sand is needed to fill a sandbox 2 yards long and 4 feet wide to a depth of 6 inches?* Although the problem is first about how cubic units are structured from linear units, exploration of the relationships among cubic inches, cubic feet, and cubic yards brings participants back into ideas of scaling. In one seminar, participants initially offered the following answers, which the facilitator duly listed on the board:

4/9 cu. yd.

144 cu. ft.

12 cu. ft.

1728 cu. in.

The teachers in the seminar were challenged to reconcile these different answers: Are they all equivalent and, if not, which ones are correct? [The correct answers are 4/9 cu. yd., 12 cu. ft., and 20,736 cu. in.] The facilitator later wrote an account of what transpired in response to those questions:

> Corinne explained how she got 12 cu. ft. "I changed all the dimensions to feet: 6 feet times 4 feet times 1/2 foot; that comes out to 12 cubic feet."...
>
> "Oh, right!" Laura exclaimed. "I forgot to change the 6 inches to feet. I multiplied 6x4x6, but that's wrong, 144 cu. ft. is wrong. But if 12 cubic feet is the right answer, then it's 144 cubic inches."
>
> When asked how she came to that conclusion, Laura thought it was obvious. There are 12 inches in a foot, so you multiply the 12 cubic feet times 12. But

Andrew disagreed. "You have to go to inches in all dimensions. It's 48 inches times 72 inches times 6 inches."

I wrote out "(4x12)x(6x12)x6" so people could see where Andrew's numbers were coming from. Now everyone set to work, some with calculators, others with pencil and paper. In the middle of all this calculation, Jean blurted out, "Oh, I did 12x12x12 and got 1728. That's the number of cubic inches in one foot, so that can't be the answer. Multiply that by 12 and you get 20,736."

On our list I had crossed off 144 cu. ft. and 1728 cu. in. and now added 20,736 cu. in. "How can we think about whether this is the right answer?" I asked.

Andrew was busily figuring numbers on his paper and declared, "It can't be right. Look, 4/9 cu. yd. is close to 1/2 cu. yd. So you take 18x18x18 and that doesn't get you close to 20,736."

It took me a few seconds to see what Andrew was doing, but I quickly realized he was making a fruitful error, one that would give us an opportunity to work on the ideas behind the exercise. I asked him to slow down and explain again what he was thinking.

"Well, I said the volume is 4/9 cu. yd., and I'm sure that's right. If you change all the dimensions to yards, you get 2 yards x 4/3 yards x 1/6 yard, and that gives you 4/9 cu. yd." I stopped him there for a moment to allow everyone to do that calculation; then I asked him to continue. "But 4/9 is close to 1/2, so I was thinking I needed to find what 1/2 cubic yard is. Well, 18 inches is half a yard, so it would be 18x18x18, and if you round 18 up to 20 you get 8000. So 18x18x18 doesn't get you anywhere near 20,736."

The issue here was exactly what we had worked on last session—what happens when you double the edges of a solid—except that Andrew was talking about halving the edges. But since the images are not so accessible—spatial visualization in three dimensions is so new for them—it wasn't clear to everyone (anyone?) that Andrew had made an error. To help the group picture what was going on, I drew a picture of a cube on the board [10].

The discussion continued with more wrinkles to it, and the facilitator remained active in slowing the pace, emphasizing particular questions, and introducing spatial representations, first as diagrams drawn on the board and then with cubes. The main idea here was for them to see that when each of the three dimensions of a cube is 1/2 yard (18 inches), you end up with 1/8 cubic yard, not 1/2. Halving just one dimension, 18x36x36 inches, will give you 1/2 cubic yard (close to 4/9).

It is important to note that the mathematical strengths called upon by the facilitator are not limited merely to knowing the effect of scaling the edges of a three-dimensional object. They also include understanding seminar participants' ideas, recognizing how scaling is at issue, posing questions that bring the results of scaling into focus, and offering representations that help participants visualize the relationships for themselves.

Once the teachers could picture the relationship between 18 inches cubed and one cubic yard and then showed that 20,736 cu. in. was a correct answer to the original problem, they could work with images of one cubic foot in relation to one cubic yard in order to see how 4/9 cubic yard is the same quantity as 12 cubic feet.

The example given here highlights how a facilitator calls upon a deep understanding of subject-matter content. However, it should be clear from the examples included in this paper that issues of learning and pedagogy are equally central to the seminars' ambitions. Certainly, facilitators must know this content, as well.

Facilitators Learn to Think in Terms of Seminar Goals, Not Just Planned Activities — In planning and in interactions with participants, facilitators must learn to think in terms of the goals of the seminar, and not merely in terms of getting through planned activities. It may *seem* obvious that, in order to identify openings in which participants' expectations conflict with the agenda of the curriculum, the facilitator must understand that agenda. However, the importance of entering each session with a set of learning goals is honored more often in the breach than in the observance. At the level of day-to-day classroom routine, many teachers view their charge as taking students through a series of prescribed activities, unaware that these activities are intended to serve the development of underlying mathematical concepts. Similarly, some teachers of teachers tend to treat the session agenda as a timetable of activities, rather than a conceptual road map.

However, without intervention from the facilitator, the purpose of an activity is likely to be missed often even after clear instructions have been articulated. In the scene presented below, a facilitator acts on her knowledge of the specific learning agenda for the session, as well as for the course as a whole, in order to bring to participants' attention issues otherwise outside their field of vision.

In the seminar *Building a System of Tens* (*BST*), teachers explore the many-faceted idea of place value: how our number system represents quantity and how this idea is employed when calculating with whole and decimal numbers [11]. Conceptual issues that are challenging to children of different ages are identified, and ways teachers and particular curricular activities can support children facing such challenges are explored.

In the second session of *BST*, teachers read a set of cases depicting children working hard to put together the ideas they need in order to use numbers flexibly. The introduction to the cases points out that many of the children are confused, and "that's what makes these good cases to study. That is, when children are doing everything correctly, the hard thinking they have done is often invisible. On the other hand, if we examine their thinking when they are confused, the ideas they are working on are often easier to identify" [11]. As teachers read the cases, they are asked to consider: "In what ways does the children's thinking make sense? What are the ideas they are putting together?"

In order to follow what happens in the second session, the details of one of the cases up for discussion are relevant: Sarah, a third grader who already knows the "carry" algorithm for addition, as well as several other procedures, chooses to represent 45 + 39 with yellow cubes for tens and black cubes for ones. Thus, after adding, she has 7 yellow cubes and 14 black cubes. "There are way too many to keep on the ones side, so I try to carry them," she says as she moves 10 black cubes to join the 7 yellow cubes. But now having lost track of the fact that 10 black cubes are to be counted as 1 ten (thus, the 7 yellows and 1 group of 10 blacks yield 8 tens), Sarah reckons she has 17 tens and 4 ones: 174. Yet she knows from the other procedures that the correct answer is 84. In the case, the teacher poses questions to Sarah that eventually enable her to find her mistake. Thus, toward the end of the exchange, she points to the 10 black cubes and explains, "It equals 10 ones. It's 10. Not 100.... It is *a* ten." In this way, she reconciles her cube representation with the other procedures she knows, all now yielding the answer, *84 [11]*.

With the story of this case in mind, let us turn to a teachers' seminar. One facilitator reported on how her group of teachers seemed unable to examine Sarah's thinking.

> I was ... struck by the group's need to find a simple fix; several people talked about what they would have done with Sarah to prevent her from making mistakes. Mainly, they said that Sarah needed to have a larger block for the quantity 10; she shouldn't have represented tens with a different color block the same size as a one. Despite my questions to the small groups, few teachers noticed that, in the course of the episode, Sarah had corrected herself. They skipped over this evidence and did not ask if she was developing a deeper understanding of multidigit addition.
>
> So at this point [now in whole group], I stopped the discussion and had someone in the group act out how Sarah had come up with 174 when combining 45 and 39. Once everyone agreed with the demonstration, we turned back to the text to read together what happened next; I actually asked someone to read it aloud. Then my next question was, "How did Sarah change her model to come up with 84, the answer she already knew was correct? What did she understand to begin with, and what did she figure out in her interaction with [her teacher]?"
>
> Marta was looking back at the first page of the case and shared what the teacher had written about Sarah: "She understood all the various methods that had been presented." [Now, following Marta's lead, the teachers began to discuss the evidence in the case, taking a closer look at what Sarah does and says to consider what she might have been thinking and what she might have figured out.] [12]

In this example, participants who initially dismiss the case with the comment that the teacher shouldn't have allowed Sarah to represent the numbers as she did are operating from the premise that confusion is best prevented. However, one of the facilitator's goals is to convey the insight that avoidance of confusion is not necessarily a useful goal. She wonders, "Can they come to see that confusion is a necessary part of the learning process? That a person who has come up against a point of confusion now has an opportunity to learn?" [12].

In order to move the group toward these insights, the facilitator takes a strong lead in whole-group discussion. First, she asks the teachers to repeat Sarah's demonstration with the cubes. Then, she asks the teachers to read a section of the case aloud. In this way, she draws their attention to the elements of Sarah's representation that do make sense, to the knowledge that

Sarah already brings to the task, and to the specific idea that Sarah needs to put into place to make her representation work. By bringing teachers back to the particulars of the case, the facilitator *opens* up opportunities for them to address the larger issues of the mathematics of the problem, the learning that took place, and the interactions that supported that learning.

<u>Facilitators Must Work to Understand Participants' Perspectives While Provoking Deeper Reflection</u> — Facilitators must work to understand participants' perspectives—their deeply held ideas and commitments. Interactions with seminar participants must be based at once on genuine appreciation of those ideas and commitments, but also on the determination to provoke deeper reflection and new insights. Remillard and Geist remark that skillful navigation of openings requires an understanding of the tensions that underlie them [2]. In order to know where the discontinuities lie between participants' goals and those of the curriculum, facilitators must constantly work to identify the ideas and commitments held by participants which, if they are learning, are in flux. In the previous examples, the facilitator was acting not only on the learning goals she held for teachers, but also what she understood about the ideas and dispositions held by those whom she was addressing.

This work of identifying participants' commitments and dispositions is explicitly illustrated in the following excerpt from a facilitator's journal, written after the fourth meeting of *BST.* In preparation, teachers had been assigned to conduct a mathematics interview of one of their students. As the session began, teachers sat in small groups to share what they had discovered.

> I went around, listening in on groups to get a sense of where people were, and I learned that they were all over the place. Despite the discussion we had at our last meeting, some teachers couldn't separate this interview task from teaching, and their vision of teaching *didn't* involve eliciting students' ideas. There were teachers who couldn't separate being successful teachers from having their students get the problem right. Tomi felt the need to report to me that she stayed with her student until she straightened him out. And Sheila seemed to be at the same place as last time—she would never ask a question of a student unless she were quite sure the student could answer it correctly; it's unfair to ask something you haven't already taught, and so forth. Her interpretation of the interview assignment was, first explain the task to the child, and then ask questions to make sure he does it right.

> So, what does it mean that it's the fourth session and some people still don't have an inkling of what it means to examine student thinking? Am I doing something wrong? Is there something I can do so that they'll get it? As I write this, I realize that there's a parallel here between how I'm feeling and the position I put them in when I assigned these interviews. Here I am, panicked (and that's only a slight exaggeration) that there are teachers in the group who just aren't getting it—they had this big assignment, and they didn't do it right. And that makes me think that maybe I'm a lousy teacher, maybe this seminar is a flop. At the same time, I am telling them to interview students and discover the ways they think about the mathematics. So they interview students and discover that they just don't get all those things they had been taught. And how does that make the teachers feel? Lousy. This isn't just an intellectual exercise. A teacher is compelled to act on what she learns about her students, and so it makes sense that some of these teachers avoid learning things they don't know how to act on.
>
> Hence, that issue comes back to me. What can *I* do? What can I do to make it safe enough for these teachers to begin to discover something about student thinking? And to make them begin to see that teaching involves listening to their students' mathematical ideas?
>
> To answer my questions, I can apply exactly what I want the teachers to learn. What I can do is listen hard to what the teachers are saying—listen to their mathematical ideas as well as their ideas about teaching and learning. But where, in all that, can I find elements of strength in their ideas that can be highlighted and leveraged to help them reconsider some of their own notions? [12]

In this session, the facilitator is disturbed by the response of a handful of teachers to the assignment to conduct a mathematics interview of a student. She is trying to figure out what to do when teachers' ideas diverge sharply from her expectations. In order to decide what to do, she must first work to consider why they are behaving as they are. Assuming that the teachers behave rationally and responsibly—they care about being good teachers—what might they believe that causes them to behave this way?

As this facilitator reflects on the teachers' behavior, she actually finds a point of contact and can empathize. Understanding something of their beliefs and commitments, she is now better able to choose a course of action that can both connect with where they are and challenge them to move on.

Supports for Facilitator Learning

Thus far, we have argued that facilitation of teachers' professional development is/should be regarded as an active role. Following Remillard and Geist, if what we are calling "openings in the curriculum"—instances of discontinuity between participants' ideas or beliefs and the goals of the curriculum—are to provide fruitful opportunities for learning, then the facilitator must take determined action to exploit them [2]. In order to choose effectively among possible responses, facilitators must understand seminar content, be guided in their work by reference to their learning goals for teachers, and respond sensitively to the beliefs, ideas, and dispositions of the participants. This is a tall order. How is a facilitator, particularly a novice, to acquire such knowledge?

The *DMI* materials were written with an eye toward facilitator as learner. The casebooks themselves provide multiple supports for the facilitator, each chapter beginning with an introduction that describes the major idea on which the set of cases is threaded. The concluding essay, "Highlights of Related Research," offers another articulation of some of the major ideas to be mined in case discussion. Of course, each session will offer the facilitator new insights into content and goals, as well as new appreciation of participants' perspectives, insights, and appreciations that will be carried forward and amplified in succeeding seminars.

In addition, the *DMI* developers have created structures expressly to support facilitator learning. In this section, we describe three of them: facilitator's guides, the *DMI* Leadership Institutes, and facilitators' inquiry groups.

<u>Facilitator's Guides</u> — As the *DMI* developers prepared facilitator's guides, we looked back on our own rich experiences facilitating the seminars and tried to find ways of sharing some of what we learned. We also looked forward: What could we offer the groups of teachers with whom we were just then working closely and who were about to lead their own *DMI* seminars for the first time?

Included in the guides are such familiar features as: lists of materials to prepare, an agenda for each session that describes the activities, pages of mathematics activities, and focus questions to copy and distribute. The guide opens with a set of "tips," suggestions for how to become familiar with the module, how to prepare for a session, how to facilitate small- and large-group discussions. Mainly, these are "how to" directions.

The major component designed to address those areas of knowledge extensively described above is a document called "Maxine's Journal," ostensibly the reflections of a facilitator written after each session of the seminar. "Maxine's Journal" was created to convey a sense of what a *DMI* seminar might look like—the types of discussions that can take place, the types of lessons seminar participants can draw from the sessions—and how it might feel to facilitate one. Maxine is a composite character and so, too, are the teachers in her seminar. Though Maxine is a fictional character, her journal entries describe events and individuals observed and recorded by the developers of the materials and by those who field tested the first *DMI* seminars. The seminar scenes depicted in the previous sections of this paper are all excerpted from "Maxine's Journal."

A primary purpose of "Maxine's Journal" is to portray a seminar in which participants' ideas take center stage, but where the facilitator actively steers discussion, persistently drawing teachers' attention to a set of ideas or issues. The seminar is neither a lecture nor merely a free-form discussion. Entries, as in the excerpts above, depict a facilitator who pays careful attention to what participants say and do, and who tries to choose responses that convey an appreciation of their ideas, but who is committed to pushing them to think harder.

Through the specificity of Maxine's references, the reader can gain insights of a more general nature. By reporting on the events that take place in each session, she conveys how, guided by the facilitator, seminar curriculum translates into participant discussion. By elaborating on the mathematical confusions and insights that arise, she provides an opportunity for facilitators to work through that same content.

Maxine is constantly trying to understand the perspectives her participants bring to the seminar. As she learns more about her group and the teachers who comprise it, some of her goals become individualized. For example, after the second session, Maxine writes:

> What do I want the teachers to learn? I guess one thing I want them to appreciate is that avoiding confusion is not a useful goal. Can they come to see that confusion is a necessary part of the learning process? That a person who has come up against a point of confusion now has an opportunity to learn? But that is not my immediate goal for Amira, Tony, and Shannon. Instead, for Amira it is simply that she become comfortable enough in this class to be able to think! And for Tony and Shannon, my goal is that they begin to expand their ways of thinking about mathematics.

Participants come with many different perspectives and beliefs, contributing to the richness of seminar discussions. As individuals exchange their ways of interpreting an event described in a case, their methods for solving a mathematics problem, or their connection to a finding presented in the research literature, then opportunities to explore mathematics, learning, and teaching become more complex.

Accompanying "Maxine's Journal" in the number and operations modules is a document called "Two Portraits of Change," tracing the learning of a pair of individual teachers [9] . Drawing on reflections these teachers recorded in regular writing assignments (prepared for each session), their facilitator tells how these two, who began the seminar with very different perspectives and despite having completed it with very different ideas, were each changed in significant ways through participation in the same set of activities.

However, the fact that participants come with different perspectives, beliefs, and personalities can make for complicated group dynamics. Hence, Maxine writes about her efforts to temper dominant personalities who present their ideas with authority, to draw out others who are thinking hard but are too timid to volunteer their views, and to manage those whose exasperation threatens to disrupt a lesson.

Maxine is by no means the "perfect" facilitator—occasionally frustrated or angry, at times confused, unsure about how to interpret what has happened. This, too, is part of the facilitator's experience, and we want new facilitators to understand that. Nonetheless, in spite of self-doubt and confusion, Maxine carries on with a sense of commitment to seminar participants and to the ideas on which they work.

Users of the *DMI* materials report that, prior to each session, they read the relevant section, saying that it gives them an image of what is possible. Even though inevitably their own seminars will take a different turn, "Maxine's Journal" provides a referent that helps them guide their group, as Lee and Buonopane wrote in their unpublished 1998 manuscript. Over time, facilitators' own store of experiences joins those of Maxine.

Leadership Institutes — Two-week institutes were created to help facilitators deepen their understanding of the mathematics, become aware of participants' perspectives, and expand and refine their repertoire of facilitation strategies. These institutes include opportunities for participants (future facilitators) to go through the *DMI* modules by experiencing mathematics explorations, engaging in case discussions, analyzing tasks from elementary and middle school curriculum, and gaining familiarity with relevant educational research. For some participants, this is an opportunity to encounter new ideas about mathematics, learning, and teaching. Those who are more familiar with seminar content take on the role of participant observer—as they move through the material with the group, they are positioned to take note of facilitators' moves and register how their fellow participants react.

Once curriculum content has been carefully discussed, goal setting becomes possible. In particular, by identifying session-to-session mathematical goals, participants become aware of the ways ideas are connected throughout the curriculum.

In order to focus on participants' perspectives, we examine one teacher's trajectory over the course of a seminar: careful reading of "Two Portraits of Change" and "Maxine's Journal" allows us to identify specific instances of movement toward seminar goals, highlighting moments of confusion that open opportunities for learning [9].

As participants gain confidence in their understanding of seminar content and goals, and in identifying participants' perspectives, the actual work of facilitation itself comes into focus. What is the facilitator's role in group discussion? When should the facilitator intervene? When should the facilitator listen quietly and move on? How might the ideas of the participants be used to raise the level of the discussions?

Our attention then turns to developing a repertoire of strategies to support more effective facilitation. We begin with hypothetical seminar scenarios, considering multiple strategies for dealing with common, but complicated, situations. In addition, we work on formulating questions that, while building on the ideas shared in small groups, raise the level of the whole-group discussion. We also analyze samples of participants' writing, focusing on the ideas being conveyed, identifying "openings" registered in their work, and creating responses both respectful and challenging.

An opportunity to co-facilitate a *DMI* session for other institute participants is the final synthesizing experience of the two weeks. Now responsible for actually setting goals, formulating questions that bridge the mathematics and the cases, and running whole-group discussions that build on and challenge the ideas of the group, institute participants are able to test their strengths in anticipation of their work as facilitators and leaders in their workaday settings.

<u>Facilitators' Inquiry Groups</u> — In addition to the annual institutes, a variety of networks and inquiry groups have been established over the years. During the first year of field tests, project staff met monthly with 35 Teacher Leaders who were, for the first time, taking on leadership roles in their systems. During the second year, an electronic discussion was established linking facilitators at various sites around the country who were working through sixteen *DMI* sessions at approximately the same pace. During these meetings or over the electronic network, facilitators described their successes, as well as dilemmas they faced. They shared strategies that worked for them, as well as those that didn't; and, they talked about the emotional challenges of the work. While these groups offered support to participating facilitators, they also provided a mechanism for feedback to the *DMI* developers responsible for the final revisions.

Now that the materials have been published, we are aware of other projects that structure opportunities for facilitators to work together on their practice. There are two such projects, in particular, that we are watching. In Boston, Amy Morse works with a group of coaches who, among their other responsibilities, facilitate *DMI* seminars. To ground discussions about their practice, coaches write their own cases—much like the cases in the *DMI* materials—about facilitation moments they choose to reflect on with their colleagues. In the Seattle area, Gini Stimpson and Christopher Fraley direct a project to cultivate a cadre of 300 *DMI* facilitators.

Conclusion

In this paper, we have described facilitation of *DMI* seminars: discussing the role of facilitator, the knowledge required to facilitate well, and the supports offered to develop strong facilitation. By confining the discussion to our own work, we are left with the question, how generalizable are our conclusions? Is active facilitation of the kind we posit for the *DMI* seminars—that facilitators use their considerable knowledge and skill in order to realize the goals of the materials—solely a function of the nature of those materials?

Although the empirical work presented here is all *DMI* related, the logic of the argument for active facilitation strongly suggests that whether these conclusions can be generalized depends on the distance between the beliefs and understandings of practicing teachers, and the goals of any particular professional development program. It is precisely when there is a conflict, a gap, or in Remillard and Geist's words, "an opening," between the understandings of the participants and the goals of the facilitator and the curriculum that determined action on the part of the facilitator is needed [2].

The general goals of the *DMI* seminar—that teachers come to recognize that mathematics is about ideas; that they and their students actively entertain mathematical ideas; that teaching involves listening to, interpreting, and analyzing what children express about their mathematical thinking; that teachers' moves be based upon their understanding of the mathematics to be learned and analyses of what students understand—tend not to be widely shared among K-12 teachers. To induce teachers to adopt these goals for themselves, professional development activities must not be easily assimilative into current frames of reference. However, even where assignments are explicitly stated (e.g., to figure out the sense in a child's mathematical mistake), teachers will tend to interpret them in familiar terms (to explain what the teacher should have done to prevent a child from making that mistake). Without a facilitator who acts with determination to draw teachers' attention to what they otherwise would not see, teachers are unlikely to commit to change their practice.

Indeed, although in this paper we have focused on facilitation of professional development seminars, the same considerations apply to other kinds of tasks a Mathematics Specialist might take on; for example, coaching teachers in their classrooms or leading discussions of demonstration lessons. Here, too, if teachers are to be helped to move forward, Specialists will need to identify and navigate openings—bringing teachers' attention to the mathematical ideas of students, or encouraging them to dig more deeply into the mathematics at hand. This work, as well, will call upon the same three areas of knowledge described above.

Responding to openings for teacher learning, however, is not just a matter of having the right cognitive dispositions. It is just as important to understand that effective facilitation requires courage—courage to challenge the thinking of other adults, to redirect a discussion that is moving in an unproductive direction, and to face the agitation, sometimes even tears, that result when firmly held ideas begin to crack.

This form of facilitation also demands a stance of respect for and commitment to the teachers being supported and the ideas to be explored. Perhaps this disposition is best reflected in one facilitator's injunction to herself and her colleagues: "We can do better—go deeper—than where we are now."

Acknowledgment

This work was supported by the National Science Foundation.

References

[1] D. Schifter, V. Bastable, and S.J. Russell, *Developing Mathematical Ideas*, Dale Seymour Publications, Parsippany, NJ, 1999.

[2] J.T. Remillard and P.K. Geist, "Supporting Teachers' Professional Learning by Navigating Openings in the Curriculum," *Journal of Mathematics Teacher Education*, **5**(1) (2002) 7-34.

[3] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[4] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.

[5] D.K. Cohen, M.W. McLaughlin, and J.E. Talbert (eds.), *Teaching for Understanding: Challenges for Policy and Practice*, Jossey-Bass, San Francisco, CA, 1993.

[6] *Knowing and Learning Mathematics for Teaching*, Mathematics Teacher Preparation Content Workshop Steering Committee, Center for Education, Division of Behavioral and Social Sciences and Education,

National Research Council, Washington, DC, 2001.

[7] D.L. Ball, "Bridging Practices: Intertwining Content and Pedagogy in Teaching and Learning to Teach," *Journal of Teacher Education*, **51**(3) (2000) 241-247.

[8] D. Schifter, "Learning to See the Invisible: What Skills and Knowledge are Needed to Engage with Students' Mathematical Ideas?" in T. Wood, B.S. Nelson, and J. Warfield (eds.), *Beyond Classical Pedagogy: Teaching Elementary School Mathematics*, Lawrence Erlbaum Associates, Mahwah, NJ, 2001.

[9] D. Schifter, V. Bastable, and S.J. Russell (eds.), et al., *Making Meaning for Operations, Facilitator's guide*, Dale Seymour Publications, Parsippany, NJ, 1999a.

[10] D. Schifter, V. Bastable, and S.J. Russell (eds.), et al., *Measuring Space in One, Two, and Three Dimensions, Facilitator's guide*, Dale Seymour Publications, Parsippany, NJ, 2002.

[11] D. Schifter, V. Bastable, and S.J. Russell (eds.), et al., *Building a System of Tens, Casebook.* Dale Seymour Publications, Parsippany, NJ, 1999b.

[12] D. Schifter, V. Bastable, and S.J. Russell (eds.), et al., *Building a System of Tens, Facilitator's guide*, Dale Seymour Publications, Parsippany, NJ, 1999c.

MATHEMATICS PROFESSIONAL DEVELOPMENT THAT FOCUSES ON STUDENT ACHIEVEMENT: A PARALLEL CASE EXAMPLE

N.R. IVERSON
Center for K-12 Education, University of Virginia
Charlottesville, VA 22904

The creation of a PreK-8 Mathematics Specialist credential provides an unprecedented opportunity for Virginia school leaders to improve student achievement in mathematics. If this opportunity is to yield hoped for outcomes, the professional development that supports shifts in teachers' understanding and practice will need to be far more focused, coherent, and job embedded than most current mathematics improvement efforts. This article examines four issues to address this challenge. First, it notes the depth of the changes in knowledge, skills, and beliefs that a substantive move toward National Council of Teachers of Mathematics reform driven and standards-based instruction will require. Next, it presents an integrated model for professional knowledge growth that considers both individual and organizational factors. Third, it examines the prevalence of both individual and organizational factors as described in a study contrasting professional development practices in high poverty Virginia elementary schools that varied markedly in their success in reducing the number of kindergarten children assessed as at risk for reading failure. Concurrently, it outlines features of professional development that support the implementation of effective mathematics improvement efforts. While the knowledge base required for effective reading instruction is different from the knowledge base needed to inculcate best instructional practice in mathematics, the approach to professional development efforts and the role of content specialists in supporting those efforts may provide insight that can help frame mathematics improvement efforts.

Thompson and Zeuli describe the challenges to substantive reform in mathematics instruction and highlight the complexity of the reform effort.

> Any serious policy—that is, any policy that does not simply endorse existing practice and call for more of it—requires some learning on the part of those who must implement it. To carry out policies based on the proposed reforms will require a great deal of learning—not merely additive learning (the addition of new skills to an existing repertoire), but transformative learning (thoroughgoing changes in deeply held beliefs, knowledge, and habits of practice) [1].

The Journal of Mathematics and Science: Collaborative Explorations Volume 8 (2005) 119 - 141

Thompson and Zeuli examine "what it would take to get the content and pedagogy of professional development right on a very large scale." [1] They contend that reformers and policymakers in science and mathematics should attend to the aspects of curriculum with which teachers have the most trouble. What they note is that change in teacher learning and practice is uneven and at times contradictory.

> Cohen's colleagues in the California Study of Elementary Mathematics (Peterson, 1990) found, at most, similar interminglings of newer and older practices without much recognition of the contradictions among the conceptions of content, teaching, and learning that undergird the disparate elements (Ball, 1990; Peterson, 1990; Wiemers, 1990). In fact, the one teacher who rejected the reform ideas seemed more aware of the differences than did the teachers who adopted them (Wilson, 1990). In our own research on science and mathematics education reform in Michigan (Spillane and Zeuli, 1997; Thompson, Zeuli, and Borman, 1997), we have found a few teachers who did seem to understand and work at the inner intent of the reforms, but a predominance of practice was remarkably similar to the patterns revealed in the California study several years earlier [1].

The authors contend that the essential point of the reforms that teachers find difficult to grasp is that the reform-based approach to mathematics learning requires students to think. While educators may verbally embrace the tenets of constructivism, the model of learning that pictures teacher as giver and student as receiver of knowledge is so pervasive that even those who actively pursue the principles of reform slip into the dominant model of teaching as knowledge transmission. Deep understanding of how students learn mathematics, complemented by deep understanding of the fundamental concepts and relationships of school mathematics, presents a daunting task for the mathematics reform agenda. Coupled with this challenge to change individual teachers' knowledge, skills, and beliefs about mathematics instruction is the equally challenging task of changing organizational knowledge, skills, and practice.

Conceptual Framework

A descriptive analysis of professional development practices in urban schools that have been successful in improving early reading performance through the assistance of Reading Specialists provides insight into key features needed for equivalent success in mathematics professional development. Creation of a threshold model to describe the interaction of individual and organizational features of professional learning provides a framework for planning professional development that is responsive to the complex nature of individual and organizational learning.

Using the threshold model as an organizer for our analysis, we focused on six urban high poverty elementary schools that differed markedly in their success in reducing the percentage of children identified as at risk for reading failure. The descriptive study examined whether there were differences in staff development practices in literacy acquisition in low SES schools that differed in achievement on the Virginia Phonological Awareness Literacy Screening (PALS) assessment [2]. We used a rubrics-based structured interview protocol that assessed individual and organizational growth features to identify school progress in using professional development as a means for reaching the elusive goal of becoming a professional learning community marked by value-added student achievement.

The six schools studied displayed real but subtle differences in the way that professional development experiences were incorporated in school instructional practices. All six schools served a high proportion of urban economically disadvantaged children. Three schools achieved a reduction in the percentage of children identified as at risk for reading failure of one standard deviation or more above the mean of 125 sample schools with parallel demographics. Three schools fell one standard deviation or more below the mean percentage in successful reduction of children identified as at risk. The most successful school reduced the percentage of children identified as at risk from 53% in the fall to 0% in the spring. The least successful school increased from 41% of children categorized as at risk in the fall to 70% identified as at risk in the spring (see Appendix A).

A number of factors probably explain this wide variation in success. We hypothesized that a complex mix of individual and organizational variables in professional learning, with concomitant variation in individual and organizational practice, might hold the key to unraveling the differences. As a foundation for our conceptual framework, we adopted the interactive school capacity model developed by M. Bruce King and Fred M. Newmann [3]. This model recognizes the interaction between individual and organizational behavior that we believe is fundamental to understanding the impact of professional development efforts. King and Newmann's school capacity model includes three components: teachers' knowledge, skills, and dispositions; professional community; and, program coherence. We hypothesized that successful implementation of these features in a kindergarten reading program would be marked by evidence of teachers collaborating to examine student work as the foundation for instructional decision making.

Our conceptual framework implies a threshold effect. Building on King and Newmann's construct of school capacity, the creation of a seven-dimension threshold model for understanding professional development permits the integration of a disparate body of research on individual and organizational knowledge. We suggest that adequate teacher knowledge applied in a coherent context of collective responsibility and evidenced by student-focused collaboration should result in improved student achievement. Drawing from literature on staff development and organizational culture, we created a series of interview questions and a rubrics-based system to test our model.

Expanding on the dimensions of school capacity identified by King and Newmann, Figure 1 displays the components of their school capacity model as grounded in professional development that incorporates the features of appropriate staff development identified in *Designing Effective Professional Development: Lessons from the Eisenhower Program* [4]. The components of the school capacity model are seen as creating conditions in which a school culture, characterized by Susan J. Rosenholtz's concept of "opportunity to learn," can flourish [5]. In the presence of these conditions, desired changes in individual practice and organizational practice may occur. Presence of the final dimension of staff development, "student-focused collaboration," is derived from the work of Judith Warren Little and is posited as being dependent on achievement of a threshold level of the supporting elements [6]. The seven dimensions illustrated in Figure 1 include:

- Dimension 1—Appropriate Staff Development includes six subdimensions: 1.1 Form, 1.2 Duration, 1.3 Collective Participation, 1.4 Content Focus, 1.5 Active Learning, and 1.6 Coherence (Prior Knowledge and Alignment)

- Dimension 2—Critical Attributes of Individual Knowledge includes six subdimensions: 2.1 Theory, 2.2 Demonstration, 2.3 Practice, 2.4 Peer Coaching, 2.5 Extended Learning, 2.6 Beliefs and Attitudes

- Dimension 3—Critical Attributes of Organizational Knowledge includes five subdimensions: 3.1 Shared Goals, 3.2 Collaboration and Collective Responsibility, 3.3 Reflective Inquiry, 3.4 Influence on Staff Development, 3.5 Program Coherence
- Dimension 4—Opportunity to Learn
- Dimension 5—Individual Practice
- Dimension 6—Organizational Practice
- Dimension 7—Student-Focused Collaboration

The third component of our conceptual framework asserts that attainment of a professional community with sufficient capacity to nurture student achievement is linked to the *interaction* of individual and organizational capacity. That interaction is evidenced by the instructional planning practice of student-focused collaboration. Student-focused collaboration is posited as a *reciprocal* contributor to schoolwide conditions for student achievement. When teacher groups accurately examine student work as a source of data to focus instructional planning, both individual and collective professional knowledge blossom and increased student achievement may result.

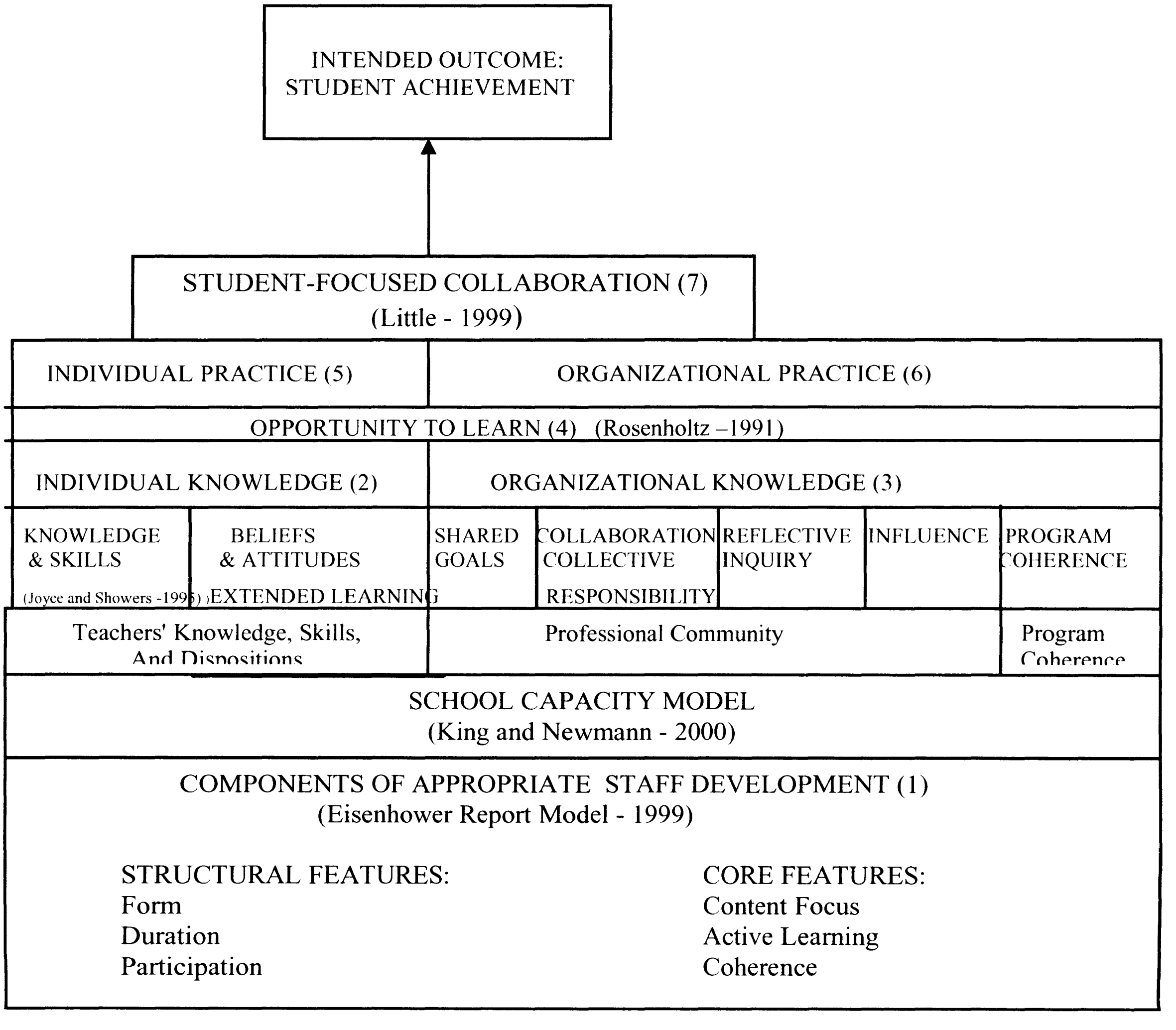


Figure 1: Professional Development—A foundation for School improvement: a threshold model.

The theory-based assertion is that development of sufficient capacity at each level functions as a threshold for acquisition of the next higher level component.

Parallel Case Example in Kindergarten Reading Professional Development

A sample of Virginia schools with a free or reduced lunch eligibility percentage of 58% or higher was drawn by examination of pre- and post-test scores of individual children from each qualifying school. The sample included individual student data from all schools that participated in the 1999-2000 PALS assessment and that had data for sixty or more children who were both pre-tested and post-tested. The final sample included 125 schools serving 8,355 children who were both pre-tested and post-tested. A random sample was taken of three schools in the group that scored one standard deviation or more above mean reduction in percentage of children identified as at risk and of three schools that scored one standard deviation or more below the mean.

Artifact and interview data were collected and analyzed for each school. As part of the analysis, we focused on data that reflected the level of student-focused collaboration. The term "student-focused collaboration" was defined as specific events that provide evidence of its presence in the kindergarten literacy setting. These included: 1) shared discussion of student responses in oral activities and written work samples;
2) student-focused team meeting minutes; 3) shared planning for professional learning about literacy; and, 4) shared planning for instruction that included discussion of strategies aimed at incorporation of designated components of literacy instruction. In our data analysis, student-focused collaboration was coded under the categories for **3.2 Collaboration and Collective Responsibility**, **3.3 Reflective Inquiry**, and **3.4 Influence on Professional Development**. Our definition of professional development included evidence of related ongoing efforts targeted to the same goal and included team meetings and other collaborative job-embedded work as a form of professional development.

There were striking differences between the higher and lower achieving schools across the eighteen reporting categories that were numerically coded. The differences included both individual and organizational features, and reflected differences in the role and degree of participation of Reading Specialists in the daily life of each kindergarten team. Appendix B illustrates the tallied data across study categories for the higher and lower achieving schools. Features of these practices in the higher achieving schools may productively inform mathematics leadership efforts to design effective roles for PreK-8 Mathematics Specialists.

Analysis and Implications of these Findings for Mathematics Staff Development and the Role of PreK-8 Mathematics Specialists

Among the group of higher performing schools studied, School Two consistently displayed professional learning behaviors that supported continuous improvement in student achievement (see Appendix C). Examination of this school's status on selected professional development variables has implications for mathematics staff development practice. The data also support our hypothesis that a threshold effect takes place in building professional learning communities. When an adequate level of individual knowledge is complemented by organizational skill and collective knowledge, the preconditions for the practice of student-focused collaboration are met. Specifically, formal staff development activities were augmented in this school by job-embedded learning opportunities. These took the form of team meetings focused on literacy practices in which the Reading Specialists played an active role as peers and as knowledge resources. Further activities of the Reading Specialists included co-teaching and coaching events in which the Specialist served as either model or observer. If Mathematics Specialists are deployed in parallel roles, then similar gains in student mathematics achievement may be expected.

Our framework identifies six categories in Dimension 1 derived from features of appropriate professional development identified in *Designing Effective Professional Development: Lessons from the Eisenhower Program* [4]. **Dimension 1.1 Form** distinguishes between traditional and reform delivery models. *Reform* activities in School Two included teacher participation in study groups, referred to as guided professional book talks, and regular use of Internet resources for individual and group exploration. *Traditional* delivery model training included three phases. The first phase, awareness level training, was provided at the district level. It was built on by phase two training, described as exploration and extension/management. This level included both district and job-embedded training. Third phase training was described as refinement/reflection and incorporated both district and job-embedded elements. The principal of School Two had carefully correlated district professional development with in-school follow-up training that explored each topic at grade specific levels. A key element of the delivery system was assignment to each school of a Reading Specialist whose sole responsibility was grade-level and classroom presentation of information, follow-up, and support of professional development work. In this school setting, this initiative took the form of weekly staff development team meetings with the entire kindergarten staff, as well as individual classroom follow-up in the form of modeling, observation, and coaching.

It appears that the *coherence* among these efforts and the coordination of efforts by the principal and the Reading Specialist who was available on a daily basis contributed to the success of the kindergarten team. Clear assignment of role responsibilities, provision of adequate time for specialist assistance, and coherence among district, building, and grade level staff development activities are markers for success that mathematics program planners might profitably emulate.

Dimension 1.2 Duration addresses the total number of content hours as well as the span of time over which training is delivered. The school's intense immersion model delivered 76.75 hours of direct and job-embedded instruction in one year. Initial direct training sponsored by the school division was followed by monthly visits by the same outside training provider. Building-based meetings included an annual total of 24 hours of quarterly daylong meetings that focused on development of literature-based thematic units to support the skills continuum of the division training. The Reading Specialist delivered an additional 20.25 hours of follow-up training to the division-sponsored training. Staff development kindergarten team meetings attended by the Reading Specialist and the Title I Literacy Teacher provided another 22.5 hours for discussion and application of the content provided in district and building level sessions. Throughout this period, the Title I Teacher taught small groups of children in each classroom during literacy instruction time, and informally modeled techniques that classroom teachers saw as effective and began to adopt. Implications for effective reform in mathematics include sufficient duration for professional development activities, both in direct instruction and in job-embedded modes. Mathematics Specialists can play a critical role in helping teachers apply new insights to specific classroom situations.

Dimensions 1.3 Collective Participation, **1.4 Content Focus**, **1.5 Active Learning**, and **1.6 Coherence** (connection to prior knowledge and alignment with other school efforts) were also addressed effectively in this professional development effort. School scheduling provided common team planning time daily for the kindergarten staff. The principal, who frequently attended these meetings, mandated the use of this time on Tuesdays for common lesson planning and on Thursdays for professional development. During the 1999-2000 school year, the Reading

Specialist took the lead in establishing topics and providing content materials. By the 2001-2002 school year, the kindergarten team had assumed major responsibility for organizing the questions examined at each weekly professional development team meeting, and submitted topics to their grade chair who circulated agenda items before the meeting. Over time, a gradually emerging team structure evolved in which the Reading Specialist and the Title I Reading Teacher assumed roles as valued peers and readily available information resources within a high functioning grade-level team. In 1994 as a foundation for development of team learning, the principal provided direct instruction in shared decision making. By the 1999-2000 school year, the school was engaged in its sixth year of working in this way. Implications for planning job-embedded mathematics professional learning initiatives and the use of Mathematics Specialists include attention to prerequisite development of team decision-making skills and provision of a layered, ongoing set of knowledge growth strategies.

Dimension 2 of our framework incorporates professional development efforts that attend to *individual* knowledge and belief systems. **Dimensions 2.1** through **2.5** incorporate components of the individual training model developed and validated by Bruce Joyce and Beverly Showers [7]. School Two was the only school studied that displayed consistent incorporation of the features of **2.1 Theory**, **2.2 Demonstration**, and **2.3 Practice** in formal and job-embedded professional development. Although teachers did not immediately respond affirmatively to questions about incorporation of theory in their training, they unanimously agreed that their training consistently included a number of theory-based components: attention to how children learn to read, to stages of literacy development, and to learning to diagnose features of print in children's work samples. Joyce and Showers make a compelling case for the incorporation of discipline specific theory in training efforts when they define presentation of theory as:

> An exploration of theory through discussion, readings, lecture, etc; this is necessary for an understanding of the rationale behind the skill or strategy and the principles that govern its use. Study of theory facilitates skills acquisition by increasing one's discrimination of the demonstrations, by providing a mental image to guide practice and clarify feedback, and by promoting the attainment of executive control [7].

Implications for mathematics professional development include incorporating attention to theory accompanied by systematic bridging of the theoretical underpinnings of instruction and of how students learn mathematics, to application in teachers' daily practice. In their work in cognitively guided instruction, Carpenter, Fennema, and Peterson have contributed important schema for analyzing children's knowledge of word problems [8]. When the researchers' knowledge is translated into grids with examples that help teachers analyze the tasks involved in problem solving, the presentation of theory becomes a valued part of the professional development experience [8].

Dimension 2.4 Peer Coaching took an alternate form at School Two. Coaching was an important part of practice as provided by the Reading Specialist. Informal peer observation and follow-up conversation also occurred between the Title I Specialist who taught daily in each classroom and the classroom teacher who was simultaneously working with another reading group. **Dimension 2.5 Extended Learning** addresses teachers' opportunities to attend professional development opportunities outside the school setting. This opportunity was available at both the higher and lower achieving schools and the school scores among the group of six schools were similar. School Two, however, displayed a critical difference. At School Two, there was an understood condition that attendance at a sponsored conference carried an obligation to report back to one's peers upon return. This practice not only increased access to knowledge for the entire kindergarten group, but also provided the conference attendee an opportunity to assimilate the knowledge in a manner that made it possible to present it to others. Adoption of this practice in mathematics improvement efforts may be beneficial.

Dimension 2.6 Beliefs and Attitudes about Teaching is based on the work of S.J. Rosenholtz in which she distinguishes between individuals who see teaching as mastery of a prescribed set of skills and those who view it as a lifelong cumulative and developmental process [5]. Teachers who view teaching as complex and understand their own development as cumulative are typically more open to continuing efforts to improve practice and more comfortable discussing the dilemmas of practice. Attention to individual beliefs and attitudes, as well as their impact on school culture, is an essential feature to consider when planning staff development efforts and an arena in which the interpersonal skills of the Mathematics Specialist will be critical.

Dimension 3 includes five critical attributes of *organizational* culture derived from the work of King and Newmann [3]. School Two outperformed its peer schools on most of these attributes. **Dimension 3.1 Shared Goals** was measured by a review of artifacts, as well as interviews with the principal, Reading Specialists, and kindergarten teachers. Conscious effort to bring teachers and administrators together frequently to discuss their work enlivened the generic goal of high student performance. The principal's stated goal was "consistency between teachers, between teachers on a grade level, and across grade levels." Teachers identified their greatest strength as learning and working together. "We try to do everything together. We say, bring your ideas." Implications for the role of the Mathematics Specialist include working with building administrators to provide school structures that facilitate teachers working and learning together. The teacher isolation typical of elementary schools does not support the kind of group effort needed to bring about consistent improvement in student achievement. Attempts to improve the performance of teachers who attend courses or programs in isolation may only add to the existing breaches in many schools between the "superstars" and the remainder of the staff. School division-level planners might do well to send school teams rather than pick one representative from each school in the division to attend workshops. The common practice of sending a single representative from each school is sometimes justified as a means of equitable resource distribution and sometimes reflects a scattershot attempt to create train the trainer models without providing resources needed to implement and maintain changes in practice.

Dimensions 3.2 Collaboration and Collective Responsibility, **3.3 Reflective Inquiry**, and **3.4 Influence on Professional Development** were examined collectively as a means for assessing school success in bringing about the practice of student-focused collaboration. The principal's leadership at School Two in articulating her support for each of these attributes apparently strengthened their day-to-day implementation. As described by Newmann, King, and Rigdon, a key feature of collaboration and collective responsibility is the willingness of teachers to assume collective responsibility for the success or failure of their students rather than to blame factors external to their classroom or to the school [9]. Where collective responsibility is evident, teachers work in a solution finding mode. If a large number of students are failing to master requisite skills, teachers first examine their instruction and assessment to identify needed changes. When all staff members have a stake in the success of every student, the likelihood of identifying needed changes in school infrastructure, curriculum, instruction, or assessment increases.

For schools starting mathematics improvement efforts, it makes sense to include a multi-grade cross section of the teaching staff in a curriculum audit, followed by analysis of current practices in instruction and assessment. This type of effort provides a foundation for developing collective responsibility by inculcating the practices of lesson study and shared diagnosis of student work. When a resident Mathematics Specialist initiates these efforts with the support of the building administration, the process should gain the emphasis and the staffing it needs to produce useful results.

Practice of **Dimension 3.3 Reflective Inquiry** is central to the effort of a school that strives to become a learning community. At School Two, the principal was able to give examples of kindergarten group discussion about literacy, citing specific children about whom the group was concerned and the strategies they had developed for addressing those concerns. The teacher group mentioned analysis of children's writing samples, shared planning for skills instruction, and comparison of children's progress on Breakthrough to Literacy computer instruction as examples of specific ways they used the children's work and specific skill acquisition to focus their conversation.

For mathematics instruction, parallel examples of reflective inquiry might include use of students' oral and written work samples for teachers' analysis of what students understand as well as their points of confusion, use of lesson study, and use of diagnostic interviews.

Dimension 3.4 Influence taps the degree to which teachers have input in defining professional learning goals and the opportunity to designate the content of professional development. The city plan for elementary reading included a concurrent central and school focus for staff development. The principal cited teacher involvement in planning weekly team meetings as evidence of influence on staff development. The grade group described their involvement in planning team meetings, but did not identify this activity as staff development. Although this school exhibited a well-integrated model of job-embedded staff development, the teachers apparently did not see their contribution to the effort as a "staff development" activity. They cited their input role in requesting in-service sessions, but seemed to see themselves as recipients of knowledge rather than as contributors to knowledge. The old definition of staff development as "something done to you" seemed to linger even in an environment characterized by lively commitment to professional learning.

For staff development efforts in mathematics, it may be helpful to define explicitly the contributions of both formal and job-embedded components. If teachers understand that their work in teams contributes to knowledge about how children learn, they may gradually adopt a more holistic and positive attitude toward professional learning that replaces the stereotypes associated with "staff development."

Dimension 3.5 Program Coherence addresses ongoing professional communication among and between grades. Kindergarten teachers at School Two had developed remarkably fluid and beneficial communication among themselves. Their communication about literacy instruction with teachers in other grades was far more scattered and haphazard. Both the teacher group and the principal expressed a desire to foster more communication and consistency across grade levels. The school schedule was structured to provide daily access for each grade level-team. This goal precluded the possibility of cross grade-level meetings during the school day. The principal scheduled occasional early morning cross grade-level meetings for professional development, used memos to communicate administrative information, and limited after school meetings as much as possible. The principal indicated that the schoolwide, shared decision making team was trying to address this need. An effort to create curriculum coherence across grades was evident in cross grade-level curriculum guides and multi-grade instructional materials.

As building-level Mathematics Specialists work with principals and teachers to plan a long-term professional learning endeavor, it will be helpful to examine allocation of professional time and decide in advance how to prioritize time resources between the conflicting demands for grade level and cross grade-level professional development.

Dimension 4 Opportunity to Learn is derived from the work of S.J. Rosenholtz. In schools that Rosenholtz describes as *learning enriched*, teachers support the need for continuous learning. Their view of schooling as a non-routine technical culture demands that they cannot use a formulaic approach, but must adjust to specific situational demands. Curriculum and learning are seen as complex and the assistance of others in seeking solutions becomes critical [5]. In response to the question, Where do your new teaching ideas come from? 92% of teachers from learning-enriched schools cited other teachers as the source of their new ideas, with 72% of this group reporting a second source as their own problem solving and creativity [5]. Teachers in School Two consistently reported turning to each other, and using their own creativity and reflection about their work as ways of improving instruction. They also cited avoiding conversations focused on venting frustration or placing blame on external factors.

Mathematics Specialists can play an important role in grade-level team learning by modeling openness to divergent solutions and ease with acknowledging the complex nature of supporting children's mathematical thinking. Modeling behavior that reflects these key elements of mathematics instruction should also support creation of a climate in which teachers feel safe discussing the perplexities they encounter in lesson planning, instruction, and assessment.

Dimension 7 Student Focused Collaboration functions as a subtype that extends King and Newmann's definition of professional community [3]. In this study, it was defined as building on achievement of a threshold level of individual and organizational knowledge and practice, and was characterized by exhibition in daily practice of *collaboration*, *collective responsibility*, *reflective inquiry*, and *influence* on the content of professional learning (see Figure 1).

In a grade-level team that optimizes its capacity to deliver effective mathematics instruction, all of these features may be expected to occur. Examples of this behavior in the mathematics setting might include group lesson study, analysis of diagnostic interviews with students, group analysis of student written work, and dialogues about classroom events that yielded puzzlement or enlightenment. Consistent presence of these behaviors reflects achievement of a culture characterized by ongoing professional learning.

Comparative Analysis of School Performance in Reading Achievement

In the study of kindergarten reading achievement, the higher scoring group of schools outperformed the lower scoring group on nineteen out of 21 components of the dimensions of staff development model. Comparison between the higher and lower scoring schools revealed the following key findings.

- Access — In the higher scoring schools, teachers made more regular use of the professional knowledge resource personnel available in the building. Availability of skilled Reading Specialists who participated actively in classroom life made information and strategy searches much easier. Teachers appeared to be more confident in articulating perplexity about practice or the need for information.

- Intentional Knowledge Growth — In the higher scoring schools, teachers took ownership of available planning time to address questions of professional interest and sought research-based solutions to problems of practice. This included use of student work samples as a focus for reflective inquiry.

- Best Practice-Based Planning — In the higher scoring schools, teachers used available lesson planning time to develop instruction that reflected research-based knowledge about reading development.

- Integration of Knowledge — In the higher scoring schools, teachers and administrators developed a shared conceptual framework to support individuals in their integration of new information and suggested practices. This included opportunities for demonstration, practice, and coaching in a non-evaluative setting.

- Experimentation — In the higher scoring schools, teachers received peer support for experimentation with new strategies, but strategies were weighed against information about appropriate practice for varying levels of reading development.

- Eisenhower Study Model — In the higher scoring schools, formal staff development initiatives included greater incorporation of practices identified by the Eisenhower study: longer duration, collective participation, content focus, active learning, attention to prior knowledge, and alignment with state standards [4].

- Joyce and Showers Model — In the higher scoring schools, formal staff development initiatives demonstrated greater incorporation of the training components of theory, demonstration, practice, and coaching [7].

Recommendations for Practice—Becoming a Professional Learning Community

If schools are to be successful in nurturing professional learning, they must discard the common view of staff development as a series of events in which teachers act as passive recipients of knowledge. The notion of continuous intentional professional learning is based on a constructivist view of teachers' attempts to make sense of their practice by continual exploration of that practice in job-embedded settings. Courses, conferences, and workshops can contribute, but their impact will only be as great as the individual school's skills in helping its faculty integrate new information into the school's continuing quest for improved practice. The authors of *What Matters Most: Teaching for America's Future* lamented the common professional development experience of teachers by noting that:

> While teachers are being asked to engage their own students in active learning, problem solving, and inquiry, they rarely experience this kind of learning themselves [10].

Job-embedded and formal initiatives for adults aimed at increasing professional knowledge and supporting development of intentional learning should attend to principles of instruction suggested by research and corroborated by the comments of teachers and principals interviewed in this study. Drawing from the literature as validated by this study, the following suggestions for professional development practice in both mathematics and reading are proposed:

Job-Embedded Practice

- Work to replace the idea of staff development as in-service workshops with a broader definition of professional learning.

- Create structures for a professional community that encourages access among teachers to the broadest possible resource knowledge base by clarifying the role of specialists and other resource personnel.

- Create structures for team planning that clarify roles, goals, and procedures for intentional professional knowledge growth, reflective inquiry, and collaborative planning.

- Establish a shared working conceptual framework for the principles and content of programs that is specific enough to guide teams in making decisions about instructional content and practices.

- Establish procedures to institutionalize the integration of new knowledge and help individuals find solutions to questions that arise from disparate information sources.

- Encourage a culture of experimentation with new strategies that routinely weighs proposed activities against best practice research.

Formal Professional Knowledge Initiatives

- Establish a specific connection between the content of study and its usefulness to the teacher as a way of understanding children's learning and planning to enhance it.

- Provide information that contains specific examples, including work samples, classroom observation, and video sequences, of how the suggested theory relates to practice and informs instructional decision making.

- Plan for practice and feedback of suggested skills in the workshop and in a supportive environment within the school. This implies active participation of building administrators in the ongoing learning of teachers both by attendance at training sessions and by establishment of procedures to support and facilitate practice and debriefing.

- Recognize that incorporating new strategies in professional repertoire takes repeated practice and refinement. Provide ongoing coaching and support.

- Provide frequent opportunities for teachers to engage each other in substantive, reflective conversations about their practice in a supportive setting.

- Provide the materials needed to inculcate the practice. Recognize, budget for, and monitor the need to update supplies and equipment.

By their knowledge, accessibility, and skill in working with both adults and children, well-prepared school-based Mathematics Specialists can support improvement of children's learning. The reforms envisioned for mathematics education demand several major shifts in understanding. *Lenses on Learning*, a National Science Foundation-funded professional development program for school administrators, identifies several key goals for school level improvement [11]. Teachers' acquisition of deep content knowledge, understanding of how children learn mathematics, and ability to facilitate discourse-based instruction are central objectives. Achieving each of these goals will require formal professional development initiatives that must be accompanied by the ongoing support in tackling questions about content and practice that school-based Mathematics Specialists will be able to provide. In our study of staff development in kindergarten reading, we learned that access to and integration of research-based knowledge was critical for success. Mathematics Specialists can help teams of teachers develop a shared conceptual understanding of effective practice. That knowledge base will guide teachers as they explore and refine their assumptions and teaching behavior. Nothing less than exceptional professional development instruction accompanied by intense ongoing support is needed. Thompson and Zeuli capture the magnitude of the task:

> The essential point—the inner intent—that seems so seldom grasped even by teachers eager to embrace the current reforms is that in order to learn the sorts of things envisioned by reformers, students must think. In fact, such learning is almost exclusively a product or by-product of thinking. By "think," we mean that students must actively try to solve problems, resolve dissonances between the way they initially understand a phenomenon and new evidence that challenges that understanding, put collections of facts or observations together into patterns, make and test conjectures, and build lines of reasoning about why claims are or are not true. Such thinking is generative. It literally creates understanding in the mind of the thinker [1].

References

[1] C.L. Thompson and J. Zeuli, "The Frame and the Tapestry: Standards-Based Reform and Professional Development," in L. Darling-Hammond and G. Sykes (eds.), *Teaching as the Learning Profession: Handbook of Policy and Practice*, Jossey-Bass Publishers, San Francisco, CA, 1999.

[2] N. Iverson, *Staff Development and Kindergarten Reading Achievement*, University of Virginia, Charlottesville, VA (unpublished doctoral dissertation, 2002).

[3] M.B. King and F.M. Newmann, "Will Teacher Learning Advance School Goals?" *Phi Delta Kappan*, **81** (2000) 576-580.

[4] *Executive Summary—Designing Effective Professional Development: Lessons from the Eisenhower Program*, US Department of Education, Editorial Publications Center, Washington, DC, 1999.

[5] S.J. Rosenholtz, *Teachers' Workplace: The Social Organization of Schools*, Teachers College Press, New York, 1991.

[6] J.W. Little, "Organizing Schools for Teacher Learning," in L. Darling-Hammond and G. Sykes (eds.), *Teaching as the Learning Profession: Handbook of Policy and Practice*, Jossey-Bass Publishers, San Francisco, CA, 1999.

[7] B. Joyce and B. Showers, *Student Achievement Through Staff Development: Fundamentals of School Renewal*, Longman Publishers USA, White Plains, NY, 1995.

[8] T.P. Carpenter, E. Fennema, P.L. Peterson, C.P. Chiang, and M. Loef, "Using Children's Mathematics Thinking in Classroom Teaching: An Experimental Study," *American Educational Research Journal*, **26**(4) (1989) 499-531.

[9] F.M. Newmann, M.B. King, and M. Rigdon, "Accountability and School Performance: Implications from Restructuring Schools," Harvard Educational Review, **67**(1) (1997) 41-74.

[10] *What Matters Most: Teaching for America's Future*, National Commission on Teaching and America's Future, New York, 1996.

[11] C.M. Grant, B.S. Nelson, E. Davidson, C. Grant, A. Sassi, A.S. Weinberg, and J. Bleiman, *Lenses on Learning*, Dale Seymour Publications, Parsippany, NJ, 2003.

Appendix A
Fall and Spring Performance of Six Schools on Phonological Awareness Literacy Screening in 1999-2000

	School Number					
Data	#1	#2	#3	#4	#5	#6
% Pre-/Post-test	86	69	87	89	93	92
# Pre-/Post-test	78	114	68	57	51	91
# Failing to Meet Fall Criterion Score	42	42	26	5	22	37
% Failing to Meet Fall Criterion Score	53.85	36.84	38.24	8.77	43.14	40.66
# Failing to Meet Spring Criterion Score	0	9	7	12	31	64
% Failing to Meet Spring Criterion Score	0	7.89	10.29	21.05	60.78	70.33
Reduction in Percentage Failing to Meet Criterion Score from Fall Testing to Spring Testing	+53.85	+28.95	+27.95	-12.28	-17.6	-29.67

Sample Schools (n=125) Mean % Pre-/Post-test = 89.25, S.D. = 6.09

Sample Schools (n=125) Reduction in Percentage Failing to Meet Criterion Score from Fall Testing to Spring Testing: Mean Change = 9.36, S.D. = 12.54

Appendix B
Comparison of Three Higher and Three Lower Scoring Study Schools on *Dimension 7 Student-Focused Collaboration*, and on Contributing Dimensions

Data Unit	Three Higher Scoring Schools	Three Lower Scoring Schools
Dimension 7 — Student-Focused Collaboration: Mean of Summed Scores for 3.2 – Collaboration and Collective Responsibility, 3.3 – Reflective Inquiry, and 3.4 – Influence on Professional Development (00.00-130.00)	75.33	44.67
Mean of Summed Scores For Dimension 4 — Opportunity to Learn (00.00–26.00)	21.33	10.33
<u>Mean of Other Mean Scores By Dimension Number:</u>		
1.2 Duration (1.00-3.00)	2.78	1.89
1.3 Collective Participation (1.00-4.00)	3.00	1.89
1.4 Content Focus (1.00-3.00)	2.25	1.08
1.5 Active Learning (1.00-3.00)	2.17	1.50
1.6 Coherence [Prior Knowledge and Alignment] (1.00-3.00)	1.52	1.00
2.1 Theory (0.00-2.00)	1.11	0.00
2.2 Demonstration (0.00-2.00)	1.62	0.17
2.3 Practice (0.00-2.00)	1.00	0.17
2.4 Peer Coaching (1.00-2.00)	1.39	0.67
2.5 Extended Learning (0.00-1.00)	0.80	0.89
2.6 Beliefs and Attitudes (1.00-2.00)	2.00	1.67
3.1 Shared Goals (0.00-1.00)	0.73	0.38
3.5 Program Coherence [Professional Communication] (1.00-3.00)	2.39	1.67
5 Individual Practice (0.00-1.00)	0.75	0.74

Note: Numbers in parentheses indicate the possible score range for each item.

Appendix C

Dimensions of Staff Development — Individual School Profile — School Two

Dimension	Sum	Mean	Summed Dimensions
1. Appropriate Staff Development			
1.1 Form	Mixed		
1.2 Duration	8	2.67	
1.3 Participation	9	3.0	
1.4 Content Focus	18	3.0	
1.5 Active Learning	8	2.67	
1.6 Coherence (Prior Knowledge, Content Alignment)	26	2.36	
2. Individual Knowledge			
2.1 Presentation of Theory	6	2.0	
2.2 Demonstration	6	2.0	
2.3 Practice	2	2.0	
2.4 Peer Coaching	6	1.5	
2.5 Extended Learning	4	0.8	
2.6 Beliefs and Attitudes	4	2.0	
3. Organizational Knowledge			
3.1 Shared Goals	6	0.75	
3.2 Collaboration and Collective Responsibility	60		Summed categories for Dimension 7 include 3.2+3.3+3.4=92
3.3 Reflective Inquiry	22		
3.4 Influence (Content of Staff Development)	10		
3.5 Program Coherence	9	2.25	
4. Opportunity to Learn			
4 Opportunity to Learn	19		
5. Individual Practice			
5 Individual Practice	10	0.83	
6. Organizational Practice			
6 Organizational Practice	Narrative		
7. Student-Focused Collaboration	92	**See Appendix B for comparative scores.**	

TEACHER-IN-RESIDENCE PROGRAM AT CALIFORNIA STATE UNIVERSITY, CHICO

W. FISHER
Center for Math & Science Education
California State University, Chico
Chico, CA 95929

Abstract

California State University, Chico has incorporated a Teacher-in-Residence program within the Department of Mathematics and Statistics. The purpose of this program is to have an elementary school teacher take a leave of absence from his or her classroom in order to work half-time in the Department of Mathematics at the University and half-time for the Chico Unified School District as a Mathematics Resource Specialist.

Background

California State University (CSU), Chico is one of 23 campuses in the California State University system. Located in a rural area approximately one hundred miles north of Sacramento, CSU, Chico is a residential campus of nearly 16,000 students. Founded in 1887 as a state normal school, the campus takes pride in its long tradition of professional development for both pre-service and in-service teachers. Teacher training continues to be an important component of the campus mission. At the present time, over 1,400 students are liberal studies majors, the most popular major on campus and the major most students elect to pursue in order to earn a multiple subjects credential, the credential needed to teach in elementary schools.

The Department of Mathematics and Statistics is the largest on campus in terms of number of students served. We have a steady number of mathematics and statistics majors, but we are primarily a service department. The Department consists of 21 tenured or tenure-track Ph.D. faculty, about one-third of who are actively engaged in work in mathematics education. We rely heavily on part-time faculty members, currently employing 45 adjunct faculty who teach a variety of courses ranging from remedial mathematics to mathematics for future elementary teachers to calculus.

The normal model for teacher credentialing in California requires that students earn bachelor's degrees in a subject area and then enter into a "fifth year" practicum, which includes the student teaching experience. Students who choose to become elementary teachers usually become liberal studies majors, a cross-curricular major that the University has created for these students. The major includes courses that ensure that California State Standards and requirements are completed; such as, child health, foreign language, psychology of teaching, and cultural and temporal concepts. Students in the liberal studies program are required to take six semester units of lower-division mathematics. The Department of Mathematics offers a standard year-long course that parallels the content of traditional mathematics for elementary teachers texts, such as those by Long and DeTemple, Peterson and Musser, and Bassarear, to name a few [1-3]. In addition, liberal studies majors are required to take at least one upper-division class from the College of Natural Sciences. Possibilities include two mathematics courses specifically designed for these students or various science classes that all include a lab. For many students, aversion to mathematics is only exceeded by their fear of science; hence, most liberal studies students take three semesters of mathematics. Finally, all liberal studies majors must choose an area of concentration. While child development is the most popular area of concentration, mathematics is second-most popular, with nearly 18% of liberal studies majors choosing a mathematics concentration. The concentration in mathematics requires a total of eighteen units, which includes twelve units of special mathematics courses specifically designed for this major.

The Teacher-in-Residence Program

Our Teacher-in-Residence (TIR) program was initially begun with a grant from the ExxonMobil Foundation. The grant, the University, and the Chico Unified School District each contributed one-third of the TIR salary. The TIR remained a full-time employee of the District, but was put on special assignment. As a result, s/he would not lose fringe benefits, seniority, or accrued time in the retirement system. However, the TIR's return to his/her regular classroom or even previous school was not guaranteed, only a teaching position somewhere within the District.

The program has many goals, but an encompassing goal is to develop better links between the University and the K-6 mathematical community. At the University level, we hope to produce college graduates who are better prepared to teach elementary school mathematics, while we also help University faculty better understand the needs of future teachers. At the elementary school level, we hope the program will help classroom teachers develop a better understanding of mathematics and that this will produce elementary school students with a deeper knowledge of mathematics.

TIR Roles

It will become immediately clear that the roles that the TIR performs cannot be broken down as those at the University and those at the District. There is far too much overlap of those roles and it is perhaps the reason why the TIR program has established a partnership between the District and the University at the departmental level where one did not previously exist.

Teaching in the Department is a major component of the TIR's University job. The TIR teaches two sections of mathematics courses for future elementary teachers. However, if this person only taught two sections, the Teacher-in-Residence would be no different than any of the other multitude of part-time instructors who teach in the Department. Consequently, in addition to teaching, the University duties of the TIR include activities designed to involve our full-time faculty, and increase their awareness and understanding of the mathematical needs of elementary teachers.

Each semester, one of our full-time faculty members team-teaches a section of the course entitled, *Mathematics for Elementary Teachers* with our Teacher-in-Residence. The team usually meets several times a week to plan, discuss, and reflect upon the coursework; other faculty teaching the same course often attend these meetings as well. The TIR gives a unique and extremely beneficial perspective to these discussions. Collaborations between University faculty and the Teacher-in-Residence are proving so fruitful for our faculty that we provide an opportunity for all new mathematics education faculty to team-teach one course with our Teacher-in-Residence.

While team teaching allows both the University faculty member and the elementary school teacher to grow professionally, it also gives the University students a much richer classroom experience. For example, since the Teacher-in-Residence has immediate access to elementary children, often a mathematics problem is assigned to both the University students and to an appropriate grade of elementary children. Once the University students have worked on the problem, they are then given the elementary children's work on the very same problem! Subsequent class time spent analyzing student work provides the University students an early contact with children's mathematical thinking that has rarely been part of our classes in the past. These child-centered activities validate the necessity of the mathematics coursework and foster a level of excitement that keeps University students engaged in and enthusiastic about mathematics (see Appendix).

While providing easy access to the work of elementary students is an important contribution, our Teacher-in-Residence has been able to establish an even stronger link between our pre-service mathematics education courses and the elementary classroom. Most sections of

Mathematics for Elementary Teachers now have an elementary class visit their University class at least once per semester. Each time, we learn more about how to make these occasions most profitable for the University students and not just a fun opportunity to work with children. The TIR arranges the visit, provides expert help in designing appropriate activities for the visiting class, and attends the visit to act as a facilitator between the University and the elementary environments. While scheduling and other details can sometimes be difficult, the value of the experience to our pre-service teachers makes the effort worthwhile.

Thanks in part to interactions with our TIR, University faculty who teach the mathematics courses for pre-service elementary teachers have become much more professionally active in this area. We have initiated a mathematics education seminar series that meets to share ideas, discuss mutual concerns, and become a learning community. As an example, we read Liping Ma's *Knowing and Teaching Elementary Mathematics*, much like a book club activity where we covered the book chapter by chapter with appropriate discussion questions [4]. We invited several key elementary school Teacher Leaders to become part of this "book club" and all of us gained a profound understanding of elementary mathematics.

In June 2001, CSU, Chico was able to send a team to San Diego for the American Association of State Colleges and Universities meeting on "Improving the Mathematics Preparation of Elementary Teachers"; there was never any question about whether our Teacher-in-Residence should be part of the team. The TIR has become a valued member of the Department by providing an insight into the needs of pre-service and in-service teachers that is not possible for those of us who work outside of the elementary school community. These insights have improved not just our work in individual courses, but are leading us to rethink our mathematics program for prospective elementary teachers. The University is close to requiring three courses for liberal studies majors; we have decided that this would be an advantageous time to consider restructuring the program and include more content in proportional reasoning and algebraic thinking.

While the contributions of the TIR are far more significant than what we would expect from a part-time faculty position, this person also has another "half" position at the Chico Unified School District. This dual role is possible, in part, because the TIR has a two- (or three-) day-per-week teaching schedule; for the rest of the week, the TIR works as a Mathematics Resource Specialist. Rather than working throughout the school district (fifteen elementary schools), he or she works at a particular school site. Different sites have been identified as needing an infusion of mathematics reevaluation based on statewide mandated testing. The TIR has an office at that site and works as a peer coach, does requested teach-ins in various classrooms, conducts "lesson study" professional development workshops with the teachers at that site on a bi-weekly basis, and acts as an on-site resource for all mathematics curricular issues.

The efforts of the TIR have improved the atmosphere at the two schools at which the TIR has been housed. Not only have the mathematics scores of the students improved substantially, there is a new level of professionalism that has been observed at these schools. More teachers have begun to attend mathematics in-service programs and conferences. The TIR has started mathematics Olympiad activities at one of these schools where no such program ever existed. Although the program is still very small, it is a step in a new direction for the school.

In addition, the TIR have been involved in some Districtwide mathematics activities. The TIR is a member of the Districtwide mathematics task force committee. This committee makes decisions on mathematics instruction and assessment within the District. The most significant accomplishment at the District level is probably the inauguration of a new in-service program available to all elementary teachers. The TIR co-directs this forty-hour program that meets after school over a seven month period and which has been developed with University mathematics faculty input.

As a result of the two different jobs the Teacher-in-Residence occupies, the blended benefits to both the District and the University are numerous and robust. The student-centered benefits are readily apparent. In addition to the visits from elementary school classes mentioned above, we now have an extensive mathematics tutor program at various elementary schools. The program uses pre-service teachers to go out into the schools and tutor in mathematics. The University students attend a bi-weekly seminar where they are given very detailed ideas, activities, and assessment tasks. They work closely with the classroom teachers to help individual students more fully understand specific mathematical ideas. The seminars are co-taught by the TIR who also serves as an on-site coordinator for the tutors.

Lessons Learned

There is no question that this TIR program is not without its own set of obstacles. The University was not permitted to hire an elementary teacher that did not have a master's degree in mathematics to teach in the Department. Indeed, both of our TIR have a strong mathematics background in elementary mathematics and not the breadth of coursework normally seen in our traditional part-time staff. The support of the mathematics education faculty allowed us to depart from normal hiring practices to hire a TIR. Now that we have had the chance to see the benefits of the TIR program, we feel that searching for a teacher that has a profound understanding of elementary mathematics is probably more advantageous than seeking someone that generally doesn't exist.

Grant funding is no longer available to pay one-third of the cost of such a person, but both the District and the University are seeking ways to continue the program. Institutionalization is not in place as of yet, but reorganization of funding has been found to continue it in the near future. Most universities and districts will need to find creative ways of financing such a person as part-time university wages do not match one-half of a senior, fully-benefited teacher.

It would not be fair to say that the TIR has become a regular member of our Department. Just as part-time faculty members are in some sense second-class citizens, this can be said to apply to the TIR as well. However, the accomplishments and benefits that the TIR has had with those faculty, both full-time and part-time and who have an interest in elementary mathematics education, have earned our TIR full status in these circles. It is a comfort to have on staff a person who knows the elementary classroom when we chart curriculum decisions for future elementary teachers. Mathematics education faculty, or those who have interest in such matters, need to take an active role in ensuring that a TIR is allowed to share his/her expertise in a university setting. A university is an entirely new working environment for a TIR and someone must help a TIR understand this setting.

Summary

The Teacher-in-Residence program has multiple benefits to both the University and to the District. The role that the Teacher-in-Residence plays at the District level is similar to that of a Mathematics Specialist in a larger district. This dual TIR gives the District a Mathematics

Specialist for less than half the cost. Smaller districts, such as the Chico Unified School District, can thus more easily afford a Mathematics Specialist.

Much larger benefits happen at the University level. Mathematics faculty have benefited tremendously from professional conversations with an elementary teacher. It seems that Ph.D. mathematicians who are not trained in mathematics education, but are truly concerned about mathematics for prospective elementary teachers, are much more open to enter into conversations on specific issues because such lack of knowledge can be couched in terms of, "What do you think is the most effective way of ...?" or "How important is ...?" What has then transpired is that everyone, even those who are mathematics education faculty, expresses their uncertainty about particular issue, and then professional dialogues begin. Now we find it common to have questions such as, "Does anyone have a good activity to use to have students understand conditional probability?" or "How much time does anyone spend on area formulas of two-dimensional figures?" raised by faculty. These types of conversations rarely occurred previously.

Having elementary classes come visit University mathematics classes has become commonplace. One of the unexpected benefits that has come from this is a belief growing among University students of a need to learn more mathematics. Quite often, the reasoning of elementary children "blows our students away" as they find it almost incomprehensible that children can have such sophisticated ways of thinking. Initially, many University students believe that there is only one way to do something, and traditional paper and pencil algorithms are the only way to approach mathematics. These visits completely alter their beliefs.

The classroom tutor program that was discussed as one of the duties of the TIR has now gained both University- and District-level recognition. Unfortunately, University funding for these student learning opportunities has dried up with the current financial crisis in California. However, one elementary school has shuffled some of their funding around to pay the University tutors because the school finds them to be better trained and able to teach those elementary children who need help in mathematics.

In short, there is a definite place for an elementary teacher in a university mathematics department. The Teacher-in-Residence brings an important perspective to bear on the mathematics courses for prospective elementary teachers. The TIR can benefit all faculty and undergraduate students taking elementary mathematics courses, not just the students in his/her specific classes.

References

[1] C.T. Long and D.W. DeTemple, *Mathematical Reasoning for Elementary Teachers*, Addison-Wesley Longman, Boston, MA, 2000.

[2] B.E. Peterson, G.L. Musser, and W.F. Burger, *Mathematics for Elementary Teachers*, John Wiley and Sons, New York, NY, 2002.

[3] T. Bassarear, *Mathematics for Elementary School Teachers*, Houghton Mifflin, Boston, MA, 2004.

[4] L. Ma, *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Lawrence Erlbaum Associates, Mahwah, NJ, 1999.

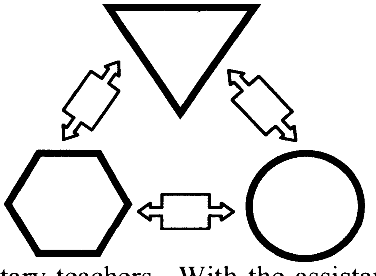
[5] W.R. Speer, D.T. Hayes, and D.J. Brahier, "Becoming Very-Able with Variables: Addition Using Algebra Networks," *Teaching Children Mathematics*, **3**(6) (1997) 305.

[6] J. Ferrini-Mudy, G.Lappan, and E. Phillips, "Experiences with Patterning," *Teaching Children Mathematics*, **3**(6) (1997) 282-88.

Appendix
Joint University and Classroom Problems

Example I. Algebra Networks

Algebra networks are described in "Becoming Very-Able with Variables: Addition Using Algebra Networks" in the "Investigations" section of the February 1997 issue of *Teaching Children Mathematics* [5]. See the figure below. Typically, the teacher presents the problem to the students by placing beans or some other kind of counter in the triangle, circle, and hexagon. Students are then asked to write the sum of the number of beans in the circle and the triangle in the rectangular space between these two figures. The same is done for the sum of the number of beans in the circle and the hexagon, and in the hexagon and the triangle. When everyone agrees on the sums, the students remove the beans and, with just the sums remaining, the students attempt to determine the original number of beans in each of the three figures. Of course, in this example, students know there *is* a solution. But what if we randomly write numbers in the three rectangles? Can we be certain there is a solution? Could there be more than one solution?
The algebra network problem appeals to a wide variety of students. This is especially significant



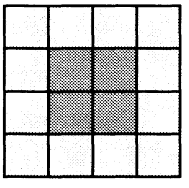
in our courses for future elementary teachers. With the assistance of our Teacher-in-Residence, we have been able to introduce the problem to our University students while an elementary teacher simultaneously introduces the problem to fifth graders. After introducing the problem and providing time to share ideas about how to approach such problems, we ask the University students to create an appropriate problem for the elementary students to solve. By the next class meeting, we are able to return the elementary school students' solutions and reasoning to the University students. The University students then analyze and critique the reasoning of the elementary students. The typical outcome of this activity is a profound sense of uneasiness on the part of the University students. The solution paths of the elementary students are often much more sophisticated than the pre-service teachers expect; in fact, elementary students often discover techniques we have not discussed in our University classroom.

Example II. Swimming Pool Problem

This is a well-known problem that can be used at many different levels. It is a wonderful problem environment that engages elementary children in rich algebraic thinking (from "Experiences with Patterning" by J. Ferrini-Mundy, G. Lappan, and E. Phillips in *Teaching Children Mathematics*) [6].

Take **two** colors of tiles, so we can all talk about the water and the pool decking mathematically and not refer to the specific color of tiles. Let's agree that:
Dark Tile = Pool Water
Light Tile = Pool Decking

Tat Ming is designing square swimming pools. Each pool has a square center that is the area of the water. Use the Dark Tile to represent the pool water. Around the water, there is a pool deck that forms a border and goes entirely around the pool. Use the Light Tile to represent the pool deck.



Here is a 2 x 2 pool

Let's generate some questions:
How many tiles are there altogether for each pool?
How many dark tiles? How many light tiles?
Are there more dark tiles than light tiles? Always? Never?
What patterns do you see in the dark tiles? In the light tiles? In the total number of tiles?
Can you predict how many tiles there will be in the next pool size?
Given the number of Pool Water tiles, can you determine the number of Pool Deck tiles? Vice-versa.
What numbers work for the number of Dark Tiles?
What numbers work for the number of Light Tiles?
What is the fractional relationship between the Dark Tiles and the Light Tiles used for each pool size? Between Dark Tiles and Total Tiles?
Can you tell me what 'pool 11' looks like?
Make a graph of the number of Dark Tiles used versus the pool size.
Make a graph of the number of Light Tiles used versus the pool size.
When do the Dark Tiles overtake the Light Tiles needed?

Similarly, University students are shocked at how many patterns elementary students find. They first question the validity of many of these patterns, which results in their interest in looking deeper into the mathematics involved.

PART IV: FINANCIAL SUPPORT

The concluding article in this section describes the ExxonMobil Foundation support and the federal grant funded support for Mathematics Specialists. Over nine million dollars has been awarded for three interrelated projects devoted to the development and offering of seamless Virginia programs to train Mathematics Specialists, and to research their ultimate effectiveness on students' mathematics achievement.

FINANCIAL SUPPORT FOR MATHEMATICS SPECIALISTS' INITIATIVES IN VIRGINIA

R.W. FARLEY and W.E. HAVER
Dept. of Mathematics and Applied Mathematics, Virginia Commonwealth University
Richmond, VA 23284-2014

L.D. PITT
Dept. of Mathematics, University of Virginia
Charlottesville , VA 22904

Introduction

The work of university faculty and school system administrators and teachers to establish Mathematics Specialists in school systems across Virginia has been supported by both corporate and federal/state grants. Initially, support from ExxonMobil Foundation was vital to the initiative to work within selected school districts to define roles and test the impact of Mathematics Specialists. Many of the manuscripts in this journal issue report on efforts to date and on their perceived effect on student learning. This early work has laid the groundwork for the current Mathematics Specialists' programs across Virginia. In Spring 2003, shortly following the release of the Virginia Mathematics and Science Coalition (VMSC) *Mathematics Task Force Report*, the Virginia Board of Education directed the Department of Education to begin the process of creating a Mathematics Specialist endorsement [1]. This action created a major opportunity and an equally major challenge for Virginia's mathematics/mathematics education community. The opportunity existed for statewide utilization of Mathematics Specialists, resulting in significant gains in student achievement. The challenge existed because there were virtually no teachers in Virginia who were prepared to serve as Mathematics Specialists. In addition, there were few courses and no full programs available to prepare individuals to serve in these roles. Furthermore, although there was a great deal of anecdotal information that Mathematics Specialist programs significantly improved student learning, there was only limited scientific research to support this conclusion and no mechanism in place to undertake this research. Placing Specialists in schools represents a significant commitment, and this commitment will not become widespread and sustained without supporting research.

To meet this challenge, over nine million dollars of grant funding has been competitively sought and obtained during the past year by principal investigators Reuben Farley, William Haver, Loren Pitt, and their colleagues. These awards were made in conjunction with VMSC, and in collaboration with Coalition partners. The current funding has enabled the project Principal Investigators (P.I.) and their university and school system colleagues to: 1) work collaboratively to establish seamless programs to prepare Mathematics Specialists; 2) simultaneously conduct controlled research studies on the effect of Specialists on student learning; and, 3) conduct studies of the statewide policy issues related to implementation of Specialists in the schools.

Virginia Department of Education (VDOE) Mathematics and Science Partnership Program (MSP)

VDOE-MSP Goals and Outcomes — The Virginia Mathematics Specialists Project is a Virginia Mathematics and Science Partnership (MSP) grant that received an initial award for $749,581 in 2004, and new supplemental awards of $295,000 in 2005. The initial partnership was led by the VMSC and included eight colleges and universities, and 26 school divisions. The overarching goal was to train the first cadre of Virginia's Mathematics Specialists.

VDOE-MSP Action Plan — The VDOE grants directed by P.I. Loren Pitt have supported the initial development of five core mathematics courses and the first of three educational leadership courses. These courses are being offered across Virginia in both two-week residential settings and as numerous on-site university courses both in summer and academic year sessions. To date, summer residential institutes have been held at James Madison University and University of Virginia; the 2005 institutes are scheduled at the College of William and Mary and Emory and Henry University. Other courses have been offered at Longwood University, Norfolk State University, University of Mary Washington, Virginia Commonwealth University, and Virginia Tech. This program offers a "Fast Track" for prospective Mathematics Specialists who have master's degrees to complete anticipated endorsement requirements which were recommended to the Virginia Board of Education in the Virginia Mathematics and Science Coalition Task Force on Mathematics Specialists [1].

The three lead universities, Norfolk State University (NSU), the University of Virginia (UVA), and Virginia Commonwealth University (VCU), agreed to work collaboratively and develop the core of a master's degree program for K-8 Mathematics Specialists. The proposal defined this core as a sequence of five mathematics courses developed especially for Mathematics Specialists and one leadership course. The five mathematics courses are: 1) Numbers and Operations; 2) Rational Numbers and Proportional Reasoning; 3) Geometry and Measurement; 4) Functions and Algebra; and, 5) Probability and Statistics.

These courses are designed with the specific goal of addressing the needs of K-8 Mathematics Specialists. They are meant to provide a profound understanding of the basic mathematics that is taught in schools, as well as providing participants with an understanding of how children develop their understanding of this mathematics, and how to evaluate their students' understanding in ways that can inform teaching.

The mathematics and leadership courses are being developed following a model that has been used successfully by the VMSC in professional development projects for a number of years. A development team is assembled consisting of five to ten individuals from higher education and the schools. The teams include teachers, mathematicians and mathematics educators, and mathematics supervisors. Working together, they identify the course goals and identify and/or develop appropriate materials. Detailed syllabi and instructor materials are then pieced together. In advance of teaching the courses, an instructor training session is held involving instructors from all the sites. During these sessions, the future instructors are guided through the materials to ensure that the course materials and the purpose of the various activities are understood by the instructors.

Eighty teachers from across Virginia will complete the sequence of six courses by September of 2005. The lead universities each committed to establishing a master's degree program for K-8 Mathematics Specialists; this has been done and will be described later in this article.

The master's degree programs are being offered in a cohort model and, in an effort to develop a common program model, four of these courses are being offered as statewide residential institutes. The grant pays partial tuition, books, living expenses, and stipends for the mathematics courses. To receive support, participants must be nominated by their school divisions and commit to attending at least two of the residential institutes.

The two 2004 institutes, Numbers and Operations and Rational Numbers and Proportional Reasoning, were held at James Madison University and the University of Virginia, respectively. They were well attended and popular, and a majority of over 90% of the participants who did not already have master's degrees has applied for admission to one of the new degree programs. The 2005 summer institutes will be in Probability and Statistics and Geometry and Measurement, and will be held at the College of William and Mary and Longwood University, respectively.

Following the success of the 2004 programs, the Virginia Department of Education awarded two supplemental awards to the Virginia Mathematics Specialists Project. These awards have two distinct purposes. First, the Project and the VMSC were asked to host a spotlight and dissemination conference aimed at central office school personnel. The aim of this grant is to highlight the potential of Mathematics Specialists as a tool for strengthening student learning of mathematics, and to inform schools of the programs for educating future Mathematics Specialists that are being developed in the state. A much larger portion of these grants was aimed at enlarging the Specialists Project and, in particular, moving the mathematics project into the rural far Southwest region of Virginia. As a result of this grant, we are planning residential institutes at Emory and Henry College in Summer 2005 and 2006. These institutes will recruit statewide, but recruiting will target the Southwest region.

National Science Foundation (NSF) Teacher Professional Continuum (TPC) Program

NSF-TPC Goals and Outcomes — The NSF-TPC project received a five-year grant of $4,444,898 for a collaborative effort led by Virginia Commonwealth University and the VMSC. Reuben Farley at VCU is the P.I. for this project.

The project focuses on two research studies. One study led by the Educational Commonwealth Policy Institute at VCU is researching the statewide policy issues associated with the implementation of a large scale Mathematics Specialists program across Virginia. This study, led by David Blount and Judy Singleton, is analyzing policy, legislative, regulatory, and funding issues regarding the establishment of the Virginia Mathematics Specialist Initiative.

The mathematics education research study, led by Patricia Campbell, a mathematics education researcher at the University of Maryland, has the goal of determining through well designed research the impact of a Mathematics Specialist program on teachers who are supported by Mathematics Specialists and on the mathematics achievement by these teachers' students. Patricia Campbell is conducting research to determine:

- The impact of the Mathematics Specialists preparation program on the participants' attitudes and beliefs;
- The impact of the Specialists on classroom teachers in their schools; and,
- The impact of Specialists on student learning, understanding, and performance on standardized tests.

NSF-TPC Action Plan: Mathematics Specialist Cohorts — The centerpiece of this project is research focused on two cohorts of twelve teachers who are preparing to serve as Mathematics Specialists (a total of 24 Specialists). Participating school systems Portsmouth, Virginia Beach, Richmond City, Stafford, and Spotsylvania have identified a total of twelve triples of schools with comparable student demographics and student performance on Virginia's *SOL* tests. One school was randomly selected from each triple, and these twelve schools have been assigned a Mathematics Specialist beginning with the 2005-06 school year. Two years later, a second school will be randomly selected from each triple, and will be assigned Specialists beginning with the 2007-08 school year. Individuals are selected by the participating school systems to receive Specialist training and support, and then are assigned to serve as Mathematics Specialists in the randomly selected schools.

NSF-TPC Action Plan: Mathematics Specialist Preparation Program — The project is refining the six graduate mathematics and mathematics education courses that were first developed under the VDOE-MSP project, and developing two additional courses. The project will also provide the additional support needed by individuals selected to serve as Specialists.

Each course will be offered by NSU, VCU, and UVA. We believe that the research conducted will benefit from having the prospective Specialists enroll in courses taught by three different sets of instructors. This will be more typical of what will occur in an established program. A set of training sessions (faculty development seminars) will be developed and offered to the team of instructors in the project, both university and school personnel, who will be teaching each section of the course/seminar. Enrollment will be limited in each section of the course to twenty individuals, including, of course, the four teachers from each region who are in the pilot cohort.

It is important that the instructional programs utilized in schools be research based. Likewise it is important that the instructional programs utilized to prepare Mathematics Specialists be research based. Very little research exists concerning the optimum preparation for Mathematics Specialists. The major thrust of the NSF-supported projects is to develop such a research base. The development and instructional teams will remain together throughout the project. They will refine the courses after their first offerings based upon their experiences, feedback from project evaluators, and the preliminary findings of the research team concerning measures of the mathematical content and pedagogical knowledge and beliefs of the Mathematics Specialists.

NSF-TPC Action Plan: Statewide Master's Degree — We will support the training of Mathematics Specialists statewide and enhance the professional development for many other teachers through the development and offering of a Statewide Master's Degree. Reuben Farley at VCU is directing this program. This training and the flexible degree concept under which it will be offered has received numerous requests from teachers and supervisors. Statewide Master's Degrees have been initiated by VCU, NSU, and UVA. Institutions across the state anticipating joining VCU, NSU, and UVA in this initiative include James Madison University, George Mason University, Old Dominion University, and Virginia Tech. Each contributing partner will create a flexible master's program featuring opportunities to earn credits from partner universities across the state in different tracks, such as: Master of Interdisciplinary Studies (Math and Science); Mathematics/Science Specialist; and a Master of Arts in Mathematics Teaching (blending mathematics, content pedagogy, and leadership). The Mathematics Specialist Track featuring the core set of seven graduate mathematics and mathematics education courses developed and/or refined and piloted as a part of this project are being offered by UVA, NSU, VCU and most recently, Longwood University and George Mason University.

A quality control board with graduate school representatives from all participating Institutions of Higher Education (IHE) will approve the content of master's degree programs offered under this umbrella, as well as approve individual plans of study and award degrees. All of the resources within Virginia (including universities, museums, and science centers) will be utilized, and individuals will be able to combine different types of credits including: on-site credit at local institutions; residential credit from various institutions offered through grant-funded Summer Institutes around the state; credits earned through various university centers statewide; transfer credits earned in-state or elsewhere; and/or, distance learning credits earned by completing on-line courses from various universities statewide.

NSF-TPC Action Plan: Research on the Effectiveness of Mathematics Specialists — The mathematics education study is being led by Patricia Campbell at the University of Maryland. It will evaluate the effectiveness of Mathematics Specialists through a treatment-control design as it investigates the potential relationship between four outcomes:

- Mathematical content and pedagogical knowledge, and the mathematical beliefs of the Mathematics Specialists;
- Leadership and support practices of the Mathematics Specialists;
- Nature of teachers' classroom mathematics instruction as interpreted by the Mathematics Specialists, the degree of engagement of teachers with the Mathematics Specialists, and the mathematical beliefs of the teachers; and,
- Mathematics achievement of students in the schools served by the Mathematics Specialists.

The data sources for measuring these outcomes will include:

- Paper and pencil assessments of the mathematical content knowledge and mathematical pedagogical knowledge of Mathematics Specialists;
- Paper and pencil assessments of the mathematical beliefs of Mathematics Specialists and teachers;
- Virginia *Standards of Learning* (*SOL*) tests;
- Modification of the Project IMPACT mathematics interview assessment [2];
- Hours of attendance in mathematics professional development activities by teachers and Mathematics Specialists; and,
- Specialists' activity and reflection logs as entered by the Specialists into a Palm Pilot™ data collection system.

The research will explore a number of core questions:

- Does professional development and practice change Specialists' mathematical content knowledge, pedagogical knowledge, and beliefs?

- What types of Specialist behaviors and interactions with individual teachers impact student achievement and teacher change?
- Does the impact of the Specialist change over time?
- Do Specialists influence teachers' mathematics beliefs and pedagogical approaches?

In order to measure potential change in Specialists', teachers', and students' understanding, as well as the relationship between these variables over time, this project will use repeated measures within a stratified randomized design. As described, twelve triples of schools will be identified, with the schools within each triple having a similar prior tradition of mathematics achievement, serving a similar population of students demographically, and operating within the same school district. Within each triple, schools will be randomly assigned to one of three categories: Treatment 1 (Cohort 1 Mathematics Specialist placed in Fall 2005); Treatment 2 (Cohort 2 Mathematics Specialist placed in Fall 2007); and, Control (No Mathematics Specialist). This analysis will access students' mathematics achievement scores over time, with a teacher having different classes of students across years and these classes having different collections of students across years. For all students in one classroom in one year, the analysis will treat their scores on the *SOL* as repeated measures of achievement that yield a teacher's classroom score for that year. Then, these classroom scores from year to year are repeated measures of the effect of the teachers' instruction, with the potential concurrent repeated effect of teachers' engagement with the Mathematics Specialists and the expertise of the Mathematics Specialists over time. Recognizing the limited scope of achievement being measured in the *SOL* tests, this project will also randomly select students from each triple of schools and administer a grade-specific mathematics interview assessment to determine sampled students' conceptual understanding and reasoning. While these interview data will not be entered in the quantitative analysis, they will address the validity of the project's assessment of student achievement.

Because a teacher has both student achievement and mathematics beliefs scores for several years and because there is a control group, this analysis essentially can serve as a control for a teacher's teaching "talent" as it evaluates the impact of the Mathematics Specialists and their offerings of professional development. This analysis will reflect any increase in teachers' professional development through either workshops or engagement with Mathematics Specialists over time. Because the data also measures the mathematical content and pedagogical knowledge and beliefs of the Mathematics Specialists, as well as their level of activity and sophistication of reflection, this analysis can examine the impact of expertise and longevity of the Mathematics Specialists on students and teachers. This technique is a multi-level model with cross-classification that incorporates within-classroom and within-teacher variance as well as school-level (Mathematics Specialist) variance.

Because schools and teachers are not randomly assigned populations of students for instruction, and because not all teachers have identical prior professional backgrounds, this analysis will collect student demographic data and teacher certification status data to serve as control variables.

NSF-TPC Action Plan: Policy Research — The policy research component is being directed by William Bosher and Daniel Norman through VCU's Commonwealth Educational Policy Institute (CEPI). Working through the CEPI, David Blount and Judy Singleton will study policy-related issues associated with the implementation of Mathematics Specialists programs across Virginia. First, CEPI will assist project leadership with issues related to policy and regulatory development and implementation including access and communications between the local school districts, appropriate state education agencies, the state legislature, and the university project investigators, researchers and evaluators.

Second, CEPI will utilize a state-level longitudinal case study approach to collect and analyze all policy, legislative, regulatory, and funding issues related to the establishment of the Mathematics Specialists Initiative. Specifically, this study will include analytical components involving political support and expectation, establishment of state licensure, funding mechanisms, training expectations, costs and benefit analyses, and implementation issues.

Third, the longitudinal case study will focus on the parallel utilization history of the project schools and districts including local policy and program regulatory issues. Specifically in this area, CEPI will work collaboratively with the project researchers to design appropriate data collection for local school and district policy and implementation issues regarding personnel selection, recruitment, job description development, and Specialist/classroom teacher interaction. Impact of Specialists upon district instructional services, support systems, and professional development will be analyzed in the policy and regulatory context. Additionally, CEPI will work closely with project researchers to include policy analysis that may be required as a component of the project's overall research design as well as to plan within the overall design appropriate data collection methodologies for the statewide and local district case studies.

Policy reports on both the statewide initiative and the local school/district implementation issues will be issued annually during the project period. Each interim report will include specific findings and recommendations intended for practical problem solving in project implementation. It is anticipated that data analysis conducted by the team conducting research of the effectiveness of Mathematics Specialists will raise additional policy, regulatory, and funding choice issues that will need to be incorporated in the case studies. Similarly, policy research likely will uncover additional issues that need to be addressed concerning the effectiveness of Mathematics Specialists. The final report will include corroborative data from survey, interview and participant polling to support/refute preliminary policy, regulatory and implementation issue findings studied during the period covered by the project.

National Science Foundation Mathematics and Science Partnership (MSP) Program

NSF-MSP Goals and Outcomes — The NSF Mathematics Specialist Partnership Institute received a five-year grant of $3,726,915 to a partnership led by VCU and VMSC, with William Haver of VCU serving as P.I. The Institute will be offered to two cohorts of 25 outstanding K-5 teachers. Each teacher will: participate in a four-week Institute for three consecutive summers; complete a total of 33 graduate credits during the Institute sessions and the subsequent academic years; participate in a rich collection of Institute enrichment activities; and, earn a master's degree and certification as a Mathematics Specialist. The first cohort has been selected and will begin their training in Summer 2005 in the VCU Summer Institute.

The VDOE-MSP Project focused on preparing teachers who already had earned master's degrees in related areas. The Institute Partnership will certify the first fully prepared group of Mathematics Specialists who will have completed the full master's degree program. As a group, the graduates of the Partnership Institute will provide leadership and serve as role models for their peers statewide as Mathematics Specialists become engaged across Virginia.

The goals of the proposed Institute Partnership program are outlined below.

- Prepare a group of fifty exemplary elementary school teachers to provide intellectual leadership as school-based Mathematics Specialists who *combine: a profound* understanding of the mathematics studied in the elementary grades; an enthusiasm for mathematics and its applications; the special knowledge needed for effective teaching of mathematics; and, the leadership skills needed to serve as inspirations and resources for their peers and the mathematics education profession.

- Determine the extent to which a quality Institute experience leading to a master's degree results in transforming the participating teachers from effective classroom teachers to disciplinary leaders who can infuse their schools and the broader profession with a commitment to taking the steps that enable all students to develop a deep understanding of mathematics and a capacity to be successful in advanced mathematics and science courses in subsequent years.

<u>NSF-MSP Mathematics Specialist Cohorts</u> — Two cohorts, each consisting of 25 accomplished elementary school teachers, will participate in a Summer Institute spanning three summers. Each participating teacher will:

- Participate in three sessions of the Summer Institute, each lasting four weeks with follow-up extending throughout the following academic year;
- Complete a total of five mathematics courses, one interdisciplinary mathematics and science course, four education courses, and a final internship/independent study project (nine of these courses will be started during the Summer Institute sessions with varying degrees of follow-up, and one will be offered entirely as a distance learning course);
- Participate in the wide spectrum of other Institute activities;
- Earn a master's degree, using the above mentioned coursework, and complete Virginia requirements to receive the Mathematics Specialist License; and,
- Receive a stipend of $15,000.

Partner school systems have:

- Made a commitment that participating teachers would serve as full-time school-based Specialists after they have completed the program;
- Representatives on the Management team to assure that the Mathematics Specialist training meets the needs of the partner systems, and that school systems participate as full partners in developing, refining, and offering the program.

The first Institute cohort includes the indicated number of teachers from the following core school system partners: Norfolk City (4), Hampton City (1), Portsmouth City (2), Richmond

City (5), Hanover County (2), Fairfax County (7), Arlington County (3), Alexandria City (3), and Culpepper City (1).

NSF-MSP Selection of Participants — The participants are nominated by the partner school systems and then receive final approval for admission to the graduate degree program by the partner universities. The school systems have committed to providing participating teachers the time and the school support to serve as in-school Mathematics Specialists after the successful completion of the Institute experience. This is a major commitment; school systems have made firm plans to provide this time. The systems have been selected to include urban and rural systems with significant minority and non-English speaking student populations. All partners are committed to selecting a diverse set of participants in terms of gender, race, age, and students served.

NSF-MSP Institute — The core of the project will be the NSF Institute that will take place in three four-week sessions. For each cohort of teachers, the first Summer Institute session will be hosted by VCU, the second session by NSU and directed by Phillip McNeil, and the third by UVA under the direction of Loren Pitt. During each session, the teachers will: complete two mathematics courses (with follow-up during school year); begin a leadership/education course (a large portion of the course will take place during the year so that teachers can put in place what is discussed in their own classes and in those of other teachers within their schools); and, participate in seminars, conduct classroom visitations, and interact with visitors to the Institute. A major emphasis will also be placed on preparing principals and school system administrators to make use of Mathematics Specialists.

NSF-MSP Coursework and Master's Degree — The Institutes will offer the five mathematics and two education courses developed under the VDOE-MSP and NSF-TPC projects. These courses will be refined based upon research findings and formative evaluation. *In addition*, two new education/leadership courses and an externship course will be developed by a team of teachers, mathematics and mathematics education college faculty, and school system mathematics supervisors. One of these courses will be a distance learning course.

Upon completion of the Institute Program, including the coursework described above, the master's degrees will be awarded by NSU, UVA, or VCU and it is anticipated that the participants will be fully licensed as Mathematics Specialists by the Virginia Department of Education.

NSF-MSP Research Study — The major research component is directed by James McMillan with the Metropolitan Educational Research Consortium. Aimee Ellington and Joy Whitenack at VCU will utilize case studies of Institute participants to study the effectiveness of the training program on participants preparing to become Mathematics Specialists. A naturalistic, qualitative case study design will be developed and implemented. This type of research allows the researcher to better understand the "why" and "how" of changes attributed to the introduction of an intervention. In this study, Mathematics Specialists' professional activities are the focus of the research project. This qualitative study complements the quantitative research undertaken in the NSF-TPC project.

NSF-MSP Research Study: Phase I — The following research questions will be addressed in Phase I of the research:

- What is the nature of the professional relationships developed between the Mathematics Specialists and the college mathematics faculty who are leading the MSP Institutes and teaching the Institute courses?
- What do the Mathematics Specialists perceive is their role in facilitating instructional change?

For Phase I, all 25 Specialists-In-Training in the first cohort will be studied. In addition to interviews and observations, the researchers will make use of the instruments utilized by Patricia Campbell in the NSF/TPC-supported project described previously in this manuscript. These instruments gather pre- and post-data of the participants concerning content knowledge, pedagogical knowledge, and mathematical beliefs. As a part of this phase, the participants will be clustered representing different approaches to the role of Mathematics Specialists in the schools (second Phase I research question).

NSF-MSP Research Study: Phase II — The following research questions will be addressed in Phase II of the research:

- Which professional development activities offered by the MSP Institutes impact the Mathematics Specialists' effectiveness in the schools?
- What is the nature of the professional relationships between the Mathematics Specialists and the school building administrators?
- What factors and processes support the successful infusion of Mathematics Specialists? How do these factors and processes facilitate change in teachers' instructional practices?
- Overall, what are the most important ways the Mathematics Specialists impact their respective school buildings, in general, and individual teachers in particular?

A sample of four to five prospective Mathematics Specialists will be purposely selected to be the subjects of case studies. Two or three Specialists will be selected from each of the most promising clusters identified in Phase I.

Multiple sources will be used to document and account for the Mathematics Specialist professional activities. Most of the data will be collected using qualitative methods, although contributing quantitative data will also be used. Sources will include the Mathematics Specialists, MSP Institutes, Institute leaders, principals and teachers.

Although data collection will involve the use of multiple techniques, the qualitative data will be collected primarily through formal and informal interviews, and through observations. The researchers will develop a core set of questions that address the project goals, objectives, and procedures. In addition, the researchers will develop potential follow-up questions to ask. Because the purpose of ethnographic interviewing is that of purposeful sampling as well as checking and triangulating information, these questions will be sufficiently open-ended to allow the participants to explain, develop ideas, and to elaborate. Further, the researchers will triangulate the interview data with other data to develop a rich description of the social contexts in which the Mathematics Specialists participate. Hypotheses will be developed, refined and, in some cases, discarded during this process of reconstructing the contexts.

Interviews will be conducted with key personnel on an ongoing basis throughout each year of the project to fully understand the dynamics of introducing Mathematics Specialists and the contexts of the schools. It is expected that there will be at least seven interviews in each of the schools each year. All formal interviews will audiotaped. When possible, the researchers will develop field notes of interview sessions (formal and informal) that will later be expanded and reviewed for accuracy. The interviewees will also have opportunities to review these informal documents to check for the extent to which the information is accurate, appropriate, etc.

Observations will also be conducted each year, with the number of observations increasing each year as greater infusion is expected. It is anticipated that at least four one-half day observations will be conducted in each school during the second year and at least seven observations will be made during subsequent years. Observers will record field notes taken during and immediately following time in the school.

Triangulation and negative case identification will be used to enhance the credibility and transferability of the findings. The development of interview and observation procedures will take place during the initial summer and fall of the project.

Both interview and observation data will be analyzed and synthesized to develop categories, case patterns, and themes that provide in-depth understanding of the Mathematics Specialists' project activities. The project findings will be coordinated with the project evaluation and other research that documents changes in the Mathematics Specialists and student learning.

Conclusion

Support from VDOE-MSP, NSF-TPC and NSF-MSP will result in the development and refinement of a research-based graduate program to prepare Mathematics Specialists. Master's degree-level programs will be offered by the University of Virginia, Norfolk State University, Virginia Commonwealth University, Longwood University, George Mason University and, most likely, additional universities. Each will include the identical, collaboratively developed, set of five mathematics and three education/leadership courses.

Support from the NSF was provided because of the research that will be conducted under these projects. By its very nature, the results of this research are unknown. However, we are optimistic that it will support the hypothesis that well-prepared, school-based Mathematics Specialists will lead to major gains in student learning.

As the primary goal of the VDOE-MSP project and the secondary goal of the NSF projects, the first group of Virginia's Mathematics Specialists is being prepared. The VDOE-MSP project will prepare approximately 120 individuals, many of whom already possess master's degrees and will meet the anticipated criteria for endorsement. The two NSF projects will prepare a total of approximately 170 Mathematics Specialists. These individuals will be primarily from the pioneering school systems that partnered in obtaining the research support and made the early commitment to Mathematics Specialists: Stafford, Spotsylvania, Alexandria, Arlington, Culpepper, Fairfax, Richmond, Hanover, Norfolk, Portsmouth, Hampton, and Virginia Beach. If evidence continues to support the need for and benefits of Mathematics Specialists, additional school systems in other regions of the Commonwealth outside of Virginia's "Golden Crescent" region may decide to deploy Mathematics Specialists. In this case, additional support at the local, state, or national level will be required to make use of the programs that have been developed to prepare individuals to serve in this capacity.

As discussed throughout the paper, the project evaluators are making important formative contributions throughout the projects. Marie Sheckels of the University of Mary Washington is evaluating the VDOE-MSP Project and Horizon Research, Inc. (HRI) of Chapel Hill, NC, under the leadership of Iris Weiss, Melissa Smith, and Sean Smith, is conducting the evaluation of the NSF-MSP and NSF-TPC projects. In addition to the formative contributions, the summative evaluation, which is closely coordinated with project research studies, will validate the research protocol and the conclusions reached.

The funding invested in the Virginia Mathematics Specialists program both from corporate and federal agencies is an indication of Virginia's national leadership in establishing the role of Mathematics Specialists in Virginia's schools. The research and evaluation components of these projects will be instrumental in determining the future training and deployment of Mathematics Specialists in schools across the Commonwealth and the nation.

References

[1] "Mathematics Specialists Task Force Report," Virginia Mathematics and Science Coalition, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 5 – 22.

[2] P.F. Campbell, *Project IMPACT: Exiting Kindergarten through Grade Five Interview Assessments*, University of Maryland Center for Mathematics Education, College Park, MD (unpublished manuscript, 1995).

AIMS & SCOPE

Articles are solicited that address aspects of the preparation of prospective teachers of mathematics and science in grades K-12. The Journal is a forum which focuses on the exchange of ideas, primarily among college and university faculty from mathematics, science, and education, while incorporating perspectives of elementary and secondary school teachers. The Journal is anonymously refereed, and appears twice a year.

The Journal is published by the Virginia Mathematics and Science Coalition.

Articles are solicited in the following areas:

- all aspects of undergraduate material development and approaches that will provide new insights in mathematics and science education
- reports on new curricular development and adaptations of 'best practices' in new situations; of particular interest are those with interdisciplinary approaches
- explorations of innovative and effective student teaching/practicum approaches
- reviews of newly developed curricular material
- research on student learning
- reports on projects that include evaluation
- reports on systemic curricular development activities

The Journal of Mathematics and Science: Collaborative Explorations is published in spring and fall of each year. Annual subscription rates are $20.00 US per year for US subscribers and $22.00 US per year for non-US subscribers.

All correspondence, including article submission, should be sent to:

Karen A. Murphy, Editorial Manager
The Journal of Mathematics and Science: Collaborative Explorations
Virginia Mathematics and Science Coalition
Richmond, VA 23284-2014
FAX 804/828-7797
e-mail VMSC@vcu.edu

- For article submission, send three copies of the manuscript.
- The body of the paper should be preceded by an abstract, maximum 200 words.
- References to published literature should be quoted in the text in the following manner: [1], and grouped together at the end of the paper in numerical order.
- Submission of a manuscript implies that the paper has not been published and is not being considered for publication elsewhere.
- Once a paper has been accepted for publication in this journal, the author is assumed to have transferred the copyright to the Virginia Mathematics and Science Coalition.
- There are no page charges for the journal.

Copy editor: E. Faircloth

(Contents continued from back cover)

PART III PROFESSIONAL DEVELOPMENT

PART IV FINANCIAL SUPPORT

CONTENTS Volume 8

(Contents continued inside)