

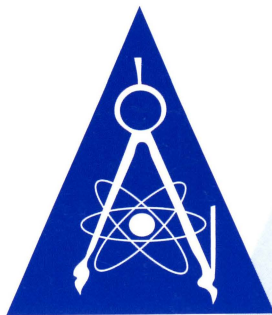
The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

Volume 9, Spring 2007

PART I: SPECIAL ISSUE
Mathematics Specialists' Experiences

PART II: REGULAR JOURNAL FEATURES



Virginia Mathematics and Science Coalition

The Journal of Mathematics and Science:

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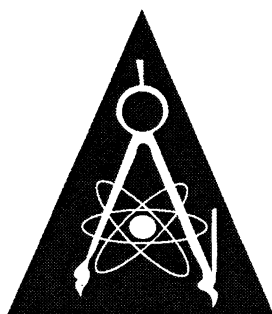
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Mathematics Specialists' Experiences

Funding for this Special Issue was provided by:

ExxonMobil Foundation through the
Virginia Mathematics and Science Coalition

National Science Foundation
TPC Grant ESI 0353360: Mathematics Specialists
in K-5 Schools: Research and Policy Pilot Study
&
MSP Grant EHR 0412324: NSF Institute:
Preparing Virginia's Mathematics Specialists

ELEMENTARY MATHEMATICS SPECIALISTS—WE NEED THEM NOW! FOLLOW VIRGINIA’S LEAD!

F. FENNELL

President, National Council of Teachers of Mathematics

Professor of Education, McDaniel College

Westminster, Maryland 21157

I am so pleased to have been asked to provide the foreword for this very important publication. As noted in my November, 2006 President’s Message, the need for mathematics leaders at the elementary school level is critical. This issue has become much more than a discussion topic. Virginia’s statewide initiative is providing an existence proof for other states and school districts who consider the role, accreditation, certification, and impact of mathematics leaders at the elementary school level, whether these professionals are called elementary Mathematics Specialists, coaches, mentors, or building leaders. The National Mathematics Advisory Panel has identified the need and use of such leaders as an area of interest in the work of the Teachers and Teaching task group chaired by Dr. Deborah Ball. However, as many know, the need for such leaders goes way back.

In 1984, an article appeared in the *Arithmetic Teacher* that asked an important question—“Elementary School Mathematics Specialists: Where Are They?” [1] This was written by John Dossey, who later served as president of the National Council of Teachers of Mathematics (NCTM). In 2007, I am again asking, where are the Mathematics Specialists? We need them, not only in Virginia and not only at the elementary school level, but in all schools throughout the country.

Many school systems are currently exploring ways to ensure that their students receive mathematics instruction from teachers who have a deep understanding of mathematics content and pedagogy; however, some still see this problem as being less important at the elementary grade level. As many of you are aware, major reports—including the NCTM *Principles and Standards for School Mathematics*, *Adding It Up: Helping Children Learn Mathematics*, and the *Mathematical Education of Teachers*—have all called for Mathematics Specialists [2-4]. In 1981, the NCTM Board of Directors recommended that state certification agencies provide for a Mathematics Specialist endorsement on teaching credentials for elementary school teachers. As readers know, Virginia has taken this challenge seriously and now offers graduate level

certification for Mathematics Specialists. I am such a fan of your initiative. Of course, I always claim our Maryland plan (still to be implemented!!!!) caught your attention. The fact is, Virginia is now THE model for a statewide initiative for elementary mathematics leadership. Having said that, the school accountability requirements of the No Child Left Behind Act relative to mathematics achievement have probably done the most to draw attention to the need for Mathematics Specialists in our schools—nationally [5].

Let's examine the critical question: why do we need Mathematics Specialists? Let's look at the elementary school level first. A student's view of what it means to know and do mathematics is shaped at the elementary school level; yet in the United States, elementary teachers in Virginia and elsewhere are, for the most part, generalists. Their pre-service teacher education typically includes two or three courses in mathematics content and one course in the teaching of mathematics. Their teaching load generally consists of a full range of subjects, with particular attention to reading or language arts, in a self-contained classroom. A Mathematics Specialist is needed because the pre-service background and general teaching responsibilities of elementary teachers do not typically furnish the continuous development of specialized knowledge that is needed for teaching mathematics today. The ongoing work of Dr. Ball and others certainly confirms this need for the specialized content and pedagogical knowledge unique to the teaching of elementary school mathematics.

What do Mathematics Specialists do? A number of specialist models are used in school districts in this country. The most common models are the Lead Teacher model and the specialized teacher model. The Lead Teacher model typically involves a teacher in the role of mathematics resource person for a single staff. Sometimes called a specialist or coach, such teachers mentor others in the building through planning, teaching, and coaching. They assist staff in interpreting data and designing approaches to improve students' achievement and instruction and to help ensure that mathematics instruction is aligned with state and local curricular frameworks. They facilitate teachers' use of instructional strategies, including differentiated instruction for diverse learners, and work with families and community leaders to foster school-based partnerships focused on learning mathematics. In addition, they provide buildingwide and, to a lesser extent, districtwide professional development for teachers. Variations of this model may include intervention with small groups of students. Some Lead Teacher/specialist/coach models emanate from the school district office, where the teacher specialist is responsible for more than one site. The specialized teacher model gives one teacher the primary responsibility for teaching mathematics. The specialized teacher typically has responsibility for a single grade; in the elementary school, it is often at the upper grade levels (e.g., fourth or fifth grade).

Although the specialized teacher cannot have the same impact as a districtwide specialist, this model allows the school district to focus professional development and related initiatives on a targeted teacher cadre. In addition, this model has economic advantages because it does not require additional teachers, just a redistribution of teaching responsibilities. Which of these models, or variations of these models, fits your needs?

As school districts determine their need for Mathematics Specialists and find ways to support them, the selection and continued support of Mathematics Specialists become very important. Who is selected? Why? Is it the best mathematics teacher in the building? Is it the teacher who knows the most mathematics? Is it the teacher who would be the best fit in working with other teachers? These considerations—content background, teacher expertise, and the potential for leadership—are all important. Emerging, countywide or school-based, programs in Virginia, and elsewhere, encounter these concerns—regularly. Equally important are recognition and support from the principal and local school district supervisor, who share the responsibility for delivering high-quality mathematics instruction to all students.

Although my focus here, and in the Virginia initiative, has been the crucial need for the teacher leader/specialist at the elementary level, there are similar needs at the middle and high school levels. Call them department chairs. Call them building specialists. Their role, as mentors and as bridges between teachers and building administrators, is essential at all grade levels. Middle and high school mathematics teachers need ongoing content and pedagogical assistance as well. We all do.

Now more than ever, teachers need support. Schools and school districts are beginning to recognize the important role of the Mathematics Specialist and the Commonwealth of Virginia is clearly a model for other states to begin to emulate—even copy. Feel good. Be proud. Enjoy the articles which follow this brief introduction as we all consider how to build on your work and the work of other mathematics leadership initiatives. As we are beginning to see, Mathematics Specialists can make a difference in improving mathematics instruction. We need them—NOW!

Acknowledgments

Dr. Francis (Skip) Fennell is a member of the National Visiting Committees for two Virginia projects: National Science Foundation Institute: Preparing Virginia's Mathematics Specialists (supported by the Mathematics and Science Partnership program); and, Mathematics Specialists in K-5 Schools: Research and Policy Pilot Study (supported by the National Science

Foundation's Teacher Professional Continuum program). This forward is an adaptation of the President's Message which appeared in the NCTM News Bulletin (November, 2006).

References

- [1] J. Dossey, "Elementary School Mathematics Specialists: Where Are They?" *Arithmetic Teacher*, **32**(3) (1984) 3.
- [2] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.
- [3] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.
- [4] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.
- [5] No Child Left Behind Act, Public Law No. 107-110, House of Representatives, 2001, Internet: <http://www.NoChildLeftBehind.gov/next/faqs/teachers.html>

ON BECOMING A MATHEMATICS SPECIALIST—FROM UNLIKELY BEGINNINGS

C. ABDELJAWAD
Arlington Public Schools
Arlington, VA 22207

The year is 1966, I'm eight years old and in the third grade. It's a typically hot and muggy afternoon in the deep south, which is why the unscreened windows of my elementary classroom are raised. The slow turning ceiling fans keep a sleepy beat as the teacher directs fifteen of us, from a class of about thirty, to the front of the room. We line up along the chalkboard rail and open our math textbooks to the page with the lists of multiplication and division facts. The drill is that we each take a turn reading and quickly answering the next fact listed in the column.

I'm not prepared. I haven't memorized the facts yet. I'm sweating and it's not due to the temperature in the room. I manage to find a place near the end of the line to delay my turn. The knot in my throat seems to constrict my breathing. I pray for an easy fact. Please don't let me get 7×8 , or 9×6 .

I listen to the other children take their turns. Kim got an easy one: 3×4 . That's 12. Why couldn't I get that one? Bobby gets 4×7 and misses it. He always misses them. Drill is delayed as the teacher performs her ritual of public humiliation by reprimanding Bobby in front of everyone. I look into my teacher's face while she scolds Bobby. She's focused on Bobby, so it's safe to look at her. I think how her angular features are as sharp as her tongue.

I feel bad for Bobby and look away to the open window. Thick, cracked, white paint separating from old wood testifies to the age of this building. I notice a big black fly buzzing in vain, trapped between panes of glass. I wonder how many children have been trapped in this room like that fly in the window. With nowhere else to turn, I look back down into my textbook.

Then I notice something else! Column one states $3 \times 4 = \underline{\quad}$, and directly across in column two, is $12 \div 3 = \underline{\quad}$. The answer to each fact is the first number in the fact directly across from it. I count my place in line and count down the column to see that the fact will be 7×8 , a fact that I do not know. On my turn, though, I confidently call out $7 \times 8 = 56$.

Round two comes around and I get another fact correct. I don't know my facts, yet I've managed to keep it secret! I breathe easily as round three rolls around. The teacher is emphasizing speed, speed, speed!

Suddenly, the world comes to a complete stop as I hear myself call out $5 \times 4 = 24$. I realize this is the wrong answer as I'm saying it. I know this one. It's one of the easy facts. Of course $5 \times 4 = 20$. I wonder what happened. I realize I must have miscounted down the column. I realize that 24 goes with 6×4 , the next fact under the one I called out.

Wait. What is happening? My teacher has figured out my strategy. She is telling the rest of the class, "If Little Miss Smarty Pants thinks she can get through life cheating, then she's sadly mistaken...let this be a lesson to everyone as Miss Smarty Pants stays in for recess and copies the page five times..."

I'm horrified that my classmates think I am a bad person, but even more embarrassed that they think I'm stupid. I want to scream out that I really do know 5×4 . It's one of my easy ones. In shame, I look back out the window. Big tears swell in my eyes, making the fly look as if it's buzzing under water.

So how is it that years later, this traumatized third grader has become a county Mathematics Specialist? Why is she now so passionate about being a change agent for teaching mathematics for enduring understanding? More importantly, how is she affecting the learning and doing of mathematics for all students and teachers? That is the story I'd like to share.

First of all, I did what many math phobics do: I avoided math as much as possible. I memorized facts and formulas for tests and forgot them as soon as I could. Just passing the test was always my goal. Being able to memorize using the visual-memory file drawers in my brain allowed me to do just that. Throughout elementary and middle school, the gift of memorizing served me well. But even with A's and B's, by high school, I knew something very powerful about myself: "I'm not good at math."

I affirmed this belief when I "hit the wall" while taking Algebra in the ninth grade. That experience sealed my perspective about my ability to think and reason mathematically. Memorizing had failed me. Being able to recall formulas helped little because I had no idea when or how to apply them. I have horrid memories of shame, sitting at the dining room table with my civil engineer father, whom I adored, stressing over factoring binomials. I still feel anxious when

I hear the words, “If a plane leaves Boston traveling at....” Oh, how well an understanding of how the distributive property works in two-digit by two-digit multiplication would have served me then!

Suffice it to say I only took the required courses in high school and college, struggling through them. I chose the likely major that lots of college-bound females of the seventies who thought they weren’t good at math chose, that of elementary education. Safe, yet honorable.

Flash forward a couple of decades to find me passionately immersed in ongoing professional development involving the teaching and learning of mathematics. About ten years ago, a few events came together to entice me onto this unlikely path. First, the Virginia Department of Education was developing a state test for the newly created *Standards of Learning (SOL)* [1]. As a fifth grade teacher at the time, my first and continuing thoughts were: my students are going to need to really understand this stuff if they are ever going to pass the state tests. Secondly, my county implemented a new type of teacher initiated professional development plan. Rather than choosing to create goals for language arts, an area I considered my comfort zone, I chose to focus on my perceived area of weakness: math. Finally, at about that time, the assistant superintendent of instruction introduced the Lead Teacher Initiative, whereby a classroom teacher is paid a stipend to act as a liaison between the Department of Instruction and their school for a specific content curriculum. No one was fighting over the Mathematics Lead Teacher position, so I went for it. Just like in the fairy tales, the three elements combined to work their magic to transform me from fearful math learner to confident math teacher.

It was about that time that I joined a collaborative teacher’s group called Teaching For Understanding. Begun by the mathematics supervisor of my county, we met monthly to discuss professional articles on the teaching and learning of mathematics. We would unpack the big ideas about concepts, before the term “Mathematical Big Ideas” had become a catch phrase. University professors and guest speakers specializing in teaching mathematics would visit our group to engage us in relevant professional development. Then one day, it happened. I stopped thinking about mathematics as discrete ideas and began to realize the interconnectedness of the mathematical themes. I began to appreciate mathematics as an exquisitely beautiful language for representing one’s thinking.

With my desire sparked, I participated in and successfully completed some graduate math education courses, if for no other reason than to free my math demons. Now, I am currently

working with a cohort of Virginia educators to complete a master's degree in Elementary Mathematics Education, funded by the National Science Foundation (NSF). All of these experiences have empowered me to pursue a more focused teaching path as a leader of mathematics reform for my county.

I am now in what I refer to as my "Disciple Era," where I've gone from having a personally vested interest in learning math to spreading the good word about how to teach it for deep conceptual understanding. The *Professional Standards for Teaching Mathematics* publication asserts that, "to reach the goal of developing mathematical power for all students requires the creation of a curriculum and an environment, in which teaching and learning are to occur, that are very different from much of current practice" [2]. In my current position of Mathematics Instructional Resource Teacher, I have the duty and opportunity to work with all students and their parents, as well as with the teachers, to create such an environment. There are, however, obstacles.

There are many persistent obstacles to making significant changes in mathematics teaching and learning in schools. Among these are beliefs and dispositions that both students and teachers bring to the mathematics classroom, as well as the assumptions held by school administrators, parents, and society in general about mathematics curriculum and instruction [2].

Most teachers that I've worked with recognize the value of moving their instructional practice toward an emphasis on mathematical reasoning, conjecturing, proving, and connecting mathematical ideas to applications for problem solving. However, it seems teachers are initially resistant and somewhat reluctant to make changes because of their deep seated belief that they just don't have the time. Then, there are the administrators who recognize the effective impact elementary Mathematics Specialists are having on raising student achievement, yet insist that budget constraints prevent them from being able to fund such initiatives. Of course, my position stands that we don't have time *not* to make time for implementing shifts in our delivery of instruction, and we can't afford *not* to afford the class released Teacher Leader positions that can make it possible.

Change will take time. It will also require sustained systematic support upon which teachers can rely. Enter elementary Mathematics Specialists. In this role, I provide systematic support through ongoing professional development by co-planning, co-teaching, and debriefing lessons with the teachers on staff at my school. Together, we assess student products to inform instruction, plan relevant and engaging mathematical tasks to build upon student understanding,

and collaborate toward building a mathematical community of learners. I provide schoolwide staff development in the form of Best Practice Days, in which my principal provides substitute release time for teachers to participate. Sometimes, I structure these into morning and afternoon sessions to allow groups of teachers from different grade levels to meet and participate in activities and discussions. Other times, I group grades together to focus specifically on an aspect of the curriculum pertinent to those teachers. I also plan and host parent information nights, Family Math Nights, countywide in-services and workshops for other teachers in the county, as well as for instructional assistants.

My passion is to complete the vision for mathematics education described in the *Principles and Standards for School Mathematics*. This vision is highly ambitious and “requires solid mathematics curricula, competent and knowledgeable teachers who can integrate instruction with assessment, education policies that enhance and support learning, classrooms with ready access to technology, and a commitment to both equity and excellence” [3]. The *Professional Standards for Teaching Mathematics* publication gives direction for moving toward excellence in teaching mathematics and makes a case for implementing five major recommended shifts in current practice [2]. I use my role as a site-based Teacher Leader to facilitate the implementation of these shifts in practice.

I’ve had the privilege to work collaboratively with staff and administrators who understand and share the vision for high quality, engaging mathematics instruction for all students. I am proud to work in a school with a diverse population that brings with it challenges associated with language learning and poverty. As a school, we’ve exceeded the requirements for passing the *Standards of Learning Test* and we’ve met the requirements of the No Child Left Behind legislation yet another year, with our focus on learning math with understanding, rather than on teaching to the test [1].

As the school-based Mathematics Specialist, I feel that I can capitalize on what I consider my greatest teaching asset: my ability to motivate others. I have a knack for knowing where someone is in their learning, and then sparking a desire to move forward and grow successfully. I have demonstrated many times a talent for building a community of learners willing to develop and explore mathematics concepts, whether it is in a classroom of fourth and fifth graders, a staff meeting of teachers, or a parent workshop.

I often begin teacher or parent workshops and seminars by providing an index card with the task to describe a math memory from childhood. It is rare to find a positive, upbeat anecdote. Most

people conjure memories of failure and disappointment. Having come from such memories of math, I suppose it is at least a little ironic that I grew up to become “The Math Lady.” I have wondered what would have changed had my third grade teacher focused on the fact that I had noticed a pattern underlying a very important mathematical concept: the inverse relationship between multiplication and division. A teachable moment was lost to accusations of cheating. This Math Lady, although still uncomfortable with the reference, is on a mission. My mission is to ensure that mathematics is accessible to all students from their earliest exposure to its content in the school setting, so that each may fulfill his or her potential to pursue any path in life where their dreams may take them. ■

References

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [2] *Professional Standards for Teaching Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1991.
- [3] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

TRICKLE-DOWN INSPIRATION: FROM MATHEMATICS SPECIALIST TO TEACHERS TO STUDENTS

M. PARUSZKIEWICZ
Hopewell Public Schools
Hopewell, VA 23860

I always knew that I wanted to be a teacher. Growing up, I never lacked for babysitting jobs. I taught Sunday school and vacation bible school, and always had a younger sibling or cousin near. I loved being around children and becoming a teacher seemed like the most obvious of career choices. I never gave much thought to any particular subject; after all, elementary teachers teach everything.

After completing my undergraduate degree, I took a job teaching third grade in a rural, at-risk school division in Virginia. I loved working with the students in this population, but every day brought new challenges. I found myself constantly having to pull new and innovative tricks out of my hat to keep my students interested and, more importantly, to make the curriculum relate to the students. The traditional methods I had learned would quickly be swept aside for more hands-on, student-centered learning. I continued in this position for two years and loved every moment I spent with my students, but I felt that it was time to move on. I took a job in a small, urban school division, again teaching third grade to a population that consisted mostly of at-risk learners. The challenge was still there, but I was ready for something new and different.

After my first year in the new school, the position of Mathematics Lead Teacher, now referred to as Mathematics Specialist, became available. I thought this might be just what I was looking for—definitely new and different. When I called my family to tell them of my new position, they proceeded to find great humor in my announcement. When I was a student in school, I absolutely could not stand math. It was my least favorite subject and the one I struggled with the most. I was an A/B student in all other subject areas but when it came to math class, I was ecstatic if I received a C. I began to wonder exactly what I had gotten myself into as I assured my family that this was not a prank call.

Life has a way of creating ironic situations for us, and I found the subject that I had detested most as a student was the subject that I loved most as a teacher. Through teaching, I had begun to develop a deeper understanding of math myself. I learned that the difficulties I had as a student stemmed from the fact that I was taught math with a chalkboard, pencil, paper, and the

math textbook. If I didn't understand the traditional algorithm, it was seldom presented differently; we simply moved on to the next topic or problem. Upon reflection, I came to understand that students need to be allowed to explore math, and to create their own understanding in order to develop an appreciation of it. This is why I teach math—in the hope that I can foster such knowledge and a love of mathematics.

As I taught, I noticed that the students often lacked a connection to the mathematics we were studying. To help alleviate this, I began developing lessons with a strong focus on the real-world application of the mathematics being learned. The most effective way to do this, I found, was through problem solving. I worked diligently to foster good problem solving skills in both the students and the teachers in my building. We had grade-level problem solving “competitions” and some weekly lessons focused on a specific problem solving strategy. It was amazing to watch students work through a problem and have an “aha” moment as they got the answer. The problems presented to the students were based on real-life situations in order to facilitate a connection between student and mathematics. A vital part of this was not only to solve the problems, but also to discuss the various approaches students took in the solution process. I wanted the students, and the teachers, to understand that math is not a cookie cutter subject and, while final answers should be the same, there are often many ways to get them. This discussion not only gave students ownership of their strategy, but it also helped foster a deeper understanding of the mathematics involved. Allowing students to problem solve and explore mathematical concepts are powerful tools. As students construct their own meaning and context for concepts, they are often able to make stronger connections within and among the concepts being taught; thus, making them stronger and more importantly, more confident mathematicians.

After my first year as the Mathematics Specialist in my building, I began taking the courses designed to provide teachers with a Mathematics Specialist endorsement. These courses have made me a stronger and more confident mathematics teacher. The student who dreaded the challenges of mathematics is now a teacher who embraces those challenges. It is this enthusiasm and love of mathematics that I strive to convey to my colleagues. Perhaps the most difficult element of holding the Mathematics Specialist position is that of being a teacher leader. I have worked closely with my administrators to implement change in a positive fashion, and have persisted when these changes were met with less than enthusiastic responses. Also, I have worked with the teachers in my building in various capacities: including modeling, co-teaching, and co-planning lessons. It takes patience and perseverance, but I have observed that the teachers in my building have become more excited about math and this excitement trickles down to their students.

As a Mathematics Specialist, there are several qualities that I strive to develop in my colleagues. I hope to help them develop *mathematical patience*. As teachers, we need to understand that wait time is essential for students to develop their own ideas and solutions. This requires a great deal of patience, as we often want to *tell* them the solution so that we can move on to the next problem. Diversity is also an important mathematical quality. We must have an understanding that almost every problem can be approached in more than one way and that traditional algorithms aren't always the best way for every student. It also takes an open-minded teacher to have the willingness to go outside the box and try new methods and strategies. Success is not always guaranteed, but as teachers, we owe it to our students to try new things in the hope that they will lead to successes, no matter how small. Finally, I want my colleagues to develop mathematical confidence so that they become more comfortable with the mathematics being taught and know that it is never too late to try a new approach.

I've often thought of those teachers I had as I went through school and I wonder what they'd think of the teacher I have become. I thank them for making me struggle because I think that has made me a much stronger teacher, in that I truly empathize with those students who look at me and say, "I hate math." I want to help those students realize that mathematics is real. We come into contact with mathematical concepts each and every day, though it may not always be apparent. Teaching students mathematics teaches them to think creatively, to reason, and to prove (or disprove) their theories. From mathematics, students understand the value of making mistakes and learning from them. It also teaches the importance of approaching a problem from more than one angle and of accepting and valuing different solutions. Simply put, mathematics is real life. ■

BEYOND THE TEXTBOOK: LESSONS LEARNED FROM TWO YEARS AS A MATHEMATICS SPECIALIST

K. RACE

Alexandria City Public Schools

Alexandria, VA 22311

I check my watch as I back down the driveway and wonder if my commute around the Washington, D.C. Beltway will be a quick one, or if an accident will delay my arrival at school. I mentally list the things I need to accomplish before the school day begins: deliver a set of pattern blocks to the kindergarten teacher who will do a lesson on patterns today; go over number grids with a first grade teacher who sent a panicked e-mail yesterday asking for a quick review of the concept; send a summary to the district staff development coordinator of the session on problem solving strategies I will be presenting to my staff next month; drop off the list of differentiated activities discussed yesterday at the second grade team meeting; and, answer all the teachers' last-minute questions as they put the finishing touches on today's math lessons. I also need to quickly review the schedule of classes in which I will be co-teaching today. Since it's Tuesday, I'll be in five classrooms, helping the teacher present the lesson, working with small groups and individuals, and providing assistance during math game time. My discussion with the principal to beg for money to purchase more geoboards for fifth grade will have to wait until our weekly meeting this afternoon.

I arrive early at school (no accidents today!), and start down my list. Suddenly, a teacher appears at my office door with a puzzled look on her face. She says, "Yesterday, I taught my students the rule that when you divide fractions you just invert the second fraction and multiply, but my students asked why that works and why the answer is larger than the numbers you started with, unlike division of regular numbers." After we work through the concept, drawing pictures and making models, and she goes off to meet her first class, I reflect on what her question tells me about her own mathematical understanding of the concept, the teaching strategies she uses, and her openness to exploring new ideas. Later that afternoon, when I check in with her, we continue our discussion, doing more problems and focusing on good questions she could pose to her students.

Background

My role as the Mathematics Specialist at Douglas MacArthur School in Alexandria, Virginia is a challenging one. Two years ago, the Alexandria City Public Schools (ACPS) placed a Mathematics Specialist in each elementary school. These were, for the most part, teachers

trained previously through the University of Chicago School Mathematics Project (UCSMP). Then in 2004, with the strong support of our superintendent, our mathematics curriculum specialist, the ACPS executive director for elementary programs, and funding from the ExxonMobil Foundation, the ACPS Board of Education directed that each elementary school in the district should have a full-time Mathematics Specialist without classroom responsibilities. Their vision created a curriculum position similar to a Reading Specialist, but with broader responsibilities.

Responsibilities/Goals

Our overarching responsibility is to increase the mathematics achievement of all students in the school by collaborating with individual teachers through co-planning, co-teaching, and coaching. In addition, our duties include:

- Supporting National Council of Teachers of Mathematics (NCTM) and Virginia standards-based instruction;
- Assisting teachers to understand and use mathematics concepts in their instruction;
- Scheduling and encouraging the use of resources such as manipulatives, technology, pacing guides, and Virginia's *Standards of Learning (SOL)* instruction modules [1];
- Co-teaching with each mathematics teacher in the school at some time during the year (strategies include modeling lessons, observing classrooms, co-planning lessons, reflecting on practice, analyzing evaluation data);
- Participating in grade-level, school, and district math meetings;
- Delivering staff development tailored to the expressed needs of classroom teachers;
- Involving families in the school mathematics program; and,
- Working closely with administrators to implement the goals of the Mathematics Specialist Program.

This list of responsibilities seemed daunting when our Mathematics Specialist cadre came together for the first time. Enthusiasm ran high, but with it came the anxiety of implementing a new program and developing a new role. As I look back on the last two years, I realize how much I have grown as a teacher, coach, mentor, and mathematician. I am excited when I hear of the many other school districts across the country that are implementing the Mathematics Specialist model. At national and regional mathematics conferences, I talk to other

Mathematics Specialists and coaches who are anxious to share their experiences and discuss “what works.” The most important lessons I have learned and suggestions I would make to other Mathematics Specialists are outlined below.

Define Your Role Clearly

Your role is to facilitate teacher learning which, in turn, leads to improvement in student learning. You will be an agent for change, the goal being to encourage teachers to change their thinking about mathematics, not just improve individual lessons. Be sure they understand that your job is to help them increase their own understanding of mathematics and also to ensure the success of their students.

Build Collegial Relationships

The relationships you develop with the teachers in your school will be a primary focus. It is critical to establish trust and confidentiality with each teacher. Perform your job so that they know they can count on you to support them in every way. Try to arrive at school before most teachers and be there at the end of the day so you are available to answer questions. In the school, be visible to teachers and parents. Build an organizational structure to your day and week, and then post your daily schedule so the staff knows you are in classrooms on a regular basis and where to find you. Your role will vary according to the needs of each teacher. Plan to spend extra time with first year teachers and those who need more help. You will observe, model lessons, co-teach (partners), and work with small groups. Be sure to listen as much as you talk. The time you spend discussing mathematics lessons may be the only opportunity teachers have to reflect on their practice. Remember, the key is collaboration.

Continue to Grow Professionally

Be knowledgeable about content and curriculum, the NCTM and Virginia standards, and how children learn. Seek out opportunities to increase your own understanding by taking courses from *Developing Mathematical Ideas (DMI)* [2]. My training with nationally known experts provided the mathematical underpinning essential to coaching. Join local, state, and national mathematics organizations like the NCTM and National Council of Supervisors of Mathematics (NCSM). Attend their conferences to keep current about new developments in the field, to increase your knowledge, and to share ideas with other Mathematics Specialists. Distribute articles from their publications to your teachers and discuss them at team meetings. Develop a lending library of manipulatives, games, reference works, and technology for use by teachers, students, and parents. See yourself as a learner and part of a learning community. Read widely in the content area [3-9].

Develop a Strong Relationship with Your Administrator

The administrator can determine the success or failure of the program at your school. If the staff knows that your administrator supports you and the Mathematics Specialist program, they will be more open to your regular visits to their classroom. Encourage the administrator to clearly state to the faculty that you will be in each classroom and that your visits are not optional.

Meet at the beginning of the year to develop common goals, and set up a regular time each week to keep the principal informed of all mathematical issues. Remember to keep the confidentiality of the teachers with whom you work; remind them that you are not an evaluator. If you are concerned about a teacher and what is happening in her classroom, suggest that the principal observe that classroom during a math lesson. Encourage the administrator to schedule a common planning time for each grade level so there will be an opportunity for you to meet with them as a group to discuss content and strategies. Trying to schedule a meeting with each teacher is difficult and many concerns can be addressed to the group.

An important role you can assume is as a liaison between teachers and parents. Encourage your principal to refer parents with questions about the math program to you. They will be pleased to be able to speak to an “expert.”

My principal believes so strongly in the value of the Mathematics Specialist model that this year, she has directed our reading teachers to become coaches working with teachers in the classroom rather than pulling students out of the classroom. More students benefit from the expertise of the Specialist when she works with the classroom teacher rather than with small groups of students.

Provide Staff Development

Provide regularly scheduled staff development sessions for the entire staff and for specific grade levels. You can address issues that are of concern to your own teachers, rather than relying on systemwide sessions that may not meet the needs of the teachers at your school. Some of the best staff development occurs during those spur-of-the-moment conversations in the hall and at lunch, which can be just as effective as more formal presentations.

Use grade-level meetings to put the focus on math. Since teachers at our school have a common planning time each day, one planning period every two weeks is devoted to mathematics. During that thirty-minute time period, we discuss content and instructional

strategies, work with manipulatives, and play the games that will be introduced in the next two weeks. Remember always to keep teachers focused on the mathematics in each lesson.

Expect Teacher Resistance

Expect teacher resistance, especially if you are using a reform curriculum. Some teachers may feel threatened and uncomfortable having another person in the classroom. Others are unsure of their mathematical knowledge or teaching ability, or simply are not comfortable with change. Plan to spend more time with these teachers, providing them with whatever will make them more confident. Offer to gather materials for a project, teach a lesson or game, develop an assessment, or write a math newsletter for their class. Work at their comfort level, and gradually increase your involvement in their class.

Develop a Network of Other Mathematics Specialists

Meet regularly with other Mathematics Specialists in your district or in a neighboring district. You will find this time invaluable for sharing knowledge, solutions to common problems, and strategies for working with teachers. You need the support of other people facing the same challenges.

Involve Families in the School Mathematics Program

Family involvement is especially important if your district uses non-traditional teaching materials. Parental resistance can be disastrous for a new adoption. Early in the school year, a general presentation at a PTA meeting will familiarize parents with the philosophy of the curriculum. During the school year, workshops for parents by grade level provide opportunities for them to participate in the hands-on activities and games that their children are experiencing in class. Family Math Nights are also effective ways to get parents into classrooms to participate in math activities. The more parents understand the mathematics and the instructional techniques of a program, the more supportive they will be.

Set Goals for Yourself

As Mathematics Specialists, we ask teachers to reflect on their practice, refine it, and be willing to try new strategies. We also need to set personal professional goals for ourselves and share them with other teachers. One area in which I would like to be more proficient is the analysis and interpretation of assessment data, including unit tests, quarterly tests, and standardized test results. Using those analyses, I want to learn to design ways to improve instruction and student achievement. I also want to help teachers become more comfortable using

differentiated instructional strategies, not only with those students categorized as English as a Second Language (ESL), Learning Disabled (LD), and Gifted, but with all students.

Conclusion

The job of the Mathematics Specialist is a rewarding one. For every teacher, the moment when a struggling student's face lights up and he says, "Oh, I get it!" makes the hard work of getting him to that point worth all the effort. The Mathematics Specialist gets the same reward when a teacher says, "When I was in school, I could do the math, but I never understood why. Now it makes so much sense. I can't wait to share this with my class." If we can be the agent of change for teachers, encouraging them to broaden and deepen their thinking about mathematics, we will have given them and their students the best possible gift. ■

References

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [2] D. Schifter, V. Bastable, and S.J. Russell (eds.), *Developing Mathematical Ideas*, Dale Seymour Publications, Parsippany, NJ, 1999.
- [3] S. Chapin and A. Johnson, *Math Matters: Understanding the Math You Teach*, Math Solutions Publications, Sausalito, CA, 2000.
- [4] J. Kilpatrick, J. Swafford, and B. Findell (eds.), *Adding It Up: Helping Children Learn Mathematics*, National Academy Press, Washington, DC, 2002.
- [5] L. Ma, *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Lawrence Erlbaum Associates, Mahwah, NJ, 1999.
- [6] "Mathematics Specialists Task Force Report," Virginia Mathematics and Science Coalition, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 5-22.
- [7] J. Mokros, S.J. Russell, and K. Economopoulos, *Beyond Arithmetic: Changing Mathematics in the Elementary Classroom*, Dale Seymour Publications, Parsippany, NJ, 1995.
- [8] J. Van de Walle, *Elementary and Middle School Mathematics: Teaching Developmentally*, Pearson/Allyn and Bacon, Boston, MA, 2004.
- [9] L. West and F. Staub, *Content-Focused Coaching: Transforming Mathematics Lessons*, Heinemann, Portsmouth, NH, 2003.

WHAT DOES IT MEAN TO BE AN ELEMENTARY SCHOOL MATHEMATICS SPECIALIST?

D. GATES

*Fairfax County Public Schools
Falls Church, VA 22042*

Introduction

An elementary school Mathematics Specialist is a change agent, a continuous learner, a facilitator, a person who keeps up with the research on best instructional practices—in short, the Mathematics Specialist is on a continuous journey of improvement. S/he arrives at school early, stays late, collaborates with teachers and administrators, and does whatever it takes to ensure students are learning mathematics with meaning and understanding. The Mathematics Specialist does not pull out small groups of students, but instead works with a school (or schools) to develop a Professional Learning Community in mathematics, provide job-embedded professional development, and enhance best instructional practices which ultimately will improve student understanding of mathematical concepts.

This can look different at every school and can be challenging, yet quite rewarding. Knowing the mathematics vision for the school, communicating the role of the Mathematics Specialist, organizing, planning ahead, and thinking about the desired outcomes will help to maintain the focus on best instructional practices and student learning. The contents of this article will describe a few elements that are advantageous in the role of a Mathematics Specialist in Virginia.

What Will We Teach and How Will We Know If They Have Learned It?

Ensuring that each teacher has the necessary curriculum documents to facilitate the learning of the mathematical concepts is an important component of student learning. During grade-level meetings, the contents of the documents and teaching tools (listed below) can be reviewed and discussed.

Mathematics Standards of Learning Curriculum Framework — This document describes every objective students must learn and be able to do by the end of the given grade level. It also provides clarity of the specific objectives [1].

Standards of Learning Test Blueprints — This document lists every objective that students must learn for the *Standards of Learning* Test beginning at grade three [1].

Standards of Learning Released Test Items — The state releases many of the test questions from previous tests. Reviewing (or even working through) the released tests is helpful in gaining a deeper understanding of what is expected from students at each grade level [1].

Curriculum Map or Pacing Guide — Whether the county school system has a preferred pacing guide or teachers create one, this document helps to keep the focus on and the momentum of what is to be learned.

Common Assessments — Many school systems or grade-level teams collaborate to develop common assessments to use throughout the school year. These assessments can be tools for determining if what is instructed is learned.

Assessment Data — This data may be extracted from at least three different sources: common assessment data; informal assessment data (analytical notes); and, *Standards of Learning* Assessments. Discussing assessment results, students' thinking, and planning next steps is an essential component for evaluating what and how the students are learning. Some questions that may be helpful in the discussions include:

- Which students do not understand the concepts?
- Which concepts are still challenging for many students?
- Which students must be challenged or enriched?
- What new instructional practice could be explored?
- What is the plan for addressing the above?
- What are common errors of students?

The answers to this last question are easy to identify when students show their thinking directly on the assessment. An item analysis is another helpful tool; for example, "If the correct answer is 'B,' why did most of the students select 'C' for their answer?"

Articles and Instructional Practices — Sharing information or articles on best instructional practices, or even working through mathematical concepts with teachers is another technique to promote and encourage teachers to keep up with the current research and understand the mathematics they are teaching.

How Will We Teach?

Numerous research studies have recommendations for best instructional practices for how students learn mathematics. Which of those practices are in the school improvement plan? Observing and listening in classrooms is one technique for gaining an understanding of the

mathematics culture in the school and for identifying components that are strong and those that may need improvement. Together with colleagues and administrators, an area of focus can be determined. A few elements that many Mathematics Specialists look for and continue to focus on are outlined below.

Communication in Math Class

- Are students writing and talking about the mathematics they are learning?
- Are students showing their thinking and explaining their reasoning?
- Are students justifying and sharing their solution strategies with peers and adults?
- Are students making connections and conjectures?

Problem Solving

- Is there a problem-solving approach to instruction?
- Are the math problems based on real life and meaningful to the students?
- Are students encouraged to explore multiple solution paths and strategies for solving problems?
- Are students encouraged to solve math problems in their own way?

Reasoning Abilities

- Are students encouraged to make sense of the mathematics they are learning?
- Are students reasoning and drawing logical conclusions?

Manipulatives

- Are manipulatives within arms' reach of the students in the mathematics classroom?
- Are students using the manipulatives to make sense of the mathematics and to solve math problems?

Evaluation

- What method is used to determine if students really understand what is instructed?
- How are students applying their understanding?
- How is the information from formal and informal assessments used?
- Are teachers able to take what they know about their students and build on it?

Mathematical Content

- Does every math teacher understand the mathematical concepts that are to be learned?
- What method is used for handling misconceptions?

Mathematical Knowledge

- Do the students have the conceptual knowledge to understand the procedural knowledge?
- Are students learning mathematics conceptually?

Teacher as Facilitator

- Does the teacher provide engaging problems for the students?
- Does the teacher listen intently to students' ideas and value student thinking?
- Does the teacher encourage students to listen to students?
- Does the teacher continually ask questions to elicit, clarify, and extend student thinking?

Some of these questions might include:

“How did you figure that out?”

“Is there a different way to solve that problem?”

“Will that strategy always work?”

“How do you know?”

“What would happen if...?”

“How are these strategies alike/different?”

“How could you make this a more challenging problem for yourself?”

Coaching, Planning, and Teaching

What are the mathematical goals for the children? What will they be able to do by the end of the lesson? How will they communicate their understanding? What misconceptions or confusions might the student(s) have? What will and how will the tasks or problems be presented? These are just a few questions to consider in planning lessons with teachers. In *Content Focused Coaching*, a lesson design is used as a structure for planning lessons [2]. Addressing such questions help to keep the focus on student learning.

There are a variety of methods for working in classrooms with teachers. Some Mathematics Specialists work side by side with three or four teachers for two or three weeks in a row, then move on to a new set of three or four teachers. Others might work with one grade level at a time. There are other Specialists that work based on need or specific focus. In the latter example, perhaps there is a grade-level team that would like some assistance in enhancing students' test taking strategies. This may require planning with a team together, and then rotating through each teacher's room to assist (or coach) each teacher as s/he tries a new strategy. This method also works if a grade-level team is trying to improve their questioning strategies, set up learning centers, explore a new teaching technique, or perhaps try their own version of the Japanese Lesson Study.

Teaching conceptually may be new to many teachers. The Mathematics Specialist can encourage teachers to give students the opportunity to explore and solve problems in ways that

make sense to them. S/he can also encourage the students to talk about their thinking and assist teachers in planning meaningful real-life tasks, facilitate lessons together, and debrief the learning afterward. These ideas will gradually lead toward teaching conceptually.

Planning and Debriefing

Defining the roles of Mathematics Specialists and teachers, ascertaining effective methods of information dissemination, and organizing uniform data collection are all efficient means of translating the day-to-day teaching activities into viable assessments for long-range planning. It is not enough for the Mathematics Specialist to meet the daily demands of the position; s/he must also keep an eye on the big picture. Some of the questions below may provide several different perspectives toward this end.

- What is the role of the Mathematics Specialist and what is the role of the teacher when facilitating math lessons in the classroom?
- When will the planning, debriefing, and examining of students' work samples and thinking take place with teachers?
- How will common assessments be developed and how will assessment results be recorded, shared, and used?
- When and how will analyzing of assessment results with teachers and with students take place?
- What method will be used for sharing and discussing current research articles or information?
- What method will be used to determine and provide professional development in the school?
- How will the professional development sessions meet the goal of the school vision for mathematics?

How Does a Mathematics Specialist Know S/He Is Making a Difference in Student Learning?

Elementary Mathematics Specialists want students to understand the mathematics they are learning, and to be confident and successful problem solvers who are eager to take on the challenge of any math problem. When a student stops you in the hall to describe how s/he solved the math problem that day, or you receive an e-mail from a teacher expressing how much she is learning from her students and that math is once again fun to teach, you know are making a difference. ■

References

- [1] Virginia Department of Education website, Internet: <http://www.pen.k12.va.us/VDOE>
- [2] L. West and F. Staub, *Content-Focused Coaching: Transforming Mathematics Lessons*, Heinemann, Portsmouth, NH, 2003.

THE ROLE OF THE MATHEMATICS SPECIALIST IN ALBEMARLE COUNTY PUBLIC SCHOOLS, VIRGINIA

A. LARUE-DAVIS
Albemarle County Public Schools
Charlottesville, VA 22902

Introduction

The call for Mathematics Specialists in elementary and middle schools has become an increasingly visible effort as research uncovers our nation's trends in success rates and challenges with teaching students a deeper understanding of mathematics. Critical as an underpinning for higher levels of mathematics in high school and beyond, elementary and middle school mathematics form the building blocks of basic number sense, problem solving, logic, reasoning, and communication about quantifiable data. A solid foundation in these early years of mathematics is of paramount importance to our long-range national success in the global economy and business world our children will face as adults, which is why this issue has become a call for action in our nation today.

Mathematics Instruction

In particular, strengthening our elementary mathematics instruction requires concentrated support for our elementary teachers in both content and pedagogy in order to provide instructional programs that advocate the teaching and learning of mathematics for deeper understanding. A significant distinction between teachers at the elementary school level and those at middle or high school levels is that in elementary schools teachers are generalists, being required to teach all content areas: language arts, social studies, science and math. Therefore, they often lack the mathematics background necessary to implement mathematics curriculum with rigor. Teachers in middle and high school levels, by contrast, typically teach a single subject, which is their specialty. Therefore, weakness in the mathematics portion of elementary teacher training unfortunately manifests itself in ways that are becoming increasingly evident in data analysis on our students' success in mathematics. If teachers lack deep content knowledge, they consequently lack understanding of how to guide mathematics discussion in the classroom. This discussion piece is critical in developing divergent thinking, and promoting reasoning and logic. The foundation of elementary mathematics needs strengthening, and this fact is well substantiated by research and data.

Strengthening deep mathematical understanding for all students is the goal. Based on the disaggregated data of Virginia's *Standards of Learning (SOL)* tests in mathematics, there is clear

trend data revealing achievement gaps between the percentage of pass rates of Caucasian students and students in subpopulations including African-American populations, children from poverty, those with learning disabilities, and students for whom English is a second language [1]. Not only is there a discernable achievement gap for subpopulations, but there is also recognition that the *SOL* tests are assessments of minimal standards. This fact makes it all the more disturbing, therefore, to note that more students are not achieving advanced proficiency levels in mathematics. The data reveal evidence that “teachers must be supported in deepening their own content knowledge along with content pedagogy knowledge” [2].

Mathematics Specialists

One viable solution to this increasing need for support for elementary mathematics teachers is the model of the Mathematics Specialist. As defined by the Mathematics Specialist 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 [3].

As our nation recognizes the increasing need for Mathematics Specialists in elementary and middle schools, it is of value to examine what effects may already be seen in some of Virginia’s schools and school divisions where such Specialists have begun this important work. While an increasing number of the Commonwealth’s school divisions have already begun to embrace and fund initiatives to put Mathematics Specialists in their schools, other divisions are in a state of transition toward that goal, and are demonstrating efforts that reflect their collective energies as they think outside the box. The following is an account of some of the supporting work currently being done in Albemarle County Public Schools in central Virginia.

Albemarle County Public Schools

Through the National Science Foundation's (NSF) funding of a six million dollar grant for systemic change in mathematics instruction, Albemarle County joined in a partnership with Virginia Tech (2000-2004), in a five-year intervention program providing professional development for elementary teachers upon the adoption of the national standards-based mathematics curriculum, *Investigations in Number, Data, and Space* [4]. This divisionwide teacher training initiative has provided professional training for a total of approximately 280 teachers thus far. The instructional team for this professional training model has included the Mathematics Instructional Coordinators for the division, as well as a Mathematics Specialist.

In addition to this training of experienced, practicing teachers already within the division, Albemarle County's efforts are also focused on working directly with all new elementary school teachers who teach mathematics. The model being implemented embraces a variety of formats, including strategies promoted strongly by the new program of studies which provides licensure for Mathematics Specialists in the Commonwealth of Virginia.

The Virginia Mathematics Specialist Program and the Virginia Department of Education have provided opportunities at several Virginia universities and colleges to attain licensure in this area. Working toward a Master of Education as a K-8 Mathematics Specialist through the University of Virginia, one Albemarle County Mathematics Specialist has been providing a model of support for fellow teachers within her school, while still being a full-time classroom teacher. This model has a transitional look about it, as support for Mathematics Specialists gains recognition for the importance of this work. Providing curricular support within the school, and assisting in the leadership of vertical articulation about expectations for K-5 math achievement within the school, have been high priorities for Albemarle County Public Schools. Using problem-based, inquiry instruction, the division is building consistency of expectation and experience for its students. They have greatly enhanced their collaborative efforts and site-based professional development to center around increased rigor in the development of mathematical reasoning and problem solving. Among other specific strategies used in this site-based approach has been the investigation and review of Bloom's Taxonomy and constructing higher-level tasks and assessments for students. Collaborative planning at each grade level has enabled teachers to carefully analyze assessment results with a focus on how and why certain cohorts of students demonstrate more success and mastery of mathematics content than do other groups. Teachers share and compare instructional techniques, and glean from one another "the best of the best." The Mathematics Specialist facilitates and participates in these grade-level collaborations, implementing content-focused coaching modeled after Lucy West's work [5]. Delving into the

mathematics behind the lesson and discussing student learning and specific instructional strategies, has strengthened the effectiveness of this mathematics instructional model. This Professional Learning Community model has had an excellent impact on the communication between colleagues as they work collaboratively and collectively for the improvement of student learning in mathematics.

Coordinating strategic scheduling and careful teacher planning, the Mathematics Specialist has been able to utilize planning blocks (when her homeroom students go to Physical Education class) in order to provide both pre-teaching and remediation to students in grades three through five within one school. The benefits of this pre-teaching strategy have been revealed through the success rates of the most at-risk students. Pre-teaching is an instructional strategy some teachers in Albemarle County explored greatly this year in working with at-risk math students. Rather than relying on remediation after the students demonstrate a lack of mastery, this strategy—sometimes referred to as “front-end loading”—involves dusting off prior knowledge, and building a stronger foundation for upcoming skills and concept acquisition. Once that background knowledge groundwork is laid, pre-teaching certain aspects of the specific skill set or concept helps trigger a series of improvements in the students’ learning, including improved self-confidence and attention during mathematics class. The cumulative effect is very notable. By pre-teaching concepts and content-specific vocabulary for the upcoming lesson, the Mathematics Specialist’s work enables these same students to enter class with an increased self-confidence in their ability to learn. They are more attentive in class, participate more confidently, and seem to retain more.

Working very closely with the classroom teacher, the Mathematics Specialist has not only been able to provide this strategic pre-teaching and remediation for at-risk students, but has also worked to develop compaction and differentiation of mathematics instruction for students with advanced capabilities. Developing a compacted fifth/sixth grade curriculum taught in fifth grade has enabled a large number of students from several of the division’s schools to receive rigorous, enriched mathematics instruction in above grade-level mathematics classes.

Conclusion

Teacher training, content-focused coaching with modeling of lessons, collaborative planning, and working directly with cohorts of students, have become diverse ways of exploring the potential benefits of having a Mathematics Specialist available at the building level in order to work with teachers to strengthen their effectiveness with meeting the needs of students. It will be the students in Albemarle County and other school divisions around the Commonwealth who will

ultimately reap the benefits of this much needed, strategically targeted mathematics support for elementary teachers in a nation striving for excellence in mathematics. ■

References

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [2] “Mathematics Specialist Task Force Report,” Virginia Mathematics and Science Coalition Task Force, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 5-22.
- [3] “Mathematics Specialists Definition,” Mathematics Specialists School and University Partners, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005) 1-2.
- [4] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: <http://investigations.terc.edu>.
- [5] L. West and F. Staub, *Content-Focused Coaching: Transforming Mathematics Lessons*, Heinemann, Portsmouth, NH, 2003.

THE MATHEMATICS SPECIALIST AS VISIONARY STRATEGIST

K. ANDERSON
Fairfax County Public Schools
Falls Church, VA 22042

Introduction

The role of a Mathematics Specialist is a multifaceted, multidimensional role and is dependent upon the district you are from, the school in which you are working, or most often, the person overseeing the position. In Fairfax County, the principal was the person overseeing my role. Having just come from a middle school, this principal was used to having department chairs. The principal treated all of the instructional leaders in our school as department chairs. It was our role to know what was happening throughout the school and to develop a plan to improve instructional practices within the school. At first, achieving an overall vision was a difficult task. It took time to learn the practices being utilized, and to build relationships with the other teachers to effectively create change. I began creating a strategy for our vision of improving mathematics instruction and student learning.

Three-Week Partnership

One way in which instructional practices began to change was through co-planning and co-teaching. Since the school I work in is very large, I spend three weeks (at least once a year) working in each classroom. I meet with the classroom teacher the week before I will begin working in their room in order to discuss what they have been working on, how they have been using their instructional block, and discussing the needs of the students and the needs of the teacher. At this time, we decide on a focus. Some of the things that we often focus on are structuring the math block, developing centers or stations, differentiation, how and what materials to use for a specific concept, and helping students communicate mathematical thinking orally and in writing.

After a focus is chosen, the classroom teacher and I sit down to begin planning the first week of lessons, and to discuss how we want to work together during the three weeks. Often, the time working together consists of the Mathematics Specialist modeling lessons, co-teaching, and observing the classroom teacher. The normal progression is for me to do all of the teaching, but gradually turn it over to the classroom teacher so that, by the end of the three weeks, s/he is doing most or all of the teaching. During the time in which I am modeling lessons, the classroom teacher is expected to be taking notes for a discussion we have following the lesson. The

classroom teacher and I discuss, either in a formal setting or via e-mail, what went well, what we could have done differently, and where to go next each day. We continue to plan and rewrite plans based on the students' learning. The goal is that by the end of the two weeks, the classroom teacher has made changes to improve math instruction and student learning.

Teacher Population

The balance of supporting teachers has been a great challenge. There are classroom teachers that are in need of significant support and others that do not need as much support, but are very open to learning and improving their instructional practices. At first, it was easy for me to get caught up in working with teachers who asked me to come in and support them; they were very open to reflecting on their own practices and often asked for suggestions for improvement. However, I also had to spend a great deal of time fostering relationships with teachers who wanted to close their door to an outsider. It was necessary for me to find a way to get into their classrooms to support their instruction.

Integrating Learning Models

The school system in which I work has adopted the Professional Learning Community model. The Professional Learning Community model is based on looking at student work and student achievement in order to determine what to do with those who understand concepts and what to do with those who don't. Part of my responsibilities as a Mathematics Specialist was to help facilitate the growth of this model, of course tying into our school math goals. Each grade-level team has common planning time every week in which they are to have discussions based on student learning and instruction. To facilitate these discussions for mathematics instruction and learning, teams were asked to schedule monthly or biweekly meetings with me. The discussions in these meetings varied based on the teams. Some teams were more established and further along the continuum while some were not ready to begin discussions on student work.

One of our primary grade levels began working with a new textbook series and needed a great deal of support with the spiraling curriculum. At these grade-level meetings, we spent much of the time discussing how the concepts in this series related to county and state standards. In doing so, we created anecdotal recording sheets to keep track of the standards for the county, state, and series. A recording sheet was created noting textbook objectives, county objectives, and state objectives. Toward the end of the year, we had the opportunity to look at these recording documents to determine student needs. The classroom teachers were able to see how their classes were doing with certain concepts while also looking at the grade level as a whole. The teachers often used this information for remediation and enrichment purposes. One of the

most powerful aspects of these discussions was for me to be able to share some of the needs with the previous grade level and the teachers for the following year.

Another one of the grade-level teams felt very uncomfortable with teaching fraction concepts. Much of this came from not fully understanding the concepts themselves. The team met twice a week during the unit of fractions, to discuss best practices in teaching this concept. We spent time developing lessons, and with each lesson spent time practicing using the tools and manipulatives that would best help the students' understanding.

Developing Student Assessment Tools

Our fourth grade team decided they wanted to rewrite their common assessments to be more informative for their instruction. We first met and looked at all of the county and state objectives. The objectives were put into a teaching order, and numbered appropriately within a spreadsheet. As a team, we then started developing assessments. Each question on the assessment correlated to a numbered objective and were written in many different formats. Some of the questions were written in multiple choice and some in short answer, since one of our school goals was developing students' mathematical thinking shown through discussion and writing. To facilitate discussions about the common assessments, another spreadsheet was created for the teachers to input the data from their tests. The teachers would bring copies of this spreadsheet to the meeting to discuss students who were having difficulties with certain concepts. These difficulties were easy to determine since all of the questions related to a specific objective. As a team, the teachers were able to learn how to best meet the needs of all of their students. They decided to spend one day a week regrouping their students based on needs for specific concepts.

Roles for the Mathematics Specialist

As an instructional leader at the school, there was also an after school book group developed based on our school goal of helping students show their mathematical thinking through discussions and writing. It was the responsibility of the Mathematics Specialist to facilitate these meetings by fostering an environment conducive to discussions.

A Mathematics Specialist can take on many roles within the school. The most important part of the role is to understand the culture of the school and meeting the teachers where they are, and then moving them forward in their instructional practices and their content understanding. ■

THE CHARACTERISTICS NECESSARY FOR A MATHEMATICS SPECIALIST

D. SOUTHWELL
Alexandria City Public Schools
Alexandria, VA 22311

Reflection

Did you ever find yourself asking, “Just how did I get here?” Did you ever think, “I never would have guessed I’d be doing this”? Did you ever question whether what you’re doing is even worth doing? If you have, you already hold one of the necessary characteristics for doing the work I do and that is being *reflective*. What are the others? I invite you to read on to learn about this educator’s foray into the world of public and private school mathematics within an urban East Coast setting. Over the course of fifteen years, I have asked myself these questions numerous times because I am a Mathematics Specialist. I have been a pioneer Mathematics Specialist, an apprentice Mathematics Specialist, a journey[wo]man Mathematics Specialist, and will soon be a Virginia certified Mathematics Specialist.

Many mathematical moons ago, I took a job as a “Mathematics Specialist” at an independent elementary school in Washington, D.C. Did the headmistress, the school board, or I know what a Mathematics Specialist’s role would be? No, but due to the birth of the 1989 *Principles and Standards for School Mathematics* from the National Council of Teachers of Mathematics (NCTM), the school board decided that the community needed to understand what this document meant so that the school could be in the front of the independent school pack showing their stuff [1]. So I plowed ahead, determined to make a difference. But why? Wasn’t I already making a difference in the lives of students? I was an established elementary classroom teacher and Learning Disabilities Teacher, and had received much satisfaction in these roles. Something about working in mathematics education intrigued me. For one thing, I saw this as a new challenge—little did I know how much of one. I also knew that the way I, and my colleagues at various United States schools, had been teaching math was not working. In addition, I wanted a position where I could work in a more *collaborative* way with fellow teachers than I had been.

Collaboration

As I look back now at my first experience as a Mathematics Specialist, I recognize to an even greater degree than I did then the strangeness of what I was doing as seen from my colleagues’ perspectives. Since my role wasn’t clearly defined, they accepted me drifting in and out of their classrooms as I sized up how they were teaching, what mathematics they were

teaching, and the extent to which the math being taught connected with the 1989 NCTM *Principles and Standards* publication [1]. Within a profession where teachers have worked historically and primarily in a solo capacity, I was an oddity for intruding in my colleagues' teaching spaces.

Flexibility and Fortitude

Many times since those early years, I experienced and witnessed a variety of reactions to my role in the exploration of classroom mathematics teaching and learning. Some people wanted a new experience, and were open to collaborating. Some wanted to show how they would try something new by using new math material—but strictly on their own terms and in their own way. Some showed me the way math was taught in their classrooms, and then indicated that I could help out within that specific structure. Others nervously laughed, joked, and apologized their way through lessons and meetings, telling me that there was just too much material to read through and they weren't exactly prepared, but would be the next time I was with them. Still others made themselves consistently unavailable. These various examples of reactions point to the *flexibility and fortitude* one must have within this role.

Decision Making Ability

Since my position as a Mathematics Specialist lasted ten years at one school, I was able to see dramatic change take place. I never thought it would take that long. In the other two settings I've worked as a Mathematics Specialist, I have also seen changes, but they've been relatively few since these schools have only recently had someone in the Mathematics Specialist position. Working with different teachers and administrators, as well as students and curricula, the work of a Mathematics Specialist calls for constant *decision making*. There is never a dull moment, and there are always various goals to be working toward.

After ten years in the independent school setting, I returned to public education. My work as a Mathematics Specialist took me to the growing educational segment of charter schools. I took a position in a progressive elementary/middle school that was only a few years old. With a young staff full of energy, there was no need on my part to motivate them on the subject of mathematics professional development. The desire was there to learn and standards-based curriculum materials were in place, but there was no vision of the road leading toward a change in teaching mathematics. No one was to blame for this. As is the case in many kinds of schools, there was no one with prior experience of learning math in a *holistic* way as is being called for by reform-based mathematics curricula and the 2000 NCTM *Principles and Standards* publication [2]. My job required me to educate teachers, administrators, students, parents, and the larger

school community. This was the inviting part of my work; but, between each of these groups and me came parental fears, the media, competing schools, and finally, the institutional memory regarding teaching and learning mathematics by society at large. The path would not be a smooth one.

Summary

Since beginning this work in 1991, I have witnessed and read about heated discussions on the evils and wonders of this “new kind of math.” From school board meetings to parent e-mails to teacher remarks in the staff room, the passion brought about by discussions related to mathematics has been certainly frustrating at times since in my school role I have been a “lonely” figure—someone who is neither in an administrative position nor a teaching position. Over time, however, I have experienced an increased sense of belonging. I chalk this up to the expanded work of NCTM and the many original publications that have been created by this organization to educate and set goals for mathematics learning in our country. Conferences, workshops, on-line seminars are a few of the mediums I have used to network and grow in my position. In the last two years, I have found a true home as a Mathematics Specialist inside a district that supports a collegial band of Mathematics Specialists who can raise consciousness and improve craftsmanship within our schools, within our district, and within our state.

Two fundamental beliefs that have guided me over the years in this work are: 1) the idea that all children can and need to learn mathematics with conceptual understanding; and, 2) the idea that both adults and students construct their mathematical knowledge. Both of these beliefs are controversial and demand time to occur. In a culture where time is money, and where the national and local politics of right versus wrong guide educational policy, these beliefs can be intentionally and unintentionally trampled and disregarded. I see it as a core piece of the Mathematics Specialist’s work to raise these beliefs for examination and reflection when providing professional development to educators of all types. ■

References

- [1] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1989.
- [2] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

BREAKING THE CYCLE: INTEGRATING THE MATHEMATICS SPECIALIST

T. HULEN

Fairfax County Public Schools

Falls Church, VA 22042

Background

As a math student, I really struggled. To myself and most of my teachers, math was all about memorizing procedures and facts, and as a result, I ended up with a limited mathematical foundation of the concepts. I always knew I wanted to be a teacher, but when it came time for student teaching, I was scared to death of teaching mathematics.

In my senior year, however, I was accepted into a program where I student taught every day during the school year. At night, I had classes in the school's library for three or four hours. My cooperating teacher and my math professor had partnered together for three years, and studied mathematics best teaching practices. At night, I was learning how to teach math conceptually while during the day, I was seeing the practice modeled within the classroom. Throughout the year, things started to click. I now understood the meanings behind the concepts and the procedures. I was learning the content as well as watching, observing, and learning about Mathematics Specialists and their technique of teaching mathematics with understanding.

The following year, I began teaching a fifth grade class (the same grade I had student taught the year before). I modeled my mathematics community after my cooperative teacher's classroom; everything I had learned from her and my professor was being implemented in my own classroom. New to the school and county, and having a new passion to teach mathematics, I involved myself in every possible area of mathematics. I took a math course and became a Mathematics Lead Teacher in my school the first year. I wrote mathematics curriculum for the school district that summer, and became a mathematics coach for summer school the following year. I gained experience working with primary grades and working with teachers during this time. Over the course of the ensuing two school years, I took several mathematics courses, and assumed various mathematics leadership roles in my school. If the teachers or administrators in the building had mathematics questions, they came to me even though I was not considered a Mathematics Specialist at the time. The following summer, I joined a Mathematics Specialist master's program, and became a Mathematics Specialist in a new Title I school in the fall.

Currently, I am now a part-time Mathematics Specialist in an elementary school. The other half of my time is spent as a math coach, coaching other Mathematics Specialists who work in Title I schools. Although titled a Mathematics Specialist, I am learning from other teachers and students every day, refining my teaching skills as I continue my journey seeking out mathematical best teaching practices.

On the Job

Most elementary teachers receive little or no training in the area of mathematics; much of their training is in language arts. Teachers teach mathematics the way they were taught, which has in turn caused a cycle of teaching isolated skills with little emphasis on conceptual meaning. Implementing Mathematics Specialists into schools as a means of breaking the cycle is ultimately necessary for systematic changes to occur in our educational system. Coincidentally, this has proven to be successful in changing the way many teachers teach language arts. Most elementary schools have a Reading Specialist who works with teachers on using best practices since there has been a recent shift in how language arts are taught. In order for this to occur in mathematics, a Mathematics Specialist is needed in every school. Typically, professional development has meant having an expert standing at the front of the room telling teachers the best way to teach a particular subject area. Changing the face of professional development where teachers are working together by planning, team teaching, and observing best practices at work will allow them to learn from one another.

As a Mathematics Specialist, I have seen the positive effects of teaming with teachers. After working closely with a first grade teacher, she thought that her students had learned more from our recent work together than from her teaching methods during the previous three years. She was open to using a curriculum that promoted conceptual understanding, really observing her students, and guiding her instruction based on their needs. Her students benefited greatly when she had began to learn the technique to “good questioning.” By the end of the school year, her first grade students were moving into the second grade with a tremendous number sense foundation. I also began to work with a more experienced kindergarten teacher. At first, she just wanted me to pull small groups of students out of her classroom for remedial instruction. I offered instead to plan and team teach with her. After several sessions, she claimed to have been very nervous about team teaching with me, but after ten minutes, she felt very comfortable, and was excited about planning and team teaching again. She later stated that she considered herself a good teacher who has been teaching for many years, but was surprised at how much she learned working together over the course of the year.

Challenges

As with most jobs, there are challenges, such as learning to work with the various personalities that reside within a school. Each teacher has a unique teaching style that coaches must learn, respect, and guide toward the desired mathematics philosophy. Some teachers can't wait to have an expert help them refine their practice, while others resist the idea. Many simply want a group of struggling students removed from class for remedial instruction. The Mathematics Specialist is not there to criticize, mandate, or tell teachers what they should or should not be doing; rather, the Mathematics Specialist is an equal-level coach in whom teachers can confide and trust. Remedial instruction only targets a small population of students, but if the Mathematics Specialist team teaches and works closely with the teacher, then both teacher and students benefit. Maintaining good rapport and strong relationships will allow teachers the opportunity to trust the Specialist they are working with, and will provide a place where risks can be taken.

Yet another challenge is the need for change. Each school, led by its administrator, has a vision for the various subject areas, and the most likely person with the best mathematics vision would be the Mathematics Specialist. There also seems to be continuous controversy regarding the standards and curricula that are used in school mathematics programs; many changes have already been made to them, but much progress is still needed. A school or district may have good standards and a great curriculum, but change cannot occur if teachers don't know how to implement them. As a result, other factors, such as a strong administrator and a Mathematics Specialist, need to be in place. The administrator lends support to the Specialist who then, in turn, provides teachers with the knowledge of how to best use the standards and curriculum. A strong administrator is essential to the Mathematics Specialist, and their role as a teacher leader and coach, if the desired vision is to be achieved.

Conclusion

I feel that I have brought about positive changes, both in my district and in my base school, as a Mathematics Specialist. As a lifelong learner, I seek out opportunities to learn best practices and share my knowledge with teachers and students. There is an art to teaching mathematics which I continue to work at each day. ■

APPROACHING MATHEMATICS UTOPIA?

F. MORTON
Stafford County Public Schools
Stafford County, VA 22554

Well, not really, but as Mathematics Specialists, we have an idea of what it looks like. The lessons learned during the first year of working with teachers will help us reach our ideal. That perfect world of mathematics instruction is best articulated in the National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics*:

Imagine a classroom, a school, or a school district where all students have access to high-quality, engaging mathematics instruction. There are ambitious expectations for all, with accommodation for those who need it. Knowledgeable teachers have adequate resources to support their work and are continually growing as professionals. The curriculum is mathematically rich, offering students opportunities to learn important mathematical concepts and procedures with understanding [1].

This is the “perfect world” Mathematics Specialists strive for as we set out to change the world—or the philosophy of mathematics instruction in our buildings, or the daily instruction in a classroom. I have come to realize through the experiences of the last one and a half years that it is the small steps and the seeds that we plant in the actual classrooms that push us and those we work with in the direction of truly changing and reforming the mathematics we teach. Since instructional practices are a direct reflection of a teacher’s belief system, one of the primary goals of the Mathematics Specialist is to promote the vision for mathematics education described above.

Stafford County’s Vision

In Stafford County, there are currently nine Mathematics Specialists, each one working in a K-5 building. The Mathematics Specialist Program is clearly defined in a five-year plan and was presented to administrators and staff before I started working in the building. The daily activities change as the needs in my building change, but the philosophy and intent of the Mathematics Specialist Program is focused on using best practices to improve student

achievement in mathematics by improving instructional practices. Stafford County Mathematics Specialists established the following mission statement:

The Mathematics Specialist takes a leadership role to increase the awareness and value of mathematics for students, teachers, parents, and the community. They work with teachers and parents to increase their understanding of how children learn mathematics. In serving as a resource and a coach to teachers, they model best practices in teaching and learning mathematics. They also collaborate with teachers and administrators to collect, analyze, and use data to inform instruction in meeting the needs of all students.

The following Focus Goals have also been established:

1. Encourage and support teachers in modeling and developing students' oral and written communication skills in mathematics to provide opportunities for student self-reflection and metacognition (through number talks, questioning, performance-based assessments, mental math activities, journals, etc.).
2. Support the divisionwide implementation of the *Everyday Mathematics* series throughout the year [2].
3. Revisit and refine current mathematics classes for parents and work to encourage more parental involvement.
4. Facilitate ongoing, monthly school-based professional development in content and pedagogy through grade-level meetings and at other times as needed.
5. Collaborate with teachers to examine formal and informal assessments in order to assess student understanding and to inform instruction.
6. Support teacher collaboration in developing common assessments and rubrics based on what they want children to know and be able to do, and to use those to *measure* student understanding and skills.

These statements are more than just words on paper; they guide our interactions with teachers, parents, and administrators and help us allocate our time. The Focus Goals and Mission Statement are designed to further our two primary initiatives: "Teaching and Learning for Understanding" and "Every Child Mathematically Proficient."

In addition to the six Mathematics Specialists already in place, three Mathematics Specialists were placed in three schools participating in a National Science Foundation (NSF) grant in Fall 2006. It seemed like such a simple plan: a Mathematics Specialist would be placed in an elementary school as part of a NSF research project to work with teachers to enhance mathematics instruction, thereby improving students' mathematical proficiency. Oh, and by the way, there would be a new mathematics curriculum tool to implement and support. Oh, and the report card would be changing for first through third grade in such a way that teachers would need to assess their students' mathematical understanding by evaluating their performance rather than scoring a worksheet. Oh, and one more thing—the county would be implementing an initiative to empower site-based decisions that would require teachers to meet continuously throughout the school year to complete and discuss research, develop action plans and strategies, and basically compromise any professional development time available. These were some of the more formidable issues that arose during my first year—underscoring a situation in which a teacher leaves the classroom, moves to a new building, takes on a new role that is relatively new in the division and is still evolving, and is not clearly understood by her colleagues.

Each of the aforementioned concerns could be the focus of discussion because they have truly impacted my ability to fulfill the responsibilities of the Mathematics Specialist. Instead, I have chosen to reflect more specifically on the coaching, co-teaching, and collaboration experiences during my first year and the lessons I learned from those experiences. On the surface, these three terms seem very similar. They all have the connotation of cooperation; they all seem to invoke a positive attitude with a common goal; and, they all even start with the letter “C”! As the layers of each of these models of working with teachers are peeled away, these three aspects of being a mathematics education leader become very distinct, yet still very much entwined.

Collaboration

I can remember clearly how excited I was to be starting this position. I had taken the math content courses that enabled me to feel fairly confident in my teaching ability. I had first hand experience building a community of learners in my own classroom, and knew how powerful inquiry-based learning and teaching could be. In addition, I would be working in a new building with a group of teachers who really wanted to be there. Most of them had competed for positions at this school, and I thought that they would be more open to reform mathematics and problem-based teaching. In short, I felt fairly competent in using the new curriculum materials and had worked hard to be ready to support each grade level as we began the schoolyear.

As Mathematics Specialists, we were asked to encourage teachers to implement our new materials as holistically as possible, keeping the spiral defined by the *Everyday Mathematics* curriculum intact [2]. At times, this went against the grain of my own notion of best practice; the material was more scripted than I was comfortable with, and many times I believed the concepts jumped around without enough time for students to fully grasp the ideas or practice application. To complicate the implementation of these materials, many teachers were just not willing to put in the time necessary to prepare for the daily lessons. At grade-level meetings, I would try to focus teachers' attention on where the lessons were going or their purpose in laying the foundation for future lessons. Many times, this approach fell on deaf ears. The teachers were used to immediate results: teach a few lessons, check it off, and move on. Lesson Number One: Adult learners will only hear what they are ready to hear or what they perceive they need to hear. This was, and continues to be, one of the most frustrating aspects of being a mathematics education leader in my building. I know that through collaboration we can make great strides and effect change. In order for that collaboration to take place, all involved must realize the need for change and embrace the challenges that arise.

I knew that supporting the implementation of the new curriculum materials would give me an opportunity to work with more teachers; it would afford me an entry with some teachers who might not have been willing to work with me. Unfortunately, questions and strategies related to different aspects of the new materials consumed our precious time together. My grade-level meetings were spent disseminating information or answering questions and encouraging teachers to "have faith in the spiral." I was perceived as the "mouthpiece" for a curriculum with which I was occasionally uncomfortable. In order to model a more inquiry-based approach to teaching with these materials, I offered to go into classrooms to demonstrate lessons. I would launch the lessons with number talks, while continually charting student responses, and then model questioning as much as possible. Many teachers asked me into their classrooms, to the point that I was having a hard time scheduling them all! Unfortunately, in my quest to get into more classrooms to model lessons, the collaborative planning and reflection on practice was lost. I know that I have to find a balance between modeling and collaboratively planning lessons, and realize that I can't be everywhere all the time. Lesson Number Two: A little change in a teacher's practice that will continue and sustain itself is better than one or two lessons that will be forgotten the next day by both the teacher and students. By taking the time to debrief for just a few minutes after the lesson has been taught, the teacher can articulate some specific student learning behaviors they witnessed which could lead to a change in their approach the next time they teach a similar lesson.

Co-Teaching

In Stafford County, the Mathematics Specialist co-teaches with a teacher for the entire year at a grade level the Mathematics Specialist has not taught before. As I look back on my first few writings and synthesis of Lucy West's *Content-Focused Coaching*, I am reminded again of my naiveté [3]. I was so enthralled in reading about this model of coaching. I really thought I could use these strategies of pre-conference planning, lesson observation, and post-conference debrief effectively to plan and teach lessons regularly with my co-teacher that would truly enhance student learning and our own pedagogy. I wrote about the coach and the “mathlete” with such high hopes. We were in this game together, and we would give 150% to reach our goal of student understanding. Thinking that my co-teacher and I were on the same page, I was a little anxious to be teaching such a high-stakes testing grade for the first time, but I had had the opportunity to plan and discuss the first few weeks' lessons with her and felt we were off to a good start. I remember vividly a day when my co-teacher and I had had an especially frustrating time. The students were confused, we were way behind in our pacing, the lessons in the teacher's manual forged ahead, and I knew the students weren't ready to move on. I suggested rearranging the sequence of the next few lessons so that there might be more continuity for the sake of student learning. My co-teacher was amazed when I suggested that we should always make our instructional decisions based on the needs of our students. She actually said, “That's the first time I've heard you say that.” I had worked and planned with this teacher for two months, so I was surprised to learn that she didn't know that student learning was the motivation and guiding principle for everything I had been doing. Lesson Number Three: Be explicit in your intentions and expectations. This co-teaching is not as easy as it sounds.

Looking back, I am sure her words were brought on by the same frustration I was feeling. To further complicate our co-teaching, we rarely had enough time for true collaboration in order to plan our lessons. On occasion, we fell into the bad habit of “drive-by” planning wherein we would divide the lessons, but leave no time for reflection on pedagogy or student learning. In November, this finally reached a critical point: I backed away from instruction and insisted she do the teaching for a while. I wrote in my journal that this allowed me the chance to observe her teaching and gave her the control of the classroom she needed. It was also an opportunity to appreciate what a truly gifted teacher she is—she is a master at making connections and promoting focused mathematical discourse among her students. In the day-to-day planning of instruction, I had focused too much on our new curriculum without giving her the freedom she was used to having in planning her own instruction. We had other incidences when one of us was not comfortable with the direction our math instruction was going, but we were able to work things out. Consequently, we reached a level of comfort and trust with each other that allowed us

to trade off and build the other's ideas during instruction. Many times, we knew exactly what the next question should be without having had the opportunity to plan for it. Lesson Number Four: The importance of planning and reflection is critical to the success of a co-teaching experience. While it wasn't a perfect situation all the time, I am happy to report that my co-teacher went against the grain of her grade level and did not insist on as much "paper proof" of student learning. She told me the other day that she felt that together, we had helped her students develop a much deeper conceptual understanding of the mathematics in fifth grade.

Coaching

So I leave that which I have been able to do the least, for last. Again, I am reminded of my high hopes dashed by reality! It is extremely difficult to implement West's model of coaching when there are so many other hats to wear and concerns to address. There have been a few occasions when I was able to use the "West protocol" with great success. In January, a third grade teacher asked me to help her understand and address her students' confusion. She wanted them to develop a deeper understanding of multiplication. We spent a lot of time discussing, planning, and anticipating student confusions with respect to the lessons that would build conceptual understanding and allow opportunities for practice. Over a period of two weeks, I observed, co-taught, then observed as she taught. We were both pleased with the outcome. This leads to Lesson Number Five: Observation and reflection of student learning enable the coach and teacher to work on the mathematical understanding of students. Another short-term coaching experience was an exciting opportunity to work with a teacher who had been resistant to concept of the Mathematics Specialist. She came to me asking for help in meeting the *Standards of Learning (SOL)*, and I was thrilled to have the chance to work with her [4]. Together, we planned some solid lessons, but didn't have as much time to actually teach and observe together. It just worked out better to split the class and work with the smaller groups so in the end, we didn't have an opportunity to share the nuances of our own practice and pedagogy. Once *SOL* testing started, she was feeling better about her students' understanding, and we built a rapport that will continue to grow.

West's model of content-focused coaching is a framework for collaboration with teachers that I continue to study. I realize now that this collegiality is not something that can occur just because you know the questions to ask and the content knowledge to help develop student understanding. Lesson Number Six: True coaching must be a collaboration involving co-teaching wherein both parties believe in the process, with mutually agreed upon goals. It takes a skillful listener to determine what the teacher needs to focus on, and the needs change with the teacher's level of expertise, content knowledge, and philosophy of teaching.

There is a delicate balance that must be achieved between invitations for teacher contribution to lesson design and offering direct assistance in designing the lesson. It is much more difficult to finesse the coaching conversation so that the teacher and the coach have equal contribution and ownership in the goals and outcomes of a particular lesson. I have learned many lessons about myself and about the teachers.

Summary

Collaboration, co-teaching, and coaching can be very different, yet each of these aspects of cooperative teaching involves similar layers of negotiating, planning, listening, and reflecting on the instruction and student understanding. I know that I must continue to work on being a good listener and ingrain those questions that will help a teacher reflect on the mathematics that will produce the collaborative teaching experience I envision. I have learned that it is critical to be explicit in my own intentions and expectations. Negotiating for time may be a constant frustration, but making the time for collaboration is crucial to the success of any and all aspects of teaching.

Most importantly, the lesson to be learned is that the learning goes on—it doesn't stop here—and that effecting change takes *time*. I've just come across something in my journal that I need to post on my wall at home and at school: "The true joy in improving things is the small, daily achievements along the way." We must revel in the baby steps to appreciate the strides. Perhaps we will never reach "mathematical utopia." There is always room for improvement, revealed through reflection on practice and pedagogy, and isn't that the point? As stated in the *Principles and Standards for School Mathematics*:

Teacher Leaders can have a significant influence by assisting teachers in building their mathematical and pedagogical knowledge. Leaders (especially Mathematics Specialists) face the challenge of changing the emphasis of the conversation among teachers from "activities that work" to the analysis of practice [1].

Enhancing mathematics instruction to facilitate mathematical proficiency requires us to develop and design the best lessons possible, but we must continue to learn from our own lessons as well. ■

References

- [1] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.
- [2] *Everyday Mathematics*, University of Chicago School Mathematics Project, McGraw-Hill, New York, NY, 2004.
- [3] L. West and F. Staub, *Content-Focused Coaching: Transforming Mathematics Lessons*, Heinemann, Portsmouth, NH, 2003.
- [4] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

THE MATHEMATICS SPECIALIST FROM A DUAL LANGUAGE IMMERSION PERSPECTIVE

M. AGUILAR
Arlington Public Schools
Arlington, VA 22207

I was motivated to go into teaching mathematics after joining a Teaching for Understanding group. I met monthly for three years with other elementary teachers in the public school system in Arlington, Virginia. Under the leadership of our mathematics county supervisor, we looked at teaching the Mathematical Big Ideas, and instructional practices that foster deep mathematical understanding in our students. Every month, we would bring samples of students' work to learn how they were developing mathematical ideas. We discussed instructional practices which we would then try in our classes, and then share our experiences. I started to take courses, attend math conferences and training sessions. In addition, I relearned math content in a very different way from the way in which I was previously instructed. It was then that I realized I needed to become an expert in mathematical ideas to help my students develop mathematical proficiency, and that learning with understanding is essential for this mathematical proficiency.

I work at Key Elementary School, a Spanish Dual Language Immersion school in Arlington County, Virginia. Key School/Escuela Key is a two-way, Spanish-English immersion school. Forty-seven percent of our students are Hispanic. Every student at Key School/Escuela Key participates fully in Two-Way Spanish-English Immersion. This internationally recognized program is designed to teach children a foreign language in a natural way through everyday conversation and content instruction. Students at Key learn Arlington County's elementary curriculum. Math, Science, and Spanish Language Arts are taught in Spanish, while Social Studies and English Language Arts are taught in English. The students use each other as language models and, by the fifth grade, are able to communicate effectively in two languages. We celebrate bilingualism and our diversity.

Our school system lessons and materials follow the *Principles and Standards for School Mathematics* from the National Council of Teachers of Mathematics (NCTM) [1]. Our school system's mathematics program aims to help all students achieve mathematical proficiency by developing both conceptual understanding and procedural proficiency. In my school, we put specific emphasis on communication and discourse within the context of mathematical problem

solving. We pay specific attention to the assessment component of units as a way of ensuring that students make adequate progress in mathematics and that "no child is left behind." We use pre- and post-assessment for every unit to assess enduring understanding of the Mathematical Big Ideas. Since I started as a Mathematics Specialist, I meet with math teachers biweekly to analyze students' work and to determine intervention strategies.

I have developed specific materials and lesson plans to promote language accessibility, cultural relevance, enhanced thinking, and discourse in the mathematics class of the dual language immersion program. Furthermore, I have gathered a diverse collection of strategies, materials, and technology to address the specific needs of the second language math student in the dual immersion program. The lessons are based on an integrated approach where vocabulary and materials are carefully chosen and adapted in order to provide comprehensible input. These activities are student-centered, hands-on experiences that enhance students' thinking skills. I regularly visit the math classrooms to demonstrate how the use of technology and diverse media—graphs, everyday objects (realia), contextualized problems, and demonstrations—make the second language as comprehensible as possible. I also lead regular, whole school in-services where we discuss the importance of culturally relevant activities and how to make mathematics multicultural through meaning and empowerment.

We have integrated both mathematical concepts and processes to develop a meaningful understanding of mathematics. The concepts of mathematics are organized under the six main mathematical strands and developed through the four mathematical processes: problem solving, communication, reasoning, and connections. Our goal is to help develop mathematical proficiency so that students understand basic concepts, are fluent in performing basic operations, reason clearly, formulate, represent, and solve mathematical problems and maintain a positive outlook toward mathematics [2].

Having a Mathematics Specialist in the school has been a very positive influence on student performance and teacher confidence. Our school has been fully accredited every year for the *Standards of Learning (SOL)* Test since 2001 when I started as a Mathematics Specialist [3]. More than 70% of the students in the math acceleration project in kindergarten through third grade have mastery of not only their own grade-level objectives, but most have some mastery of the next grade-level objectives. Teachers in our school attend monthly meetings to discuss assigned articles and reading related to math instruction and best practices, evaluate student portfolio pieces, and plan mathematic instruction for understanding. Teachers in our school now

place more emphasis on curricular goals based on inquiry and problem solving. More efforts are now made to engage students in higher-order thinking skills and meaningful math exploration.

I believe that as a Mathematics Specialist, I have a catalytic role in:

- Monitoring and analyzing student achievement results;
- Developing daily and long-range plans and strategies with teachers;
- Developing organizational and flexible grouping procedures with teachers;
- Demonstrating teaching strategies and methods for teachers through model lessons with students;
- Coordinating and facilitating communication about mathematics across grade levels and within grade levels;
- Helping implement our Math Acceleration Project;
- Planning and providing appropriate professional development to grades K-5 teachers (e.g., *Investigations*, integration of technology, manipulatives, and integration of *Understanding by Design* in math lessons) [4-5];
- Providing assistance to classroom teachers in implementing ideas and techniques gained through the professional development provided; and,
- Facilitating parent and teacher communication about mathematics.

I also conduct parent outreach programs, in the PTA forum or during informational coffees, to inform them about content from NCTM standards, and how to prepare for the math *SOL*. I have put a specific emphasis in creating a series of hands-on demonstrations and workshops to invite parents to challenge students at home through “good questions” and games. In addition, I also meet with our “Padres Unidos,” the Latino parent support group in our school, to provide the same information in Spanish and address specific issues to help our Latino students succeed in mathematics.

I feel fortunate and very proud to have the opportunity of inspiring and guiding my teaching colleagues through the process of creating an inviting classroom environment based on trust and high expectations. I would like them to pose mathematical tasks that will engage *all* students to figure things out and make sense of mathematics. I hope they engage their students in mathematical discussions and that they listen actively to how their students develop reasons and offer explanations. I would like them to look at their students’ math work to inform their

instructional decisions. I believe that “Mathematics is the science of pattern and order” [6]. I agree that mathematics discovers, explains, represents, and formulates this order that manifests itself in nature, art, engineering, music...and that we use it to improve our lives and further our advancement. As a Mathematics Specialist, I have experienced how students of all ages love math when it is presented this way and they become absorbed in this wonderful creative exploration and discovery of pattern and order. ■

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] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [4] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: <http://investigations.terc.edu>.
- [5] G. Wiggins and J. McTighe, *Understanding by Design*, Association for Supervision and Curriculum Development, Alexandria, VA, 1998.
- [6] *Everybody Counts—A Report to the Nation on the Future of Mathematics Education*, National Research Council, Washington, DC, 1989.

THE MATHEMATICS SPECIALIST: A PERSONAL VIEW

E. SINCLAIR
Alexandria City Public Schools
Alexandria, VA 22311

What I like best about my job as a Mathematics Specialist is how broad and far reaching my responsibilities are. From meeting with parents, to embedded staff development for teachers, to data analysis, to meeting with our principals, we Mathematics Specialists have our work cut out for us. The trickle-down effect of working with twenty-six teachers over the course of the year means that I have direct responsibility for the math content of almost 600 children. That may sound daunting to some but for me, it's my apple.

Some of the nicest people I know are the teachers and administrators with whom I work. That is not to say that my work is without challenges. I just look at challenges as the problem solving strand of my job. As a Mathematics Specialist, I see teachers with little, some, and a great deal of math content and pedagogy understanding. As a result, my plans for the teachers I work with are highly individualized. My goal is to lead each on a path where all meet at the final destination: a highly qualified math class where student achievement is preeminent.

In our school district, Mathematics Specialists are responsible for spending an entire math unit with a teacher. This helps both of us refine our practice and develop our planning, delivery, and assessment together. The unit begins with a pre-conference. Realistically, it's hard to find time to do this. However, this year I am writing this in my plan book and making it happen by meeting with my principal, and explaining the importance of this step. He is fully supportive and advises me to meet with particular teachers to set up a time for this. I have learned that without this step, too much happens "on the fly," and this is not a comfortable or productive mode. Planning really does need to be planned. This week, I sat down for a pre-conference with a first grade teacher. This is her first year, so she asked me to model a lesson for her next week. She is being observed at the end of the month and feels observing me will better prepare her. I was thrilled to be sought out and looked forward to modeling the lesson on Monday. We looked at the lesson, taking into consideration what materials would be needed and the steps I would follow to teach the lesson. We discussed the math objective and how it would be met. I believe that asking, "What's the math?" in any given lesson is a pivotal question. It allows us to focus on just what we want to impart mathematically to the students. We discussed

informal assessment and how she would be looking for understanding by her students either using slate assessments or anecdotal notes taken on a class list. We ended the fifteen-minute meeting feeling prepared and promised to meet afterward to debrief. This debriefing is the post-conference where we discuss how the lesson went, as well as look over student work. Many times, it is also a kickoff for the next lesson. Some of the teachers I work with teach more than one math class per day so they have a chance to refine the lesson after we meet when they teach it a second time. As I work with teachers, we truly learn from each other which makes us both stronger, and expands my own learning opportunities. Mathematics Specialists provide embedded staff development but for me this is definitely a two-way street.

Here in Alexandria, we have very strong support and guidance from our district curriculum specialist, meeting at least twice per month as a group. There are twelve Mathematics Specialists and we have very good relationships. We fully support each other by helping with materials, teacher concerns, ideas for working with parents, and other issues that come up. Our bimonthly sessions range from sharing sessions to staff development given by university professors. On those days, we are the students with ongoing learning opportunities ranging from math strands to pedagogy. Once a year, Mathematics Specialists meet with the principals, along with all the other Mathematics Specialists and their principals, in order to write goals for the coming year. There is also a presentation for us. Last year, one of the professors spoke to us as a group. She communicated the importance of having students justify their solutions, both verbally and in writing. She emphasized quality over quantity with regard to problem solving in the classroom. Both Mathematics Specialists and principals came away with practical ideas to put into practice. In addition to these types of meetings, our curriculum specialist is always readily available, providing support for us at our respective schools. Just this week, I asked her to meet with my third grade team; they are concerned about their English as a Second Language (ESL) students working with such a language-based math curriculum. We listened and offered suggestions with a promise to get them more resources. At the next meeting of the Mathematics Specialists, the curriculum specialist alluded to this meeting and asked the other Specialists for suggestions to help ESL students. Some very good and specific ideas were offered which I took back to these third grade teachers. I also provided them with some articles on how to help ESL students with the curriculum. Our curriculum specialist will be meeting with the ESL director relating these concerns and will brainstorm to help these very capable students. We introduced these teachers to a new on-line math game reviewing basic facts. We felt that this type of activity would be particularly helpful for ESL students in that it deals with "naked numbers." That way, classroom teachers can truly recognize the aptitude of these students. In addition, I have spoken with the ESL teachers and will provide each of them with the vocabulary list from the particular

grade level Teachers' Guide so they can help these students come to understand the vocabulary rich math curriculum. This is only one example of how broad based a Mathematics Specialist's responsibilities are.

That same morning, our curriculum specialist also observed two teachers at opposite ends of the math spectrum. She provided me with very clear suggestions and followed up by sending e-mail to these teachers, praising one and offering constructive criticism to another. She takes a hands-on approach and is very detail oriented; we are lucky to be working with such a dedicated professional.

This is my second year as a Mathematics Specialist and my second year at this school. Last year, I worked with every teacher in the building who taught math, and navigated among different personalities as the "new kid." I was also learning a newly adopted curriculum along with them. The year was challenging, but extremely rewarding. It was exciting to me to be doing what I love and to be in a position to help so many students. While most of the teachers I worked with were very accepting of me, I had my first encounter with the "resistant teacher," and learned not to take things personally. This experience made me more adept at dealing with such personalities, a skill I found useful during my second year. Despite the occasional resistant teacher, my primary goal is to be a catalyst for the students' success.

As a participant in the National Science Foundation (NSF) Mathematics Specialist Program, I have grown in the content and leadership areas. Before the Institute began, I had already taken Number and Operations. I have to say that the first time I took it, I didn't understand the power of taking numbers apart and putting them back together. Upon completing this course a second time, I finally understood. It was during the summer of 2005 as we made our way through Number and Operations, and Geometry and Measurement that the ideas started to fall into place for me. I saw and understood the value of working flexibly with numbers and how that flexibility can be realized in geometry as well. While we went about taking apart 2- and 3-dimensional figures, I started to see the connectivity of both courses. Leadership responsibilities were also foreign to me. That course helped me see the big picture of how Mathematics Specialists can make a difference in our schools. From working with teachers to meeting with administrators, I now feel equipped to carry out the responsibilities placed on me. This year, we are concentrating on coaching; the Leadership I and II courses have provided me with a blueprint and the tools to begin coaching more effectively. I feel extremely fortunate being a part of the Institute. Our professors are the best; they are supportive and an approachable resource. We are being guided as we put into practice what we're learning. Just last summer, I voiced a concern to

our Leadership professor, which was how to put into practice the pre- and post-conferences with the teachers. She assured me that we weren't expected to follow this practice with each and every teacher. She advised me to start with one and after a period of time, move onto another. I felt much better knowing that her suggestion was practical; mine was unrealistic. That's the kind of support that is readily available at the end of an e-mail or phone call. Institute participants are gaining a wealth of resources to impart to our teachers and students at our schools. The more I learn, the more empowered I feel to make a difference. I expect my learning to continue long after this Institute is over.

This continual learning mindset was sparked as I began my journey into research. I am simply fascinated at how students learn. Now I understand how talking and writing about math increase students' understanding. My job, among other things, is to convince the teachers I work with the value of this. I am already heartened by questions I hear some of the teachers asking their students: "How did you get that answer? Did anyone solve it another way? How did you know where to begin?" As we deal with the obstacles, it is important to reflect on the many successes. Our collaborative efforts and openness to new methods of teaching enable our schools to boast that our success overshadows the challenges. ■

A DAY IN THE LIFE OF TWO MATHEMATICS SPECIALISTS: BRINGING MATH TO THE FOREFRONT IN ELEMENTARY SCHOOLS

B. RODRIGUEZ and S. GARTHWAITE
Fairfax County Public Schools
Falls Church, VA 22042

The idea of having Mathematics Specialists at individual schools has long been overlooked. Educators are beginning to see the value in having a Mathematics Specialist in every elementary school to help teachers understand correct math content, as well as address the specific needs of the students at that school. This article will follow the typical day of two Mathematics Specialists in their schools. Though the goal is the same for both teachers—to increase student achievement and teacher knowledge—their days are very different in order to meet the individual needs of their schools.

8:00 a.m. Beth Rodriguez arrives at the Title I school in which she works, but her day started long before then. On her ride into school, she had begun thinking about what her day would entail and more specifically, how to make the pre-conference with a new third grade teacher more meaningful.

8:05 a.m. As she walks down to her room, “the math closet” as she likes to refer to it, teachers are busy preparing for the arrival of their students. It is in the math closet where the many materials for teachers’ use are stored. Beth has ordered these materials over the years with the assistance of teacher requests. Teachers stop in at all times during the day to talk to Beth about ideas for math lessons and to pick up resource books and/or materials to make their instruction more meaningful and engaging for their students. Some stop her as she walks down the hallway, asking for the most appropriate math manipulative for a lesson they have planned that week or for strategies to teach a math concept. Beth is eager to help and feels her expertise is needed in a school with numerous needs.

8:10 a.m. The new third grade teacher enters Beth’s room, complete with his laptop computer and a smile, anxious to get their pre-conference started. They had decided beforehand to co-teach a lesson on fractions to his third graders. This pre-conference will help them determine “the math” in their lesson and what they

want the students to learn. The structure of the lesson will also be discussed, as well as their roles throughout the lesson. They know that in the sixty minutes they have for the lesson, they want to see what the students already know about fractions and to give opportunities for them to understand that fractions are relationships to the whole. They come to a decision to build this understanding through many different forms: the region or area model, the measurement model, and the set model. Today, they opt to use fraction circles and fraction rectangles to build understanding of the region model.

8:30 a.m. *Susan Garthwaite begins her day across town in another Title I elementary school. She reviews her schedule for the day to determine with which teachers she will be working. She then begins to gather materials for her day and checks her e-mail. Many teachers e-mail Susan with questions about materials or lessons early in the morning. She wants to respond as quickly as possible. She also needs time to gather any materials from the math storage area that she may need to drop off in classrooms.*

8:50 a.m. Beth's pre-conference with the third grade teacher has ended so the teacher can return to his classroom in preparation for the students' arrival. They have both enjoyed the collaboration and see how many wonderful ideas they each have contributed to the lesson. Beth asked a lot of leading questions so the teacher felt a part of the instructional decisions. She kept the discussion focused on the Mathematical Big Ideas to add to his repertoire of knowledge and pedagogy while centering on what the students need to know according to the Program of Studies for third graders in Fairfax County Public Schools, as well as the objectives of the *Virginia Standards of Learning (SOL)* [1]. Both teachers are looking forward to the lesson they will be co-teaching the following day.

8:55 a.m. Beth now delivers base 10 blocks to a second grade classroom. She has sorted them into containers for easier use during the upcoming lesson. Students will be solving problems with a partner. She often helps teachers prepare materials for their math lessons. Beth is greeted by students as they come down the hallways hastily entering their classrooms. Since she works with kindergarten through fifth grade, she has worked with many students in the school at each grade level. Students often stop her to discuss the math they are doing in their classrooms.

- 9:00 a.m. Beth enters the second grade classroom to drop off the supplies and co-teach a pre-planned lesson with the classroom teacher, and the English Speakers of Other Languages (ESOL) teacher. The teacher has already begun the lesson. It will be Beth's turn then to engage the students in the lesson building the concept of subtraction using a real-life problem solving situation. Working with Beth, the teacher has allowed students to construct their own meaning of problems and to solve them in a way that makes sense to them. As the students move into the active learning part of the lesson, each teacher plays a role in facilitating the learning through their planned questioning. They have discussed which students may need more support and which ones will need more challenging problems and are prepared to differentiate the instruction as needed. After fifty minutes, the ESOL teacher leads the students to the rug area to share their strategies for solving the problem with one another in a whole group setting. Beth and the classroom teacher watch, not afraid to ask the presenting student questions of their own. Through Beth's modeling during previous lessons, the classroom teacher's and the ESOL teacher's questions have become more effective at understanding the students' thinking. Beth closes the hourlong math class by restating the strategies presented and posting them on the wall for tomorrow's lesson.
- 9:30 a.m. *Susan enters a fourth grade classroom. The teacher is a second year teacher. Susan worked with her last year when she was new to teaching. They focused on understanding the state and county mathematics objectives for fourth grade students, as well as lesson plan design during their first year working together. This year, Susan and the teacher decided to focus on implementing best practices during math. The teacher wanted to look at her questioning of students. Susan models a lesson on fractions in which she implements good questioning techniques. The teacher observes the instruction and then the two teachers walk together to help individual students during their work time. By doing this, the teacher can begin to try out some questioning techniques of her own with support.*
- 10:00 a.m. Beth heads to a fourth grade team meeting. The teachers asked Beth to bring ideas and resources for the next unit of study. They want to use other resources besides their textbook for instruction, but are uncertain how to do this. Beth and the teachers had previously discussed the objectives they would be teaching

throughout the upcoming unit of study, which allowed time at this meeting to focus on the variety of resources available to them on the topic. As always, Beth is enthusiastic and asks many questions so she can help them where they are.

- 10:30 a.m. *Susan makes her way from the fourth grade classroom to a fifth grade classroom. This teacher is very traditional in the way she teaches mathematics. She reviews homework and then looks at the textbook with the students to demonstrate a procedure for solving an operation problem. Students get assigned practice problems to complete at the end of the lesson. Susan knows that when students are actively engaged in their learning, they comprehend at a deeper level. She has been working with this fifth grade teacher to add some student investigations into her lessons. Susan has planned a lesson which involves students using their own methods to solve an operation problem. Students solve the problem, then discuss their strategies. The strategies are posted and a similar problem is given to allow students to try a new strategy. The teacher observes the lesson, paying attention to what the students are doing. Susan's goal is for the teacher to notice that students do not always need to be shown how to solve a problem before trying to solve it on their own, and that students' strategies can be very powerful.*
- 11:00 a.m. Beth is back in the “math closet,” gathering alternative lessons from teacher resources she has ordered for the school. She also uses this time to answer e-mails from teachers and other Mathematics Specialists in the county. Beth then meets with another teacher to help her search the National Council of Teachers of Mathematics' *Principles and Standards* to make sure the spirit of the *Principles* has been captured in the lesson she has planned for the following day, as well as to review the math content in the lesson [2].
- 11:45 a.m. *Susan stops by a second grade classroom on her way to lunch. The teacher had sent her an e-mail earlier that morning asking about game ideas for a probability unit. Susan drops off the games she collected earlier that morning and spends a few moments to explain how to play each one and why they are powerful mathematically. The teacher asks her some questions about next steps, so the two of them set up a meeting for the following day.*
- 12:00 p.m. At least once a month, Beth meets with the administration to discuss goals/initiatives that she is working on throughout the year. This month, Beth is

working on using data to form study groups for math in the fifth grade. She shares her idea to look for strengths and weaknesses with each student when forming the small groups, and using that data to help teachers steer their instructional decisions.

12:15 p.m. Susan joins a third grade classroom as they begin their math lesson. The teacher has written a song about difficult geometry vocabulary. Students are using words and body movements to sing about points, lines, angles, and other abstract terms. The students then move into their activity for the day. This class has been working with 3-dimensional figures. Students work in groups to identify the number of faces, edges, and vertices for different 3-dimensional objects. Susan notices that one student is singing the song to herself to help her remember what some of the terms on the activity sheet mean. During the lesson, Susan and the teacher walk around to each group asking them thoughtful questions in order to make them defend their findings about the 3-dimensional objects. Susan and the teacher have discussed some students who are struggling with this unit, so Susan focuses her attention on that group to allow for more guided instruction if necessary.

1:00 p.m. Beth enters a fourth grade classroom to model a lesson for a teacher who is new to the grade level. She has been working with this teacher to help her take a textbook lesson and restructure it to be more investigative. Beth modeled her thought process for the teacher as she planned it and is now going to teach the lesson while the teacher observes.

1:15 p.m. Susan moves on to the next third grade classroom. This teacher has been working with Susan to incorporate more problem solving, writing, and discussion into her math lessons. Together, the two have created math tool kits filled with manipulatives for each group of two students to use daily. Susan has also helped the teacher begin to use a problem solving notebook in which students have a chance to solve real-life problems that focus on the topic being taught that day. The students are working on the same activity as the previous third grade classroom. Susan asks the teacher if she can share the song she saw earlier since she noticed how much it had helped some students. After she teaches it to the students, Susan models how to facilitate a discussion using the activity with

3-dimensional objects. The teacher observes because she will be leading the discussion for the following lesson.

2:00 p.m. Beth moves to a fifth grade classroom next. The teacher she is working with wants to use a more investigative approach to teaching geometry. The teacher did not know how to move away from the traditional textbook, so Beth introduced some possible resources to use for this purpose. The teacher chose to try the *Investigations* series [3]. They are now teaching a lesson from this series which allows small groups of students to sort polygon pieces by their attributes.

2:15 p.m. *The third grade teacher takes her class to art and Susan prepares for their post-conference. Susan has prepared some questions to ask the teacher to help her think about what she will do when she leads the math discussion. Upon the teacher's arrival, the two begin their meeting. First, she asks the teacher to share what she observed and to ask any questions of her own. The two discuss Susan's role for the following lesson so the teacher will receive the feedback she desires. Before the meeting is over, the two decide ways to differentiate throughout the lesson and how they plan to assess student learning.*

3:15 p.m. *Susan stops by the teachers' mailboxes in the office to drop off an article she read from Teaching Children Mathematics that she thought a first grade teacher would enjoy [4]. She sees another teacher walk in who tells her about the math lesson he taught earlier that day. He was excited to share how well his students were explaining their thinking and making connections between concepts. Helping students do this was something he and Susan had been focusing on this year. Susan was happy to hear his lesson went well.*

3:00 p.m. The day is winding down. Beth goes into the computer lab to talk to the technology specialist. Beth wants to make mathematics a focus in the morning message broadcasted throughout the school every morning. She knows it would be an opportunity to reach all the students and teachers, and to discuss math topics based on the needs of the school.

3:40 p.m. *Susan meets with the fifth grade teacher who observed her earlier that day. They are meeting to discuss the teacher's thoughts about what she saw the students doing that morning. The teacher expresses that she was surprised and excited to*

see how much her students could do on their own. She then shares her concern that by not showing her students a specific procedure, they will not be able to solve the problems on the Virginia SOL Test they will take in May. Susan knows that change takes time, so she helps the teacher set up a plan to include some more investigative activities within her regular lessons. She also plans to help her work in some test preparation lessons that will allow students to make the connection between their investigations and what they see on the test.

Math has become a focal point at both Beth's and Susan's schools as a result of their positions as Mathematics Specialists. Both of them analyze student data and assess teachers' needs to decide the best way to support the mathematics program at their individual schools. Even though their method of providing this support varies, both Beth and Susan offer assistance to teachers when they are unsure about math content and when they want to attempt a new strategy in their classrooms. Beth and Susan share new resources with teachers, and model best practices in their classrooms so that they become skilled at teaching mathematics to all learners. They also make teachers aware of the latest research on how students learn mathematics. Their role is critical to improving mathematics education at the elementary level because with their assistance, teachers are thinking critically about the math concepts they are teaching and the methods they are using to do so. ■

References

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [2] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.
- [3] *Investigations in Number, Data, and Space*, TERC, Cambridge, MA, 1998, Internet: <http://investigations.terc.edu>
- [4] *Teaching Children Mathematics* website, Internet: http://my.nctm.org/eresources/journal_home

THE ROLE AND IMPACT OF THE MATHEMATICS SPECIALIST FROM THE PRINCIPALS' PERSPECTIVES

D. BLOUNT and J. SINGLETON
*Commonwealth Educational Policy Institute
School of Education, Virginia Commonwealth University
Richmond, VA 23284-2020*

Introduction

The National Science Foundation (NSF) Teacher Professional Continuum (TPC) program grant includes a parallel utilization study of local school and school district policy and implementation issues associated with the introduction of Mathematics Specialists in elementary schools. In this parallel utilization study, policy and implementation issues are viewed as distinct. School district policy is established by the local appointed or elected school board in the contexts of state policy decisions, local education community priorities, and the availability of personnel and resources. The district superintendent, principals, and other staff create the structure and practices necessary to implement the local board's policy choices, such as the placement of Mathematics Specialists in selected elementary schools.

The five-year NSF grant, now in its third year, has as its centerpiece two cohorts of twelve teachers each preparing and then serving in elementary schools as Mathematics Specialists for two years. Funding for the two-year school assignments for each cohort of Specialists is provided jointly by the NSF and the five partner districts of Portsmouth, Richmond City, Spotsylvania, Stafford, and Virginia Beach.

The first phase of the parallel utilization study focuses on local school implementation of Mathematics Specialists. During July and August of 2006, the grant's two policy associates interviewed the principals of the schools in which the first cohort of twelve Mathematics Specialists had begun their assignments in September, 2005. The twelve elementary schools vary in grade configuration (PreK-5, PreK-6, K-5) and a few schools had changed configurations for the 2005-2006 school year. One school is quite new; others are rather old. There is also variety in student demographics, school size, and in Title I eligibility with some schools having schoolwide Title I programs, some targeted programs, and some not participating. Math achievement is variable as well. For example, on the 2005 *Standards of Learning (SOL)* assessments, fifth grade pass percentages ranged from the high 60's to the low 90's [1].

Methodology

Each policy associate traveled to six of the twelve schools so that all interviews were conducted in person. The principals were cooperative and verbal, apparently pleased to talk about their first-year experiences. Interviewer-interviewee rapport was easily established. Almost all came across as highly engaged in integrating the Mathematics Specialists into their schools. While all principals viewed the Specialists as positive staff additions and were eager to have them back for the second year, their responses are considered credible.

The utilization information sought was school specific. The interview itself was loosely structured by means of a list of recommended discussion items provided to the principals before the interviews. A summary of the interviewer's notes taken during the meeting was sent to the principal for revisions and additions.

The major focus of each discussion was how the Mathematics Specialist's activities reflected the seven-part definition being used for Virginia's grant [2]. Other areas of planned discussion included the reason for the school's inclusion, work space provided to the Specialist, other school responsibilities assigned, as well as school and parent satisfaction. In addition, the principal was asked for comments on any area not explicit in the discussion plan and about their expectations for the program during the 2006-2007 school year, the second year the Specialist would be working in the building.

For this article, the principals' comments, along with the related observations of the policy associates, are reported for themes that appear to provide the most helpful information about implementation and school-level decision making regarding the use of the Mathematics Specialist: 1) the role of the principal in integrating the Specialist into the school; 2) the Specialist's actual activities compared with the Mathematics Specialist definition; 3) teacher improvement and retention; 4) diverse learners; 5) parent and community interaction; and, 6) the principal's expectations for the second year—2006-2007.

Summaries and Observations

The Role of the Principal in Integrating the Specialist into the School — As might be expected, the principals were forthcoming about their roles in introducing and supporting their new Specialists. There were several instances of principal/Specialist collaboration prior to the start of the school year: interactions that included discussions about school test scores, the direction of the math program, and about transition to a new math series. However, the principals were

equally forthcoming about the personal and professional qualities of their Specialists; many of them noted their Specialist's personality traits as ingredients for success. Some illustrative accounts follow.

- “Because the school’s math scores seemed good to us, my veteran staff was concerned about the Mathematics Specialist’s impending arrival. They required reassurance from me that the scores really were good and they were not doing anything wrong!”
- “I made a concentrated effort to create a good relationship between the incoming Mathematics Specialist and my great Title I Teacher, initially holding a social meeting with the two of them and then progressing to meetings to define math goals as well as the two individuals’ roles.”
- “The positive and active role of the principal is critical to the Specialist’s acceptance and success. I was visible in supporting her, attending the grade-level planning meetings she held with the math teachers, and meeting with her regularly.”
- “The Specialist came with great things in mind and the staff embraced her. She has been good at putting teachers at ease over their apprehensions about math, and works especially well with veteran teachers.”
- “The Specialist was a very calming and patient person, and her performance exceeded expectations.”
- “She was very resourceful, organized, task oriented...and available.”

Two predominant factors arose from this set of interview data as strongly influencing the nature and quality of school-site implementation. They are: 1) a principal with vision and force; and, 2) a Specialist with confidence and knowledge. When both were present, a noticeable synergy resulted; when both were absent, not much appeared to be accomplished mathwise in that building. Other factors, such as student demographics, school size, grade configuration, and parental involvement, did not seem relevant to successful implementation.

Actual Activities versus Mathematics Specialist Definition — There is ample evidence that the Mathematics Specialists, with one exception, worked in all seven activity areas included in the definition. One Specialist’s role presented as restricted in that she was directed to work more

with students than with teachers and assigned to teachers to focus on reteaching unmastered skills. However, the principal intends that the Specialist perform more data interpretation and assist with the school's weekly math assessments in the 2006-2007 school year.

Specifically, the Mathematics Specialists engaged in frequent group and individual staff development, including coaching, mentoring, modeling/demonstrating lessons, and co-teaching. They had significant roles in data analysis as related to targeted instruction and assisted grade-level teams with planning and pacing curriculum delivery, and in introducing a new math series. In addition, they were active with diverse learners in programs for remediation, students with disabilities, and accelerated learning, and interacted frequently with Title I Teachers, and Gifted and Talented Teachers.

There was variability in the amount of parent and community contact. There were many examples of school math program leadership. Several Specialists served, or will serve in 2006-2007, as members of school leadership/improvement teams that shaped the school improvement plan or its math or literacy components. Some Specialists met with both grade-level and administrative teams to analyze test scores. Others were on teams that reviewed curriculum matters and test data. Almost all principals respected the definitional intent that Mathematics Specialists be Teacher Leaders. Some of their observations:

- “On a day of in-school in-service before school opened, the new Specialist jumped in to help teachers struggling with the assessment portion of *Everyday Mathematics*, for which they had recently attended a divisionwide in-service” [3].
- “Our Mathematics Specialist came to school to introduce herself to me and the staff *before* the teacher workdays began.”
- “She has such initiative; for example, bringing in a Norfolk State University instructor to teach selected material to the sixth grade math teachers, a grade level we had just acquired.”
- “The transition to the new math series would have been very difficult for both teachers and parents without the Mathematics Specialist.”
- “She also built a good rapport with teachers. She came on board with good ideas and was willing to work.”

- “Though there was some resistance at first, the teachers soon felt comfortable approaching the Specialist and came to see her as a colleague.”

Teacher Improvement and Retention — The principals quickly homed in on the Specialists’ value in improving inexperienced and weak teachers. Not surprisingly, many focused the Mathematics Specialists on fourth and sixth grade teachers as these grades took *SOL* math tests for the first time in 2005-2006. At times, Specialists were directed toward grade levels that had a number of new, ineffectual, or inexperienced teachers. In one school, the principal reported that after the Specialist coached and collaborated with five second grade teachers identified as having math instructional deficits, four improved noticeably. In some cases, principals ensured that the teachers-turned-Specialists spent time working with faculty at grade levels different from the ones they had taught for the purpose of gaining experience across the elementary spectrum. On the other hand, one principal realized in hindsight that she had been unwise in pairing the Specialist with a Mathematics Lead Teacher and should have placed her with a weak teacher to better utilize her as a resource.

A Specialist worked closely with a first-year third grade teacher who needed assistance and with a long-term substitute teacher in fifth grade. Another Specialist teamed regularly with a new fifth grade teacher whose principal observed, “As a result, that teacher will be a good math teacher next year.” Specialists also were asked to assist teachers moving to a new and higher grade level, a so-called “hard jump up.”

Diverse Learners — The principals used the Specialists for assistance with a range of diverse learners, and many were heartily grateful for help with the Virginia Grade Level Assessment (VGLA) used for certain students with disabilities as an alternative to the *Standards of Learning* tests. These assessments require considerable effort and extensive record keeping. At least one principal pointed out the Specialist’s role in ensuring that the individual assessment used for each student was aligned with the grade-level curriculum and in keeping the individual student portfolios current. This same principal considered the Specialist a boon for assisting with the first year of the school’s full inclusion model. Another principal had the Specialist pay special attention to the inclusion classrooms and the VGLA. Another principal made the VGLA her Specialist’s primary responsibility.

There was considerable evidence that Mathematics Specialists collaborated with and served as resources for Special Education Teachers. In one school, the Specialist served on the

district team for Special Education and identified “holes” in Special Education math instruction. Another Specialist worked with both Special and General Education Teachers on strategies to reinforce skills of students who lacked a strong mathematics foundation, specifically targeting students not meeting expected benchmarks. Keying in on her principal’s interest in accelerated as well as remedial learning, a Specialist instituted Tuesday-Thursday afternoon groups to help students prepare to take algebra in middle school. She recruited a university student to assist with the groups. The students loved the algebra readiness sessions and the principal reported that the parents were very appreciative of this attention. The principal in another school pushed a schoolwide basic facts program after the Specialist observed there was a basic facts deficit throughout all learner groups—including the gifted and talented.

A pattern emerged of principals seeking help from the Mathematics Specialist for a variety of different learning groups when the demographics or size of the student body changed due to boundary adjustments or the addition of another grade level. The Specialists are seen as key to enabling the teaching staff to instruct more and/or different types of students.

Parent and Community Interaction — Not all principals used their Mathematics Specialists for parent or community interaction. However, the responses indicated that the amount of parental involvement for the Mathematics Specialist was equivalent to that for the school. For example, one principal noted that parental involvement was quite limited because the school was not a neighborhood school.

Nevertheless, there were numerous examples of Mathematics Specialists linking with parents and the community in a variety of ways. With the institution of a new math series in one division, parents had lots of questions. The Specialists in this division’s schools fielded most of these questions and facilitated discussions about the new program in several parent workshops. They also met with parents on an individual basis. One principal noted that the Specialist was instrumental in explaining the new math program and the philosophy behind it at school open houses. In one school near a NATO installation, the Specialist met with foreign parents to answer their questions about how math was being taught in the United States.

Mathematics Specialists helped organize the math and science nights at their schools. They conducted workshops for parents of Special Education students and Title I students on math skills to enable them to assist their children at home, and shared information with parents through the school newsletter on how to help their children with math. A Specialist was praised for recruiting parent teacher association volunteers to assemble the math game kits used in *Everyday*

Mathematics for children to take home to play with their parents and siblings. Still another spearheaded a “Thinking and Games” event in conjunction with the parent teacher organization [3]. One principal was proud that the Mathematics Specialist, in her role as a member of the school improvement team, had brought up good ideas for the school and community in general. This Specialist led activities to build local school support and publicized improved academic achievement in the community.

Expectations for 2006-2007, the Second Year

All principals have high expectations for the Specialist’s second year. According to one, “Next year will be even better than this first very good year because developing comfortable personal and instructional relationships in a new school requires a full year.”

Interestingly, each principal worded her expectations in terms of what she—the principal—would ask the Specialist do. The impression is that the principals have learned lessons about managing the Mathematics Specialist Program and have identified specific ways they will adjust the first year’s implementation plan. Moreover, they are excited about how their Specialists are adapting and expanding their roles as Teacher Leaders. A few of their expressed intentions are listed below.

- “For 2006-2007, the Mathematics Specialist will be a member of the School Leadership Team. She will chair the math action team and thus have an expanded influence on the way math is taught in our school.”
- “The Mathematics Specialist will come in early to review the 2005-2006 *Standards of Learning* test data as it becomes available. What is learned will be used in instructional team planning for the 2006-2007 school year. One focus will definitely be curriculum alignment.”
- “We’ll focus more on differentiation among the student populations, for example, taking the gifted students up a notch.”
- “She’ll have more involvement with parents and conduct a deeper analysis of *SOL* scores and strategizing to address needs of students.”

- “She’ll work with grade levels that remain concerned about pacing, breaking down data/scores to see what needs to be done for different subgroups and strands.”

School Satisfaction

Without exception, all principals are pleased to have had the Mathematics Specialists assigned to their schools and are enthusiastic about the second year. In fact, a principal who was reassigned to another school during the summer said she frequently pleaded (to no avail) with the central office to allow the Specialist to move with her. A Specialist reassigned to another school in November for administrative reasons unrelated to her performance, also received high marks from her new principal.

Moreover, most principals reported that their staffs had been pleased. Their comments follow.

- “She’s a wonderful addition to our school.”
- “The classroom teachers have been re-invigorated by the Mathematics Specialist’s presence in the building. They were pleased with the in-house in-services.”
- “The staff liked her and would seek her out. Teachers who had difficulty teaching math were especially appreciative.”
- “She really became a ‘source of comfort,’ especially at the upper grades where she had been focusing her efforts.”
- “I could not imagine not having the Specialist there.”
- “Staff reaction was very positive. I don’t know what we would have done without her.”

Next Phase of the Study

The second data collection phase for the parallel utilization study will be conducted during the 2006-2007 school year with division policy-maker interviews. According to the plan approved by the grant project team, the policy associates will seek interviews with school board members and the superintendents (or their designees) of the five partner divisions employing the first cohort of Mathematics Specialists.

Information will be sought regarding policy decisions about division participation in the Mathematics Specialist grant, the process that led to that decision, whether the division expectations have been satisfied, obstacles to implementation that have been identified, and estimated costs of the participation to the division. ■

References

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995; Internet: <http://www.pen.k12.va.us/VDOE/Superintendent/Sols/hom.shtml>
- [2] "Mathematics Specialists Definition," Mathematics Specialists School and University Partners, *The Journal of Mathematics and Science: Collaborative Explorations*, **8** (2005), 1-2; Internet: <http://www.math.vcu.edu/g1/journal/Journal8/Part%201/Definition.html>
- [3] *Everyday Mathematics*, University of Chicago School Mathematics Project, McGraw-Hill, New York, NY, 2004.

The Journal of Mathematics and Science: COLLABORATIVE EXPLORATIONS

Volume 9, Spring 2007

PART II: REGULAR JOURNAL FEATURES

Virginia Mathematics and Science Coalition

WHAT BELIEFS AND INTENDED ACTIONS DO REFORM-PREPARED MATHEMATICS AND SCIENCE TEACHERS CONVEY TO THE WORKPLACE?

J.R. MCGINNIS

*Dept. of Curriculum and Instruction, University of Maryland
College Park, MD 20742
jmcginni@umd.edu*

G. MARBACH-AD

*School of Education, Tel-Aviv University
Ramat-Aviv, Tel-Aviv, 69978, Israel
gilim@post.tau.ac.il*

Abstract

This study investigated to what extent, if any, undergraduate mathematics and science courses (content and pedagogy) are taught cumulatively impact teacher interns' beliefs and their teaching practices. The subjects ($n=68$) were recent graduates of an undergraduate, reform-based upper elementary/middle school mathematics and science teacher preparation program. Survey methodology was used. The survey instrument measured the following constructs: teachers' beliefs about the nature and teaching of mathematics and science; teachers' perceptions about student skills required for success in mathematics and science; and, teachers' intentions about implementing reform activities in mathematics classes and in science classes. Subjects' responses were compared with a large United States database of practicing teachers' responses to identical survey items. Findings indicated that along all measures (many determined to be statistically significant), the new graduates expressed more reform-oriented perspectives concerning subject matter and instruction. These findings strongly suggest that a systematic, reform-based undergraduate science and mathematics program could produce new teachers who entered the workplace with desired perspectives. Continued research in this area was described.

Introduction

This study was conducted within a major research agenda in the mathematics and science education research communities. Researchers are focusing on the possible links between features of teacher preparation programs and the performances of new teachers [1]. The assumption of this research agenda is that teachers teach as they have been taught, and that improvements in the way undergraduate mathematics and science courses and pedagogy courses are taught should result in improvements in the way teacher interns teach when they later become practicing teachers [2]. Thus, for example, engaging teacher interns in group discussions might enhance their support in cooperative learning, and using interdisciplinary teaching in their college courses might encourage them later as classroom teachers to make connections between different subjects (i.e., mathematics and science).

The Maryland Collaborative for Teacher Preparation (MCTP) program, a statewide undergraduate program, was aimed at generating new understandings in reform-based undergraduate mathematics and science teacher preparation. The MCTP program responded to the national and international calls for reform advocated by major United States professional mathematics and science education communities, as well as in international reform documents, such as *Beyond 2000* [3-6].

The program was designed for undergraduate students who planned to become Mathematics and Science Specialists in upper elementary or middle schools. While the teacher interns selected to participate in the MCTP program were in many ways representative of typical teacher interns in elementary teacher preparation programs, they were distinguished by agreeing to participate in a program that consisted of an extensive array of mathematics and science experiences (formal and informal) that made connections between the two disciplines and that placed an emphasis on teaching for understanding.

The MCTP program was systemic. It was a long-term effort (ten years) to improve undergraduate mathematics and science instruction that involved nine teaching and research institutions of the university system of Maryland, in collaboration with community colleges and public school systems. Among the goals of the program was to develop professional teachers who were confident teaching mathematics and science using technology, who could make connections between and among the disciplines, and who could provide an exciting and challenging learning environment for students of diverse backgrounds [6]. The program overview of the MCTP is detailed in a variety of venues [7]. The MCTP was designed around these notable reform-based recommendations:

- new content and pedagogy courses that model inquiry-based, interdisciplinary approaches combined with regular opportunities for teacher intern reflection;
- the participation of faculty in mathematics, science, and methods committed to modeling best teaching practices (especially by diminishing lecture and emphasizing problem solving);
- the development of field experiences in community schools with exemplary teachers trained to serve as mentors;
- the availability of summer internships in contexts rich in mathematics and science; and,
- the support of new teachers by university and school personnel during their first years of teaching.

The MCTP recommendations were aligned with the large body of research that is focusing on the possible links between features of teacher preparation programs and the performances of new teachers [8]. However, the question remains: to what extent, if any, does the way undergraduate mathematics and science courses (subject matter and pedagogy) are taught cumulatively impact teacher interns' beliefs about their teaching practices? It is imperative that reform-based mathematics and science teacher education programs test the assumption that systematic and defined interventions make a positive difference by measuring their effectiveness on how well they nurture beliefs and actions that are consistent with the program's philosophy of learning and teaching.

To document and interpret the effectiveness of the MCTP program, studies from different perspectives were designed. McGinnis, Kramer, Shama, Graeber, Parker, and Watanabe measured MCTP and non-MCTP teacher interns' attitudes and beliefs about mathematics and science teaching, and found the MCTP teacher interns' attitudes and beliefs to be more aligned with overall program goals than the non-MCTP controls [9]. Moreover, they found that over two and one half years, the MCTP teacher interns' attitudes and beliefs continued to move in the desired direction. McGinnis examined faculty discourse (mathematics and science content specialists and pedagogy specialists) in the MCTP [10]. He found that faculty who made up the MCTP speech community (content specialists and pedagogy specialists) expressed similar and different referents to mathematics and science. The findings supported and extended earlier reported studies by Mura in a mathematics teacher preparation program [11, 12]. As stated by McGinnis, in the context of a mathematics *and* a science teacher preparation program, "differences between content discipline experts and content method experts tend to exist in how they conceive their content disciplines" [10]. A key implication of this finding was the recommendation for project managers of reform-aligned teacher preparation projects to anticipate differences in faculty beliefs concerning subject matter and pedagogy and to use that knowledge to devise targeted faculty transformation professional development activities. Such activities would seek to move faculty beliefs and practices in directions that would align with projects' reform-based goals (e.g., science is both a content and a process, and mathematics is more than a tool). The implication made was that as faculty made these changes, the teacher interns they taught would be more likely to exhibit similar reform-aligned beliefs and practices in their classroom teaching.

In this study that used survey methodology, we examined what beliefs and intentions MCTP teachers bring to the workplace. Do MCTP teachers report beliefs that are more aligned

with reform-based recommendations than other teachers? We focused our study on the following three research questions.

- 1) Do MCTP teachers' beliefs about the nature and teaching of mathematics and science align more with reform-based beliefs than with those held by other teachers?
- 2) Do MCTP teachers' perceptions about the student skills required for success in mathematics and science align more with the reform-based perceptions than perceptions held by other teachers?
- 3) Do MCTP teachers' intentions about implementing reform activities in mathematics and science classes align more with the reform-based recommendations than with other teachers?

Theoretical Background and Related Research

In many nations around the globe, mathematics and science education is currently going through a process of change [13]. The reform efforts in different countries, such as science education in the United States and the United Kingdom, share important characteristics which are related to a dissatisfaction with how mathematics and science are taught traditionally [3,5,6]. To change the status quo, efforts in the last decade have focused on the enhancement of the teaching profession, under the assumption that upgrading the profession will increase teachers' commitment and motivation. It is assumed that these changes in teacher preparation and professional development will result in better teaching, as defined by the major reform documents, and improved student learning [14]. According to this scenario, the literature suggests efforts to improve the teaching profession on the two main levels outlined below.

Reforms in Teacher Preparation Programs — Such reforms have different foci, from developing extended graduate-level teaching programs, with an emphasis on additional content courses, to programs with the emphasis on pedagogical aspects, such as promoting innovative teaching approaches (e.g., active learning) [2].

Professional Development — These services support teachers beginning with the inductive years, advancing to the early and mid-career stage, and culminating in the master teacher or late career phase [15]. This effort assumes that learning to teach is a developmental process during which teachers progressively refine their beliefs and practices during their years of teaching [16].

The MCTP reform was located primarily under the first type of reform, since it was concerned with formulating new content and pedagogy courses that modeled inquiry-based and

interdisciplinary approaches. However, it also has functioned under the second type of reform by supporting, to a limited extent, the graduate new teachers during their first years of teaching [17].

The current approaches to reform in mathematics and science teacher preparation programs, and in-service teacher professional development have led to unprecedented interest in research on the efficacy of such reforms [18]. Gallagher and Richmond stated that, “Despite the seeming efficacy of the goals and claims that underlie current reform, there has been little formal, scholarly effort on the part of the science community to ground the reform carefully in research” [19]. One way to evaluate and understand the role of teachers with respect to educational reform is to examine their beliefs and views toward the discipline that they teach, as well as toward teaching and learning [20].

In recent literature, there is a growing consensus that educational reform efforts are doomed to failure if the emphasis is on developing specific teaching skills, unless the teachers’ cognitions, including their beliefs, intentions, and attitudes, are taken into account [13]. There have been a series of studies describing how teacher beliefs about student learning, teaching, and the nature of science impact teaching practices and form barriers to implementation of reform-oriented curricula [19-23]. Anderson and Helms discussed the central role of teachers’ values and beliefs in their attempts to initiate change [24]. They pointed out the necessity of changes in teachers’ values and beliefs to bring about changes in classroom practice. Grossman and Stodolsky argued that attempts to reform secondary schools will fall short if the teachers’ beliefs, norms, and practices are not taken into full account [25]. They concluded that teachers’ professional identity is permeated by their beliefs about the nature of subject matter. The professional identity of the teachers, according to Anderson and Helms, is the result of their own education, beginning with the undergraduate major and extending to career-long professional development activities [24].

At present, there is not only substantial evidence that teachers’ performances are influenced by their beliefs about teaching and learning, there is also evidence that teachers’ beliefs and attitudes are linked to their students’ achievement [2, 26-28]. Thus, *it seems that* teachers should be knowledgeable about the types of attitudes they are expected to promote. For example, teachers who see science as a static collection of facts tend toward instructional approaches that rely on “teacher talk” and direction, as well as on student practice and memorization [9]. Mathematics teachers, who view their discipline primarily as an abstract subject, could cause students to have mathematics phobia.

Hashweh examined the effects of the beliefs of thirty-five science teachers, with different science backgrounds and teaching at different educational levels, on their teaching practices [29]. Through the use of a three-part questionnaire consisting of critical incidents, direct questions about teacher strategies of conceptual change, and ratings of the use of importance of specific teaching strategies, Hashweh showed that teachers holding constructivist beliefs: are more likely to detect students' alternative conceptions; have a richer repertoire of teaching strategies; use potentially more effective teaching strategies that focus on student conceptual change; report more frequent use of effective teaching strategies; and, highly value these teaching strategies compared with teachers holding empiricist beliefs.

In light of such studies, an important goal of teacher education programs should be to assist teacher interns to develop beliefs and dispositions that are consistent with the reform philosophy [30]. Nevertheless, beliefs are hard to change, as many teacher interns enter education programs with preconceived notions about teaching based on their years in school [28]. Therefore, it is imperative to assess the impact of programs designed to change teachers' beliefs to be more consistent with the reform philosophy.

Recently, Hart introduced the "Mathematics Belief Instrument" (MBI) as a tool for evaluating the effectiveness of teacher education programs in promoting teacher beliefs and attitudes that are consistent with the underlying philosophy of current reform efforts in mathematics education [30,31]. She presented data from fourteen teacher interns, suggesting that participation in a teacher education program that espoused the philosophy consistent with current mathematics education reform could change teachers' beliefs to be more consistent with this philosophy. Wilkins used the MBI tool to investigate and evaluate the potential impact of an elementary mathematics methods course for teacher interns in promoting teachers' beliefs and attitudes that are consistent with the underlying philosophy of current reform efforts in mathematics education [28]. The data from eighty-nine teacher interns suggested a positive relationship between participating in the course and change in teachers' beliefs and attitudes.

Guided by our research questions in the present study, we were particularly interested in the following constructs: teachers' beliefs about the nature and teaching of mathematics and science; teachers' perceptions about the student skills required for success in mathematics and science; and, teachers' intentions about implementing reform activities in mathematics and science classes.

Teachers' Beliefs about the Nature and Teaching of Mathematics and Science

Mathematics and science teachers' knowledge of subject matter, curriculum, and pedagogy goes hand in hand with a set of beliefs about the nature of mathematics and science as disciplines and the way that mathematics and science are most effectively taught. Pajares stressed that beliefs are "the best indicators of the decisions individuals make throughout their lives" [26]. Thus, beliefs play a major role in teacher decision making about curriculum and instructional tasks. There is a complex interaction between teachers' beliefs, which are mental, and teachers' actions, which take place in the social arena. What teachers actually do in the classroom is representative of their beliefs [32].

In the case of subject matter beliefs, different views of mathematics and science as disciplines can be placed on a continuum. Williams, Jocelyn, Martin, Butler, Heid, and Haynes suggest that at one end of the continuum are viewpoints commonly characterized as "external," "abstract," and "formal" [33]. In these frameworks, mathematics and science are seen as codified bodies of knowledge. At the opposite end are the "internal views," which place great significance on the processes of building individual

knowledge and establishing accepted knowledge in the discipline. Williams, et al. stressed that teachers who are holding internal views see their field more as a dynamic field and are more inclined to take an active learning approach in their teaching that is characterized by the use of student problem solving. Teachers that hold an external view stress formalisms in their teaching and place a focus on teaching their discipline as a set of algorithms or rules.

In the case of beliefs about students and the ways in which they learn mathematics and science, there is a strong recommendation in the standards that mathematics and science must be for all students. This recommendation is connected to teachers' views about the cognitive demands that mathematics and science make on all students [4,5]. In our survey, we asked if the teachers believed "Some students have a natural talent for math/science and others do not."

The recommendation that mathematics and science must be for all students also aligned with the recommendation for teachers to use different teaching strategies that take into consideration students' different cognitive and motivation levels. Different teaching strategies, recommended by the MCTP project director, were to use innovative teaching approaches, such as: active learning, where students are involved in discussions and debates, and teachers promote student questions in class, as well as involve students in hands-on laboratory experience; and, cooperative learning, where students are engaged in structured cooperative learning activities, including teaching through cooperative problem solving [34-36].

Teachers' beliefs about the ways in which students learn mathematics and science could also be influenced by the teachers' Pedagogical Content Knowledge (PCK), which has been introduced as an element of the knowledge base for teaching [37]. The PCK consists mainly of two key elements: a knowledge of instructional strategies incorporating representations of subject matter; and, an understanding of specific learning difficulties and student conceptions with respect to that subject matter [13]. Another MCTP goal was to promote teachers' PCK and address conceptual change.

Teachers' Perceptions about the Student Skills Required for Success in Mathematics and Science

There are different taxonomies that refer to the cognitive skills required from students. Recently, Mayer suggested, in his paper *Rote Versus Meaningful Learning: Revising Bloom Taxonomy*, that there are two major categories of students' cognitive skills: retention and transfer [38]. *Retention* is the ability to remember material at some later time in much the same way it was presented during instruction. *Transfer* is the ability to use what was learned to solve new problems, answer new questions, or facilitate learning new subject matter.

Based on his taxonomy, Mayer defines three learning outcomes: no learning, rote learning, and meaningful learning. No learning is the situation in which students cannot recall key terms and facts that they were studying. Rote learning is the situation when students remember the important terms and facts that they studied, but are unable to use this information to do higher level operations, such as problem solving. Meaningful learning is recognized as an important educational goal, in which students can use the information they learned to do higher level operations. It requires that instruction go beyond simple presentation of factual knowledge, and that assessment tasks require more of students than simply recalling or recognizing factual knowledge.

A focus on rote learning is consistent with the view of learning as knowledge acquisition in which students seek to add new information to their memories. Educational objectives for promoting retention are fairly easy to construct. In contrast, a focus on *meaningful learning* is consistent with the view of learning as knowledge construction in which students seek to make sense of their experiences, and educators may have difficulty in formulating, teaching, and assessing learning outcomes aimed at promoting meaningful learning.

One of the goals of the MCTP program was to promote meaningful learning. The faculty in the MCTP mathematics, science, and methods courses were committed to modeling best

teaching practices, such as inquiry-based and problem solving approaches [10]. Thus, in our survey, we would need to measure the MCTP graduates' beliefs concerning students' learning skills.

It is noteworthy that, according to the skill "Think in sequential manner" (which appears in our survey), Felder differentiated between students who progress toward understanding sequentially—in a logical progression of small incremental steps—and those students who progress toward a global, holistic understanding in large jumps [39]. Felder claimed that students who fall in both categories (global learners or sequential learners) have the potential to be excellent scientists.

Teachers' Familiarity with Curriculum Materials

Teachers need to be acquainted with curriculum materials appropriate for their discipline, and the level and area they teach. Coble and Koballa reinforce the importance of curriculum knowledge by examples from the past [8]. The science curricula projects developed during the 1960s and 1970s, supported by funding from the National Science Foundation (NSF), offered teachers numerous units and lessons that could be used or adapted to meet their own instructional needs. Research has shown that the students in classes using these curricula learned more and held more positive attitudes toward science than most students in traditional science courses [40].

Williams, et al. suggested that curriculum knowledge today is closely linked to the most recent plans for reform of mathematics and science curricula and teaching, as exemplified in statements of standards for curriculum content and the teaching process [33]. Most notably, the National Council of Teachers of Mathematics' (NCTM) *Curriculum and Evaluation Standards for School Mathematics* and *Professional Standards for Teaching Mathematics* articulate this position [4,31]. The counterparts of these standards for science were those developed by the American Association for Advancement of Science (AAAS) and reported in *Benchmarks for Science Literacy* and more recently, the *National Science Education Standards* and *Beyond 2000* [3,5,6].

It is noteworthy that curriculum knowledge is not limited to the materials and programs from which teachers choose when deciding what to teach, but also includes recommendations for pedagogical approaches, such as alternative methods for teaching and assessing students' understanding. Since the philosophy of the MCTP program was in accord with the latest mathematics and science reform documents, we would need to include in our survey questions about the teachers' familiarity with them.

Teachers' Intentions about Implementing Reform Activities in Mathematics and Science Classes

Since the MCTP program was a standards-based program, its educational goals were in accord with current educational practice reforms advocated by the national mathematics and science reform documents. As such, the MCTP innovation included the premises outlined below. In our survey, we asked the MCTP teachers to report concerning these activities.

Assisting All Students to Achieve High Standards — The AAAS's publication of *Science for All Americans* defined the scientifically literate person as one who: is aware that science, mathematics, and technology are independent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and, uses scientific knowledge and scientific ways of thinking for individuals and social purposes [41]. This call for "science for all" required not just providing guidelines for what students should know and be able to achieve in mathematics and science, but also required providing recommendations of how to teach in class. Such recommendations included instructional models, such as: teaching for understanding, teaching for conceptual change, and constructivist teaching. The published standards for mathematics and science education shared many of the tenets of the constructivist philosophy. In the constructivist paradigm, the student has a more central role. Instruction, activities, and discussion are designed so that the students will manipulate the information and materials to construct the underlying principle that is being taught, emphasizing both hands-on and minds-on exploration of content [33]. In our survey, we asked the MCTP teachers if they were assisting all students to achieve high standards and if they were using the standards-aligned curricula.

Using Authentic Assessments — According to Fey, the most common strategy for assessing student learning in K-16 is through competitive, timed, written quizzes and tests that require individual students to answer a collection of specific short questions or to perform routine calculations to solve well-defined problems or multiple-choice tests [34]. Brooks and Brooks asserted that multiple-choice tests are structured to determine whether students know information related to a particular body of knowledge and their focus is on material, *not on personal construction* [42]. Authentic assessments, which are defined as tasks and problems already relevant or of emerging relevance to students, also relate to a particular body of knowledge. However, rather than stretching the assessments around specific bits of information, they invite students to exhibit what they have internalized and learned through application.

Teachers' beliefs about assessment and their use of assessment to determine students' progress are an important influence on activities taking place in mathematics and science classrooms [33]. Williams, et al. stressed that because testing drives teaching, most teachers will eventually cease much of their teaching and prepare their students for the reality of having to pass a multiple-choice test. Some students do very well in this sort of testing, but for many others, the forced response testing paradigms do not give accurate readings of their knowledge. Moreover, even students who are successful on standardized tests often have embarrassing gaps in their understanding of key scientific and mathematical ideas [34]. The agreement, in the last decade, on the influence of the assessment approaches to the learning process is reported by leading groups in mathematics and science education, and curriculum and standards documents, such as the *National Science Education Standards* [5]. The MCTP program stressed the importance of authentic assessments and other alternative assessments.

Using Telecommunication-Supported Instruction — It is suggested, “Just as information technology has improved effectiveness in medicine, finance, manufacturing, and numerous other sectors of society, advanced computing and telecommunications have the potential to help students master these complex twenty-first century skills” [43]. Sophisticated computers and telecommunications have unique capabilities for enhancing learning. These skills include: centering the curriculum on “authentic” problems parallel to those adults face in a real-world setting; involving students in virtual communities of practice; utilizing modeling and visualization as a powerful means of bridging between experience and abstraction; supporting sophisticated manipulation of information (e.g., generating, transmitting, sorting, processing, and retrieving information); and, serving as a communication facilitator (e.g., e-mail, group conferencing, and Internet Relay Chat) that enables learning in any time, any place, on any path, and at any pace [44,45].

Many teachers realize that telecommunications have the potential to revolutionize instruction and are interested in using this resource with their students. However, they need models, support, and practice to integrate telecommunications into curricula and a way to connect these activities to learning outcome [46]. One of the goals of the MCTP program was to employ faculty in mathematics, science, and methods committed to modeling best teaching practices. This included faculty who sought to infuse technology and telecommunications into their teaching practices.

Making Connections between the Sciences and between Mathematics and the Sciences — Currently, widespread support exists for teaching mathematics and science in an integrated

fashion in the school curriculum as articulated by the prominent mathematics and science reform documents, such as the *National Science Education Standards* [5]. Integration is advocated as a means by which students can develop deeply organized knowledge structures that are richly interconnected. However, there is no consensus about the definition of integrated mathematics and science [47]. The clarification of the meaning of integration is more than a matter of semantics. In particular, some individuals define integration as situations in which traditional disciplinary boundaries (e.g., mathematics and science) are significantly blurred or even lost. In such cases, students are typically asked to solve problems or reach decisions on matters of everyday relevance, and they are unaware of whether they are using/learning mathematics or using/learning science. On the other hand, many individuals define integration in a manner that maintains traditional disciplinary boundaries, and the focus of instruction stresses the interactions between mathematics and science. This second situation can also be labeled as interdisciplinary [48]. The MCTP promoted the interdisciplinary position. The goal of the MCTP was to promote the development of teachers who were confident teaching mathematics and science, and who could make connections between and among the disciplines [10]. This philosophy was in accord with the assumption that the growth of mathematical and scientific knowledge has also been accompanied by increasing specialization in research fields, and mathematics and science in secondary schools tend to be organized in ways that honor those specializations. However, recent developments have demonstrated that progress on major scientific problems usually requires integration of mathematics strategies; and likewise, mathematics that is detached from life experience is seen by many students as irrelevant [34].

Research Design and Methodology

To examine what beliefs and intended actions the MCTP graduates brought to their classrooms, we decided that a research design using survey methodology would be appropriate. Our goal was to assess the effectiveness of the MCTP program. As such, we needed to collect the total population of MCTP graduates' reported beliefs about mathematics and science, and their intentions toward the teaching of those subjects so that we could: 1) describe our sample; and, 2) compare our sample (total and disaggregated by level and subject) with a larger, more representative sample of practicing mathematics or science teachers.

Instrument Development — We decided to craft a survey that used existing reported survey items to which practicing teachers had previously responded. Thus, we could make a comparison between the MCTP graduates' responses concerning beliefs about subject matter, mathematics/science, and intentions regarding instruction of mathematics/science with responses by representative practicing teachers in the workplace. This strategy required us to examine the

literature for accepted and reported surveys that measured practicing teachers' constructs. We then targeted and developed a new survey for the MCTP sample consisting primarily of items taken verbatim from those reported surveys.

We found success in our search when we inspected survey data reported in the *National Science Board, Science and Engineering Indicators—1998* [14]. Specifically, we found existing valid and reliable surveys that measured: “Teacher beliefs about the nature and teaching of mathematics and science,” 1994-95; “Teacher perceptions of the student skills required for success in mathematics and science,” 1994-95; “Teachers’ knowledge of the standards,” 1994-1995; and, “Percentage of mathematics and science teachers implementing reform activities,” 1996 [33,49,50]. Upon inspection, we determined that these instruments were based on items used in the Third International Mathematics and Science Study (TIMSS).

From these existing surveys, we crafted a new 51-item survey (see Appendix A), “MCTP Teachers’ Actions and Beliefs of Mathematics and Science,” consisting of forty-five previously administered items taken from those reported surveys. We added two items to our survey that related to a unique aspect of the MCTP, making connections between mathematics and science in instructional practice (items 40, 47). We added another item that asked about the teacher’s familiarity with the *National Science Education Standards* (item 33), and we also included four items that asked for background information (items 48-51) [5].

The items in the new MCTP survey can be divided into four categories.

- 1) Teachers’ beliefs about the nature and teaching of mathematics (see Appendix A, items 1-9) and science (items 10-18). An example for one such item was: “Is mathematics/science primarily an abstract subject?”
- 2) Teachers’ perceptions about the student skills required for success in mathematics (items 19-24) and science (items 25-30). An example for one such item was to ask if learners needed to “Think in sequential manner.”
- 3) Teachers’ intentions about implementing reform activities in mathematics classes (items 34-40) and in science classes (items 41-47). An example for one such item was to ask if they intended to use standards-aligned textbooks and materials in their instructional practices.
- 4) Teachers’ familiarity with standards documents and benchmarks for mathematics (item 31) and science (items 32, 33) literacy. An example for one such item was to ask if they were familiar with the *National Science Education Standards* [5].

With respect to this last category, we did not present and discuss data regarding the section titled, “Teachers’ familiarity with standards documents and benchmarks for mathematics and science...” in this paper. These data were of interest to the project leaders, but were assessed as provisional due to the limited number of items.

Subjects — We sent out our survey by mail to the MCTP program’s graduates three times: in Spring 1999 to all graduates from 1997 to that date ($n=57$); in Fall 1999 ($n=28$); and, in Fall 2000 ($n=28$). From these 113 graduates, we received sixty-eight surveys, with approximately 70% from those who had just graduated from college and 97% from new teachers with less than two years of teaching experience. Our total response rate was about 60%, moderately high for survey research of this type. Responses came from graduates of all seven of the MCTP participating institutions with baccalaureate programs. We attribute the high level of response partially to these strategies for increasing a return rate to mail-in surveys: sending a token honorarium such as a \$2 bill or a \$1 coin in the first mailing and a \$20 honorarium in our final mailing; sending a subsequent reminder letter with another copy of the instrument; and, using e-mail and telephone reminders. To enhance the validity of our analysis, we conducted a non-response bias check in both administrations by randomly selecting a sample of eight non-responding MCTP graduates. Upon contact, we encouraged them to complete the survey. Using both the Pearson chi-squared statistic and the Cochran-Armitage Trend statistic, early and late response groups were compared on all fifty-one items. No significant differences were detected.

For the first survey administration, the majority of the sampled MCTP graduates (approximately 70%) were recent graduates who had not started teaching, while 97% were in their first or second year of full-time practice. The instructional level of the employed MCTP new teachers ranged from first grade to eighth grade (see Appendix B).

Data Analysis — We conducted three levels of data analysis. For our first level of data analysis, we examined our data to see how the MCTP graduates responded to each item, by frequency and percent. For our second level of data analysis (i.e., comparing our sample responses with a larger, more representative sample of practicing teachers), we used inferential statistics. For our third level of data analysis (i.e., comparing the responses of our sample over the three administrations separated across time), we manually examined the data for any noticeable differences before application of inferential statistics. Since responses were nearly identical between the first administration and our final administration on all items, an inferential analysis was not required.

We first made comparisons by total MCTP response and the national sample of practicing eighth grade teacher response. We made the assumption that since the MCTP graduates were certified to teach up to eighth grade that the samples were comparable groups. We wanted to ascertain if the MCTP graduates were different in any way from practicing teachers on a range of items that could be linked to reform-based perspectives. However, we were sensitive to possible arguments that the groups were incomparable; i.e., the MCTP graduates were not necessarily employed teachers at the time they responded to the survey or, if they were, they taught at different levels and subjects. Therefore, to test if those differences between the samples made a difference, we next performed a comparison between disaggregated MCTP samples by employed new teacher's level (elementary or middle school) and by subject focus (mathematics or science). What follows are our results reported by instrument section (representing our targeted constructs).

Findings

We report our findings according to the three categories of interest in the MCTP survey. First, we examined to what extent the MCTP responses aligned with the philosophy of the MCTP program, and then we made a comparison between the MCTP graduates and the national sample of teachers. When it was possible to analyze by teaching level (elementary or middle school) we reported that, also.

Findings: Teachers' Beliefs about the Nature and Teaching of Mathematics and Science

In this section, teachers were asked to rate on a scale from 1 (strongly disagree) to 4 (strongly agree) eighteen statements concerning their beliefs about the nature and teaching of mathematics (see Appendix A, items 1-9) and science (see Appendix A, items 10-19). Tables 1 and 2 show the national sample and MCTP responses, the percentages in these tables reflecting the combined proportion of teachers who either agree or strongly agree with the statements.

Teachers' Beliefs about the Nature and Teaching of Mathematics — Table 1 shows the findings concerning teachers' beliefs about the nature and teaching of mathematics. The national sample group, in this section, was composed of eighth grade mathematics teachers ($n=246$) who were surveyed in 1995 as part of the Third International Mathematics and Science Study (TIMSS).

Table 1
Comparison of MCTP New Teachers' Beliefs about the Nature and Teaching of Mathematics with Those of MSEG Sample by Percentage Agreeing or Strongly Agreeing

Item	National ¹ %	MCTP ² %	MCTP ³ %
1. Math is primarily an abstract subject.	31.0	10.4***	0.0***
2. Math is primarily a formal way of representing the real world.	79.1	74.2	57.1
3. Math is primarily a practical and structured guide for addressing real situations.	88.8	85.3	85.7
4. Math should be learned as sets of algorithms or rules that cover all possibilities.	35.2	19.7*	14.2
5. A liking for and an understanding of students are essential for teaching math.	96.5	86.8***	92.9
6. If students are having difficulty, an effective approach is to give them more practice by themselves during the class.	22.4	13.2	0.0***
7. More than one representation should be used in teaching a math concept.	98.3	94.1	100
8. Some students have a natural talent for math and others do not.	81.4	73.1	92.9
9. Basic computational skills on the part of the teacher are sufficient for teaching elementary school math.	17.3	26.5	14.3

* $P < .05$ ** $P < .01$ *** $P < .001$

¹ National Center for Education Statistics, *Mathematics and Science in the Eighth Grade: 1995*, Middle school mathematics teachers, $n=246$

² MCTP Graduates' Beliefs and Actions of Mathematics and Science, $n=68$.

³ MCTP-middle New Teacher's Beliefs and Actions of Mathematics and Science, Middle school mathematics teachers, $n=14$.

The MCTP graduates' responses toward the nature and teaching of mathematics differed significantly ($p < .05$) from the national sample on several beliefs. Specifically, they were *less likely* to believe: that mathematics is primarily an abstract subject (10.4% MCTP, 31.0% National); that mathematics should be learned as sets of algorithms or rules that cover all possibilities (19.7% MCTP, 35.2% National); and, that a liking for and an understanding of students are essential for teaching (86.8% MCTP, 96.5% National).

These differences aligned with the reform philosophy, since a major goal of the MCTP program was “science and mathematics for all” [34]. A way to achieve this goal was to “produce new teachers who are confident teaching mathematics and science” and who believe that mathematics and science are not primarily abstract subjects [51]. Teachers who can provide an exciting and challenging learning environment for students of diverse backgrounds believe that learning the process of mathematics and science is more important than having a collection of facts or a set of algorithms that cover all possibilities.

A disaggregated analysis of MCTP middle school mathematics teachers' responses ($n=14$) compared with the national sample on the same construct found that MCTP middle school mathematics teachers differed significantly ($p < .05$) from the national sample on two beliefs (Table 1). Interestingly, not a single MCTP middle school teacher believed that mathematics is primarily an abstract subject (0% MCTP middle, 31.0% National); or that if students are having difficulty, an effective approach is to give them more practice by themselves during the class (0% MCTP middle, 22.4% National). We speculate that the emphasis on cooperative learning in the MCTP program promoted the MCTP teachers' beliefs that it is more effective when students practice in groups instead of practicing by themselves.

Teachers' Beliefs about the Nature and Teaching of Science — Table 2 shows the findings concerning teachers' beliefs about the nature and teaching of science. The national sample group, in this section, was eighth grade science teachers ($n=232$) who were surveyed in 1995 as part of the Third International Mathematics and Science Study (TIMSS).

Table 2

Comparison of MCTP Graduates' Beliefs about the Nature and Teaching of Science with Those of National Sample by Percentage Agreeing or Strongly Agreeing

Item	National ¹ %	MCTP ² %	MCTP ³ %
10. Science is primarily an abstract subject.	18.2	15.4	44.4%
11. Science is primarily a formal way of representing the real world.	84.3	70.8**	88.9%
12. Science is primarily a practical and structured guide for addressing real situations.	88.0	77.9*	100%**
13. Some students have a natural talent for science and others do not.	62.0	55.2	33.3%
14. A liking for and an understanding of students are essential for teaching science.	89.6	79.4*	88.9%
15. It is important for teachers to give students prescriptive and sequential directions for science experiments.	75.8	45.5***	33.3%*
16. Focusing on rules is a bad idea. It gives students the impression that the sciences are a set of procedures to be memorized.	32.0	41.2	55.5%
17. If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning.	2.8	7.4***	11.1%
18. Students see a science task as the same task when it is represented in two different ways.	42.8	27.4*	33.3%

* $P < .05$ ** $P < .01$ *** $P < .001$

¹ National Center for Education Statistics, *Mathematics and Science in the Eighth Grade: 1995*, Middle school science teachers, $n=232$.

² MCTP Graduates' Beliefs and Actions of Mathematics and Science (2001), $n=68$.

³ MCTP-middle New Teacher's Beliefs and Actions of Mathematics and Science (2001): Middle school science teachers, $n=9$

The MCTP graduates' responses differed significantly ($p < .05$) from the national sample on six items (items 11, 12, 14, 15, 17, 18). They were *less likely* to believe: that science is primarily a formal way of representing the real world (70.8% MCTP, 84.3% National); that science is primarily a practical and structured guide for addressing real situations (77.9% MCTP, 88.0% National); and, that a liking for and an understanding of students are essential for teaching science (79.4% MCTP, 89.6% National). While these differences between the national sample and the MCTP graduates were statistically significant, the percentages suggest that they might not be educationally significant.

More pronounced differences, however, were found concerning the statements "It is important for teachers to give students prescriptive and sequential directions for science experiments" (45.5% MCTP, 75.8% National); and, "Students see a science task as the same task when it is represented in two different ways" (27.4% MCTP, 42.8% National). The differences on these items probably reflect the fact that MCTP teachers were exposed during their studies to research in science education. They became aware of students' alternative conceptions in science and to the recommendation to involve students in inquiry and investigative approaches rather than to give students prescriptive and sequential directions for science experiments.

In this respect, it is relevant to discuss the concept of Pedagogical Content Knowledge (PCK) which Shulman introduced as an element of the knowledge base for teaching [37]. The PCK consists mainly of two key elements: a knowledge of instructional strategies incorporating representations of subject matter, and an understanding of specific learning difficulties and student conceptions with respect to that subject matter [13]. One of the MCTP program goals was to promote teachers' PCK and address conceptual change. It has been widely documented that different representations of essentially the same tasks often trigger responses that differ and sometimes even clash [52,53]. Exposure to such research could be the cause for the fact that MCTP graduates were less likely to believe that "Students see a science task as the same task when it is represented in two different ways."

The sixth statement (Table 2, item 17), in which the MCTP graduates' responses differed significantly from the national sample, runs counter to the MCTP reform philosophy. The MCTP teachers were *more likely to believe* that if students are allowed classroom debates about ideas or procedures covering the sciences, it can harm their learning (7.4% MCTP, 2.8% National). The percentage of MCTP teachers agreeing with this statement is not high (five students out of sixty-eight); however, we would expect that no MCTP graduate would agree with this statement, given that the MCTP program promoted student discourse.

The analysis of the MCTP middle school science teachers' responses ($n=9$) found that the MCTP middle school science teachers differed significantly ($p < .05$) from the national sample on two beliefs (Table 2). They were *less likely to believe* that it is important for teachers to give students perspective and sequential directions for science experiments (33.3% MCTP middle, 75.8% National) and *more likely to believe* that science is primarily a practical and structured guide for addressing real situations (100% MCTP middle, 88% National). We suspect that the reform recommendations to relate science to everyday life and to use real-life problems in teaching science promoted teachers' beliefs that science is primarily a practical and structured guide for addressing real situations.

Findings: Teachers' Perceptions about the Student Skills Required for Success in Mathematics and Science

In this section, teachers were asked to rate on a scale from 1 (not important) to 3 (very important) the importance of particular kinds of skills for success in the discipline. These skills have elements ranging from remembering through understanding to thinking creatively. The items in this section (see Appendix A) are parallel across the two disciplines: mathematics (items 19-24) and science (items 25-30). The national sample group, in this section, was eighth grade mathematics ($n=246$) and science ($n=232$) teachers who were surveyed in 1995 as part of the Third International Mathematics and Science Study (TIMSS). The national sample and the MCTP graduates' responses are shown in Figures 1 and 2. The percentages in these figures were rounded and reflect the percentage of teachers who chose the category "very important." The statistically significant differences between the national sample and the MCTP graduates are denoted by underlining the percentages and putting them in boldface.

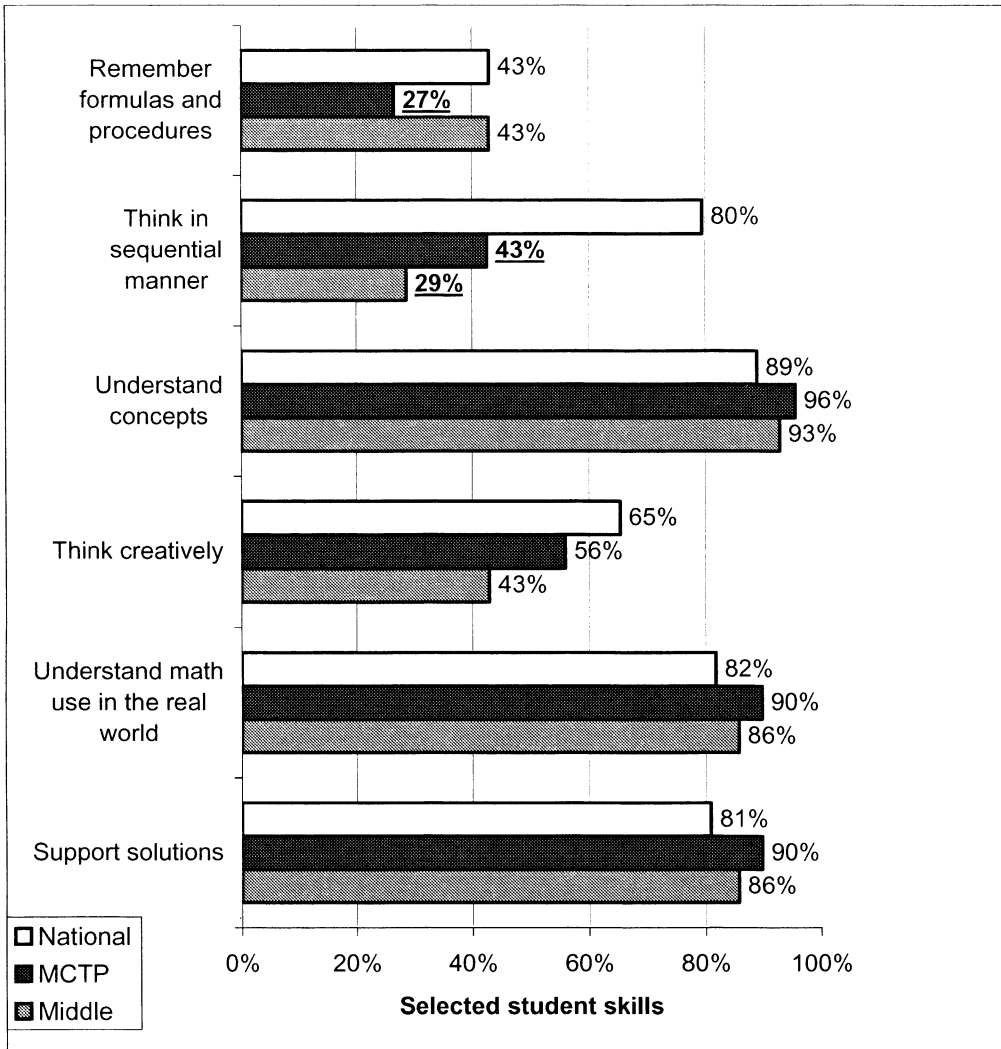


Figure 1. Comparison of MCTP Graduates’ perceptions of the student skills required for success in mathematics with those of MSEG sample by percentage responding “Very Important.”

National Center for Education Statistics, *Mathematics and Science in the Eighth Grade: 1995*, Middle school mathematics teachers, $n=246$
 MCTP Graduates’ Beliefs and Actions of Mathematics and Science, $n=68$.
 MCTP-middle New Teacher’s Beliefs and Actions of Mathematics and Science: Middle school mathematics teachers, $n=14$.

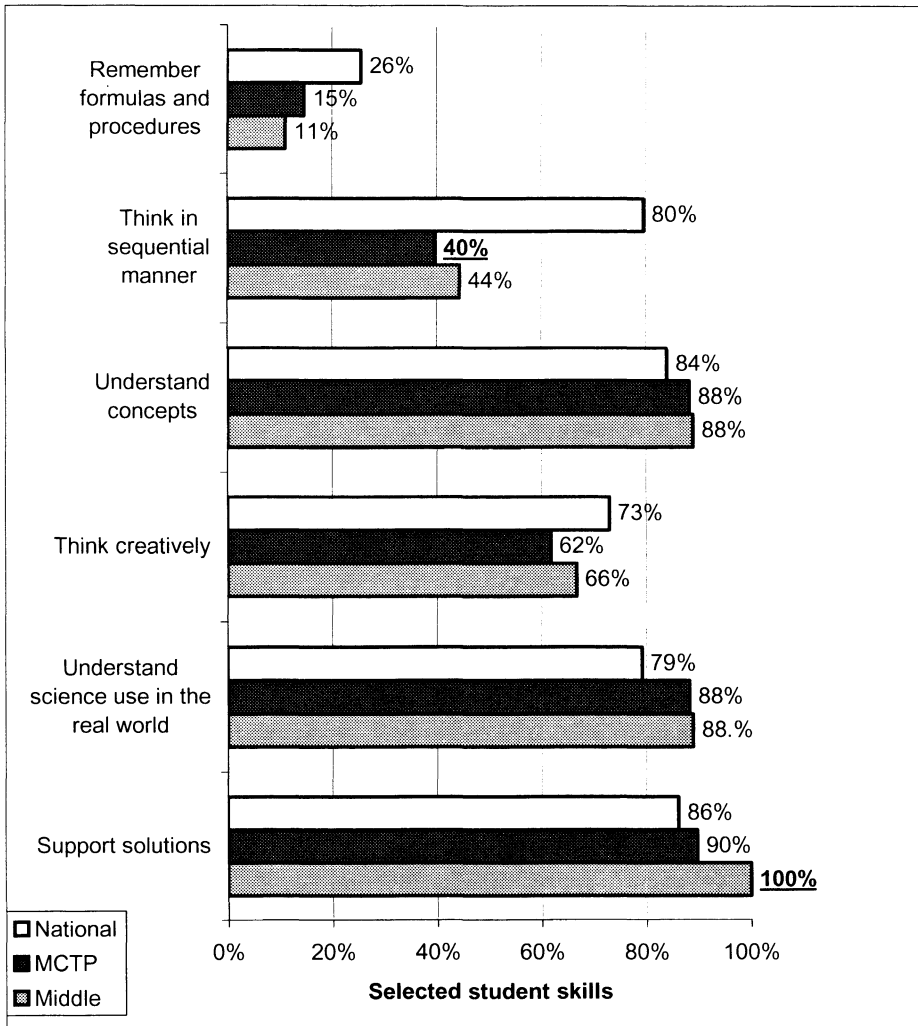


Figure 2. Comparison of MCTP graduates' perceptions of the student skills required for success in science with those of MSEG sample by percentage responding "Very Important."

National Center for Education Statistics, *Mathematics and Science in the Eighth Grade: 1995*, Middle school science teachers, $n=232$.

MCTP Graduates' Beliefs and Actions of Mathematics and Science, $n=68$.

MCTP-middle New Teachers' Beliefs and Actions of Mathematics and Science: Middle school science teachers, $n=9$.

The findings show that there was substantial agreement between the MCTP graduates and the mathematics and science teachers from the national sample on the aptitudes and skills students need to succeed in learning mathematics and science. Over 80% of the teachers consider it “very important” for students to understand concepts, to understand how the subjects are used in the real world, and to be able to support their results and conclusions.

However, there are some areas of difference in these views. The MCTP teachers were *less likely to think* it is very important for students to remember formulas and procedures in **mathematics** (27% MCTP, 43% National). Interestingly, there were no such differences between the national sample and the MCTP teachers in the case of remembering formulas and procedures in **science**. However, inspection of the data show that, in the case of science, both populations (15% MCTP, 26% National) were *less likely to think* that it is very important to remember formulas and procedures in **science** in comparison to mathematics.

The fact that the MCTP graduates were less likely to mark “remember formulas and procedures” as “very important” is aligned with the reforms recommendation to put the emphasis on meaningful learning (characterized by a focus on understanding) instead of rote learning (characterized by memorization of facts). As earlier reported, Mayer’s taxonomy, while not rejecting the importance of “remembering,” emphasized that learning in school should be expanded to include a wider range of cognitive processes, such as the ability to use what was learned to solve new problems, answer new questions, or facilitate learning new subject matter [38].

Differences between the MCTP teachers and the national teachers were significant also concerning the importance of “Think in sequential manner” in mathematics (43% MCTP, 80% National) and in science (40% MCTP, 80% National). In all, Figures 1 and 2 show that the MCTP graduates identified “Think in sequential manner” and “Think creatively” as being less important than “Understand concepts,” “Understand math use in the real world,” “Understand science use in the real world,” and “Support solutions.” This might be connected with recent theories about how students’ backgrounds may influence the manner in which they prefer to engage with content. Felder, referring to college science students, stressed that students are characterized by significant different orientations toward content, and teachers should not desire to change their preferred orientations, but to modify their teaching practices to accommodate and reach all students [39]. In the case of “Think in sequential manner,” Felder defines sequential learners as students who absorb information and acquire an understanding of material in small connected chunks, as opposed to global learners who take information in seemingly unconnected

fragments and achieve understanding in large, holistic leaps. Felder suggests that sequential learners can solve problems with an incomplete understanding of the material and may lack a grasp of the big picture. Global learners work in a more all-or-nothing fashion; they may appear slow and do poorly on tests until they grasp the big picture, but once they have it, they often can see connections to other subjects that escape sequential learners.

The analysis of the MCTP middle school mathematics and science teachers' responses found that the MCTP middle school teachers differed significantly ($p < .05$) from the national sample on two perspectives (Figures 1 and 2). Mathematics teachers were *less likely to believe* that it is important for mathematics students to think in a sequential manner (29% MCTP, 80% National), and science teachers were *more likely to believe* that it is very important for students to support solutions (100% MCTP, 86% National).

Findings: Teachers' Intentions about Implementing Reform Activities in Mathematics and Science Classes

In this section, teachers were asked to report on the kind of reform activities they are implementing in their classrooms (items 34-47). Tables 3 and 4 summarize the MCTP graduates' responses and the national sample. The percentages in these figures were rounded and they reflect the percentage of teachers who chose to answer "yes." The national sample groups, in this section, were public elementary and secondary school mathematics and science teachers who answered a survey in 1996 [14].

Table 3

Comparison of MCTP School Teachers' Use of Instructional Practices in Mathematics with Those of National Sample by Percentage Responding "Yes"

Item	Elementary School		Middle School	
	MCTP ¹	National ²	MCTP ³	National ²
34. Assisting all students to achieve high standards.	100***	77	100***	85
35. Providing examples of high-standard work.	100***	63	100***	66
36. Using authentic assessments.	100***	55	100***	49
37. Using standards-aligned curricula.	100***	64	93*	72
38. Using standards-aligned textbooks and materials.	93***	66	85	72

39. Using telecommunication-supported instruction.	64***	20	69***	27
40. Making connections with science.	93	-----	92	-----

¹ MCTP Teacher's Beliefs and Actions of Mathematics and Science: Elementary school teachers, $n=29$.

² Public School Teacher Survey on Education Reform: Elementary and middle school (1996), $n=152$.

³ MCTP Teacher's Beliefs and Actions of Mathematics and Science: Middle school mathematics teachers, $n=14$.

Table 4
Comparison of MCTP School Teachers' Use of Instructional Practices in Science with Those of National Sample by Percentage Responding "Yes"

Item b	Elementary School		Middle School	
	MCTP ¹	National ²	MCTP ³	National ²
41. Assisting all students to achieve high standards.	100***	71	100**	78
42. Providing examples of high-standard work.	100***	48	88.9	64
43. Using authentic assessments.	100***	44	100***	42
44. Using standards-aligned curricula.	96***	66	100***	65
45. Using standards-aligned textbooks and materials.	86**	58	100***	60
46. Using telecommunication-supported instruction.	75***	17	75*	29
47. Making connections with mathematics.	97	-----	100	-----

¹ MCTP Teacher's Beliefs and Actions of Mathematics and Science (2001): Elementary school teachers, $n=29$.

² Public School Teacher Survey on Education Reform: : elementary and middle school (1996), $n=95$.

³ MCTP Teachers' Beliefs and Actions of Mathematics and Science (2001): Middle school mathematics teachers, $n=9$.

The MCTP elementary school mathematics teachers differed significantly from the national sample on all mathematical teaching practices. They say that they were *more likely to*: assist all students to achieve high standards; provide examples of high-standard work; use

authentic assessments; use standards-aligned curricula; use standards-aligned textbooks and materials; and, use telecommunication-supported instruction. Also, 93.1% stated that they would make connections with science in their practices.

The MCTP middle school mathematics teachers differed significantly from the national sample on several actions. They say that they were *more likely to*: assist all students to achieve high standards; provide examples of high-standard work; use authentic assessments; use standards-aligned curricula; and, use telecommunication-supported instruction. Also, 92.31% stated that they made connections with science in their practices.

The MCTP elementary school science teachers differed significantly from the national sample on all practices. They say that they were *more likely to*: assist all students to achieve high standards; provide examples of high-standard work; use authentic assessments; use standards aligned curricula; use standards-aligned textbooks and materials; and, use telecommunication-supported instruction. Also, 96.6% stated that they made connections with mathematics in their practices.

The MCTP middle school science teachers also differed significantly from the national sample on several practices. They say that they were *more likely to*: assist all students to achieve high standards, to use authentic assessments; use standards-aligned curricula; use standards-aligned textbooks and materials; and, use telecommunication-supported instruction. Also, 100% stated that they made connections with mathematics in their practices.

Overall, it seems that except for “Using telecommunication-supported instruction,” most or all of the MCTP mathematics and science teachers in both levels of instruction (elementary and middle school) reported that they use or intended to use each of the instructional practices that were included in this section. Actually, all of the instructional practices that appear in this section are recommended by the MCTP program. The call for “science and mathematics for all” dictates that teachers have to assist all students to achieve high standards and, in order to reach all of the students, there is a need to use different assessment strategies, since for many students the conventional testing paradigms do not give accurate readings of their knowledge [34]. Interestingly, only about 70% of the MCTP mathematics and science teachers reported using telecommunication-supported instruction; these percentages are low in comparison to the other practices that MCTP teachers reported that they use. However, they are high in comparison to the national group reports of using telecommunication-supported instruction. These results probably reflect not only the MCTP philosophy to enhance technology and telecommunication-supported

instruction, but also the time difference. Currently, educators (teachers, developers, researchers, students) are much more aware of the potential of Internet technology than they might have been eight years ago [45].

Results and Discussion

The goal of the MCTP was to produce new teachers who were confident teaching mathematics and science using technology, who could make connections between and among the disciplines, and who could provide an exciting and challenging learning environment for students of diverse backgrounds. As such, the goals of the MCTP were in alignment with other reform-oriented undergraduate mathematics and science teacher preparation programs. The present analysis provides quantifiable evidence that the graduates of this program held perspectives that aligned with the MCTP reform-based goals. The present analysis also provides a striking comparison between the perspectives of practicing MCTP teachers and other teachers at the same level and subject specialization. Along all measures (many determined to be statistically significant), the MCTP new teachers expressed more reform-oriented perspectives concerning subject matter and instruction. These findings strongly suggest that a systematic, reform-based undergraduate mathematics and science program can produce new teachers who enter the workplace with desired perspectives. One might infer that the MCTP teachers expressed beliefs that they thought were consistent with our reform ideas, but this is also a step toward change. As stated by Haney, Lumpe, and Czerniak, "The beliefs that teachers hold regarding reform ideas are truly at the core of educational change..." [54]. This is why comparison with other teachers is so important, since they did not express these thoughts.

It is intriguing, however, that among all of the other positive findings, our analysis showed one anomalous result. When the MCTP graduates were compared with the entire sample of practicing teachers, the MCTP graduates were more likely to believe that if students engaged in classroom debates about ideas or procedures covering the sciences, it could harm their learning ($p < .0003$). While the percentage of MCTP graduate responses was low (7.4%), the result even at this level was surprising given that the MCTP program promoted learner discourse throughout. Furthermore, since the new MCTP middle school teachers' responses to this item were not determined to be statistically different from the sample of practicing middle school teachers, 11.1% also expressed this view. We speculate that for some new teachers the notion of student debate may be a threatening occurrence linked to a loss of classroom management, a prominent consideration of new teachers.

Limitations

One limitation of this study is that our survey was forced to use the same questions from the original surveys in order to compare between populations (MCTP and others). For example, in our survey items in which we asked about practice, the use of a 5-point Likert scale would have been our preference instead of “yes” and “no” responses. However, the original survey items used the “yes” and “no” responses, so we used the same.

Also, since not all of the MCTP graduates became eighth grade teachers, we recognize this as another limitation. As a result of this possible inability to compare with the national eighth grade sample, we recommend a guarded interpretation of the comparison between the total samples.

Educational Implications

The 1990s were exciting times within the mathematics and science teacher preparation communities. The reform movement (as guided by recommendations in the mathematics and science standards documents) influenced all aspects of the professional development of mathematics and science teachers, particularly in undergraduate teacher preparation. The present study adds empirical data to the discussion on the impact of large scale, reform-based undergraduate teacher preparation programs on teachers’ beliefs and intentions concerning mathematics and science if the research-based recommendations are used systematically throughout the interns’ program [55].

The study also illuminates one area of needed research—the impact of the workplace on graduates of such high quality programs. To what extent do reform-prepared mathematics and science teachers maintain their beliefs and intended instructional actions as they are inducted in schools? Policy makers, educators, and community members concerned with mathematics and science education need this information to design and maintain effective learning and teaching environments for the twenty-first century.

Continued Research

McGinnis, Marbach-Ad, and associates are currently engaged in continued research that builds directly on the findings from this study. This research is being supported by the National Science Foundation [56]. A new undergraduate preparation model for upper elementary/middle school science is being tested that incorporates comprehensive connections among the mathematics and sciences; including, transformative science content courses, science method courses, field-based placements in informal after school science internships, and professional

development schools. The standards-based curricular and instructional strategy used is focused on data management and analysis. The teacher preparation programs under study represent examples from an Historically Black College/University (HBCU) and a Predominantly White College/University (PWCU). The instrument reported in this study, "MCTP Teachers' Actions and Beliefs of Mathematics and Science" was used to develop an improved and more generic instrument to measure the same constructs. The new instrument is entitled, "New Teachers' Actions and Beliefs of Mathematics and Science." ■

Acknowledgments

This research was supported by the National Science Foundation's Collaboratives for Excellence in Teacher Preparation program and the Teachers Professional Continuum program. We gratefully acknowledge the MCTP graduates who participated in this study.

References

- [1] R.D. Anderson and C.P. Mitchener, "Research on Science Teacher Education," in D. Gabel (ed.), *Handbook on Research on Science Teaching and Learning*, Macmillan Publishing Co., New York, NY, 1994.
- [2] S.L. Adamson, D. Banks, M. Burtch, F. Cox, E. Judson, J.B. Turely, R. Benford, and A.E. Lawson, "Reformed Undergraduate Instruction and Its Subsequent Impact on Secondary School Teaching Practice and Student Achievement," *Journal of Research in Science Teaching*, **40** (2003) 939-957.
- [3] *Benchmarks for Science Literacy*, American Association for the Advancement of Science: Project 2061, Oxford University Press, New York, 1993.
- [4] *Professional Standards for Teaching Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1991.
- [5] *National Science Education Standards*, National Research Council, Washington, DC, 1996.
- [6] R. Millar and J. Osborne, *Beyond 2000: Science Education For the Future*, Fulmar Color Printing Company, London, 1998.
- [7] J.R. McGinnis, S. Kramer, A. Graeber, and C. Parker, "Measuring the Impact of Reform-Based Teacher Preparation on Teacher Interns' Attitudes and Beliefs," in J. Rainer and E. Guyton (eds.), *Research on the Effects of Teacher Education on Teacher Performance: Teacher Education Yearbook IX*, Kendall/Hunt Publishing Co., Dubuque, Iowa, 2001.
- [8] C.R. Coble and T.R. Koballa, Jr., "Science Education," in J. Huston, T. Buttery, and E. Guyton (eds.), *Handbook on Research on Teacher Education*, Macmillan Publishing Co., New York, NY, 1996.

- [9] J.R. McGinnis, S. Kramer, G. Shama, A. Graeber, C. Parker, and T. Watanabe, "Undergraduates' Attitudes and Beliefs of Subject Matter and Pedagogy Measured Longitudinally in a Reform-Based Mathematics and Science Teacher Preparation Program," *Journal of Research in Science Teaching*, **39**(8) (2002) 713-737.
- [10] J.R. McGinnis, "College Science, Mathematics, and Methods Teaching Faculty Talk about Science and Mathematics: An Examination of Faculty Discourse in a Reform-Based Teacher Preparation Program," *International Journal of Mathematics and Science Education*, **1** (2003) 5-38.
- [11] R. Mura, "Images of Mathematics Held by University Teachers of Mathematical Sciences," *Educational Studies in Mathematics*, **25**(4) (1993) 375-385.
- [12] R. Mura, "Images of Mathematics Held by University Teachers of Mathematics Education," *Educational studies in Mathematics*, **28**(4) (1995) 385-399.
- [13] J.H. van Driel, D. Beijaard, and N. Verloop, "Professional Development and Reform in Science Education: The Role of Teachers' Practical Knowledge," *Journal of Research in Science Teaching*, **38** (2001) 137-158.
- [14] *National Science Board, Science & Engineering Indicators—1998*, National Science Foundation, Arlington, VA, 1998.
- [15] J.A. Luft, G.H. Roehrig, and N.C. Patterson, "Contrasting Landscapes: A Comparison of the Impact of Different Induction Programs on Beginning Secondary Science Teachers' Practices, Beliefs, and Experiences," *Journal of Research in Science Teaching*, **40**(1) 2003.
- [16] R. Yerrick, H. Parke, and J. Nugent, "Struggling to Promote Deeply Rooted Change: The 'Filtering Effect' of Teachers' Beliefs on Understanding Transformational Views of Teaching Science," *Science Education*, **81** (1997) 137-157.
- [17] J.R. McGinnis, A. Parker, and A. Graeber, "A Cultural Perspective of the Induction of Five Reform-Minded New Specialist Teachers of Mathematics and Science," *Journal of Research in Science Teaching*, **41** (2004) 720-747.
- [18] P.E. Simmons, A. Emory, T. Carter, T. Coker, B. Finnegan, D. Crockett, L. Richardson, R. Yager, J. Craven, J. Tillotson, H. Brunkhorst, M. Twiest, K. Hossain, J. Gallagher, D. Duggan-Hass, J. Parker, F. Cajas, Q. Alshannag, S. McGlammery, J. Krockover, P. Adams, B. Spector, T. LaPorta, B. James, K. Reardon, and K Labuda, "Beginning Teachers: Beliefs and Classroom Actions," *Journal of Research in Science Teaching*, **36**(8) (1999) 930-953.
- [19] J.J. Gallagher and G. Richmond, "Stimulating Discourse on Science Education Reform: An Editorial and Call for Papers," *Journal of Research in Science Teaching*, **36** (1999) 753-754.
- [20] K. Tobin and C.J. McRobbie, "Cultural Myths as Constraints to the Enacted Science Curriculum," *Science Education*, **80** (1996) 223-241.

- [21] N.W. Brickhouse, "Teachers' Beliefs about the Nature of Science and Their Relationship to Classroom Practice," *Journal of Teacher Education*, **41** (1990) 53-62.
- [22] L.L. Cronin-Jones, "Science Teachers' Beliefs and Their Influence on Curriculum Implementation: Two Case Studies," *Journal of Research in Science Teaching*, **28** (1991) 235-250.
- [23] H. Munby, M. Cunningham, and C. Lock, "School Science Culture: A Case Study of Barriers to Developing Professional Knowledge," *Science Education*, **84** (2000) 193-211.
- [24] R.D. Anderson and J.V. Helms, "The Ideal of Standards and the Reality of Schools: Needed Research," *Journal of Research in Science Teaching*, **38** (2001) 3-16.
- [25] P.L. Grossman and S.S. Stodolsky, "Considerations of Content and the Circumstances of Secondary School Teaching," *Review of Research in Education*, **20** (1994) 179-222.
- [26] M.F. Pajares, "Teachers' Beliefs and Educational Research: Cleaning up a Messy Construct," *Review of Educational Research*, **62** (1992) 307-332.
- [27] V. Richardson, "The Role of Attitudes and Beliefs in Learning to Teach," in J. Sikula (ed.), *Handbook of Research on Teacher Education*, Macmillan Publishing Co., New York, NY.
- [28] J.L. Wilkins, "Change in Pre-Service Beliefs: An Evaluation of a Mathematics Methods Course," *School Science and Mathematics*, **104** (2004) 226-232.
- [29] M.Z. Hashweh, "Effects of Science Teachers' Epistemological Beliefs in Teaching," *Journal of Research in Science Teaching*, **33** (1996) 47-63.
- [30] L.C. Hart, "Pre-Service Teachers' Beliefs and Practice after Participating in an Integrated Content/Methods Course," *School Science and Mathematics*, **102** (2002) 4-11.
- [31] *Curriculum and Evaluation Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1989.
- [32] C.S. Wallace and N. Kang, "An Investigation of Experienced Secondary Science Teachers' Beliefs about Inquiry: An Examination of Competing Belief Sets," *Journal of Research in Science Teaching*, **41** (2004) 936-960.
- [33] T. Williams, L. Jocelyn, P. Martin, P. Butler, C. Heid, and J. Haynes, *Mathematics and Science in the Eighth Grade: Findings from the Third International Mathematics and Science Study*, National Center for Education Statistics, Washington, DC, 2000.
- [34] J. Fey, "Guiding Principles: New Thinking in Mathematics and Science Teaching," in C. Bell, & D.J. Katherine (eds.), *Journeys of Transformation II: The Impact of the Maryland Collaborative for Teacher*

Preparation on Science and Mathematics Instruction, Maryland Collaborative for Teacher Preparation (II), Towson, Maryland, 2002.

- [35] N.A. Davidson, *Cooperative Learning in Mathematics: A Handbook for Teachers*, Addison-Wesley, Reading, MA, 1990.
- [36] D.W. Johnson, R.T. Johnson, and K.A. Smith, *Active Learning: Cooperation in the College Classroom*, Interaction Book Company, Edina, MN, 1991.
- [37] L.S. Shulman, "Paradigms and Research Programs in the Study of Teaching: A Contemporary Perspective," in M.C. Wittrock (ed.), *Handbook of Research on Teaching*, Macmillan Publishing Co., New York, 1986.
- [38] R.E. Mayer, "Rote versus Meaningful Learning," *Theory into Practice*, **41** (2002) 226-232.
- [39] R. Felder, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education," *Journal of College Science Teaching*, **23** (1993) 286-290.
- [40] J.A. Shymansky, L.D. Yore, and R. Good, "Elementary School Teachers' Belief about and Perceptions of Elementary School Science Reading, Science Textbooks, and Supportive Instructional Factors," *Journal of Research in Science Teaching*, **28** (1991) 437-454.
- [41] *Science for All Americans*, American Association for the Advancement of Science, Washington, DC, 1989.
- [42] J.G. Brooks and M.G. Brooks, *In Search of Understanding: The Case for the Constructivist Classroom*, Association for Supervision and Curriculum Development, Alexandria, VA, 1993.
- [43] C. Dede, "Emerging Influences of Information Technology on School Curriculum," *Journal of Curriculum Studies*, **32** (2000) 281-303.
- [44] D.N. Gordin and R.D. Pea, "Prospects for Scientific Visualization as an Educational Technology," *Journal of the Learning Sciences*, **4** (1995) 203-226.
- [45] D. Mioduser, R. Nachmias, O. Lahav, and A. Oren, "Web-Based Learning Environments: Current Pedagogical and Technological State," *Journal of Research on Computing in Education*, **33** (2000) 55-76.
- [46] J.M. Stuhlmann and H.G. Taylor, "Analyzing the Impact of Telecommunications on Learning Outcomes in Elementary Classrooms," *Journal of Computing in Childhood Education*, **9** (1998) 79-92.
- [47] A.M. Huntley, "Design and Implementation of a Framework for Defining Integrated Mathematics and Science Education," *School Science and Mathematics*, **98** (1998) 320-327.
- [48] N.G. Lederman and M.L. Niess, "5 Apples + 4 Oranges = ?" *School Science and Mathematics*, **98** (1998) 281-284.

- [49] *Status of Education Reform in Public Elementary and Secondary Schools: Teachers' Perspectives*, National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1997.
- [50] *Mathematics and Science in the Eighth Grade*, National Center for Education Statistics, U.S. Department of Education, Washington, DC, 2000.
- [51] J.R. McGinnis, "Research on Teacher Education in the MCTP," in C. Bell and D.J. Katherine (eds.), *Journeys of Transformation II: The Impact of the Maryland Collaborative for Teacher Preparation on Science and Mathematics Instruction*, Maryland Collaborative for Teacher Preparation (II), Towson, Maryland, 2002.
- [52] A. Arcavi, D. Tirosh, and R. Nachmias, "Science and Mathematics Teaching: Interaction between Research and Practice," in S. Vinner (ed.), *Science and Mathematics Teaching: Interaction between Research and Practice*, Hebrew University, Jerusalem, 1989.
- [53] P. Tsamir, "When 'The Same' Is Not Perceived as Such: The Case of Infinite Sets," *Educational Studies in Mathematics*, **48** (2001) 289-307.
- [54] J.J. Haney, A.T. Lumpe, and C.M. Czerniak, "From Beliefs to Actions: The Beliefs and Actions of Teachers Implementing Change," *Journal of Science Teacher Education*, **13** (2002) 171-187.
- [55] R. Pekarek, G.H. Krockover, and D.P. Shephardson, "The Research-Practice Gap in Science Education," *Journal of Research in Science Teaching*, **33**(2) (1996) 111-114.
- [56] Project Nexus website, Internet: www.projectnexus.umd.edu

Appendix A

MCTP Teachers' Actions and Beliefs of Mathematics and Science

Directions: Please select the letter response that best represents your actions and beliefs.

SECTION I.

To what extent do you agree or disagree with each of the following statements?

Choices:

(A)	(B)	(C)	(D)
Strongly disagree	Disagree	Agree	Strongly agree

Mathematics

1. is primarily an abstract subject.
2. is primarily a formal way of representing the real world.
3. is primarily a practical and structured guide for addressing real situations.
4. should be learned as sets of algorithms or rules that cover all possibilities.
5. A liking for and an understanding of students are essential for teaching math.
6. If students are having difficulty, an effective approach is to give them more practice by themselves during the class.
7. More than one representation should be used in teaching a math concept.
8. Some students have a natural talent for math and others do not.
9. Basic computational skills on the part of the teacher are sufficient for teaching elementary school math.

Science

10. is primarily an abstract subject.
11. is primarily a formal way of representing the real world.
12. is primarily a practical and structured guide for addressing real situations.
13. Some students have a natural talent for science and others do not.
14. A liking for and an understanding of students are essential for teaching science.
15. It is important for teachers to give students prescriptive and sequential directions for science experiments.
16. Focusing on rules is a bad idea. It gives students the impression that the sciences are a set of procedures to be memorized.
17. If students get into debates in class about ideas or procedures covering the sciences, it can harm their learning.
18. Students see a science task as the same task when it is represented in two different ways.

SECTION II.

To be good at mathematics [science] at school, how important do you think it is for students to [fill in the blank with each of the items below]?

(A) Not important	(B) Somewhat important	(C) Very Important
--------------------------	-------------------------------	---------------------------

In Mathematics

19. remember formulas and procedures?
20. think in sequential manner?

21. understand concepts?
22. think creatively?
23. understand math use in real world?
24. support solutions?

In Science

25. remember formulas and procedures?
26. think in sequential manner?
27. understand concepts?
28. think creatively?
29. understand science use in real world?
30. support solutions?

SECTION III.

What is your familiarity with the reform documents?

- | | | | | |
|-------------------|---------------------|---------------|------------------------|---------------------|
| (A) | (B) | (C) | (D) | (E) |
| Not at all | Small extent | Fairly | Moderate extent | Great extent |

31. Mathematics standards document (*Curriculum and Evaluation Standards for School Mathematics*).
32. Science standards document *Benchmarks for Science Literacy*.
33. Science standards document *National Science Education Standards*.

SECTION IV.

Please indicate if you use (or would use if you taught mathematics and science) the instructional strategies listed below.

- | | |
|---------------|----------------|
| (A) No | (B) Yes |
|---------------|----------------|

In Mathematics

34. Assisting all students to achieve high standards.
35. Providing examples of high-standard work.
36. Using authentic assessments.
37. Using standards-aligned curricula.
38. Using standards-aligned textbooks and materials.
39. Using telecommunication-supported instruction.
40. Making connections with science.

In Science

41. Assisting all students to achieve high standards.
42. Providing examples of high-standard work.
43. Using authentic assessments.
44. Using standards-aligned curricula.
45. Using standards-aligned textbooks and materials.
46. Using telecommunication-supported instruction.
47. Making connections with mathematics.

SECTION V.

48. If you have taught since graduation, for what duration?
a. in beginning year b. 1 to 2 years c. 3 to 4 years d. > 4 years
49. If applicable, what grade level are you teaching this year?
a. 1 or 2 b. 3 or 4 c. 5 or 6 d. 7 or 8 e. other
50. If applicable, are you a specialized teacher (by content)?
a. yes b. no
51. If you are a specialized teacher, what is your content area?
a. mathematics b. science c. both mathematics and science d. other

Appendix B
Background of MCTP Graduates at Time of Survey Response

Sample Size	Number	Percent
Total	68	100%
Number of years teaching		
In beginning year	46	69.7%
1 to 2 years	18	27.3%
3 to 4 years	2	3.0%
More than 4 years	0	0.0%
Instructional level		
1 st or 2 nd grade	6	10.2%
3 rd or 4 th grade	10	16.9%
5 th or 6 th grade	19	32.2%
7 th or 8 th grade	19	32.2%
Other	5	8.5%
Specialized teacher (by content)		
Yes	40	66.7%
No	20	33.3%
Main subject area taught		
Mathematics	13	31.0%
Science	16	38.1%
Both mathematics and science	8	19.0%
Other	5	11.9%
Employed elementary or middle school teacher		
Elementary	29	47.5%
Middle school	32	52.4%
Middle school (mathematics)	14	23.0%
Middle school (science)	9	14.8%
Middle school (math and science)	9	14.8%

PRE-MATRIX BALANCING OF CHALLENGING CHEMICAL EQUATIONS WITH A SIMPLE FORMULA REGISTER AND MIDDLE SCHOOL ARITHMETIC

L. HUTCHINGS

*School of Education, Francis Marion University
Florence, SC 29501*

L. PETERSON

*Dept. of Chemistry, Francis Marion University
Florence, SC 29501*

A. ALMASUDE

*Graduate School of Education, Capella University
Minneapolis, MN 55402*

Abstract

This paper describes a procedure employing basic relational concepts (analogous to certain matrix algebra concepts), but structured by a simple formula register and using only middle school arithmetic to balance chemical equations ranging from easy to moderate to difficult redox reactions. This procedure allows average students and below average students to experience ready success in balancing, thus avoiding a traditional source of frustration and failure which might contribute to their losing interest in chemistry. One interesting serendipity of this procedure is how quickly it turns able pre-matrix students into extremely fast and accurate balancers.

Introduction

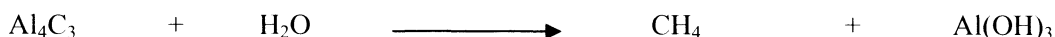
The balancing of chemical equations can be made much easier, especially for those who find it difficult, by moving the procedures toward the algorithmic and away from the heuristic. That is, a “step to step” procedure is simpler to master than is the haphazard hopping of inspection, even a highly refined inspection.

Computer-based balancing procedures use matrices. Excellent analogous procedures have been developed for humans, notably by Peterson, et al. [1] Unfortunately, a large number of students at the secondary and tertiary levels have no exposure to matrix algebra before they begin chemistry. Many of these, especially the lab focused rather than the theoretically focused, never do. Fortunately, there is a way to use matrix balancing concepts with a simple formula register and only middle school arithmetic to make balancing easy for almost everyone.

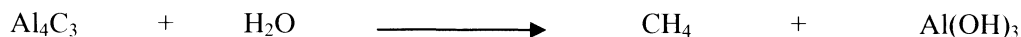
This allows average, and even low achieving students, a real chance at success. It can remove what is often a source of frustration and failure that turns students away from chemistry. Also, it allows the high achieving to become very fast and very accurate even with relatively difficult equations. A balancing technique based on quasi-matrix protocols is described below. Because of its unusual nature, it is best explained through demonstration; therefore, a balancing of three equations with the new procedure is presented. These equations will be shown in step-by-step instructional sequences that make all components of the new procedure explicit: new formats, new operations, and new terms. This technique provides students with a sharply delineated graphic organizer that improves their perceptions of quantity relationships within a chemical equation by expressing that equation in a quasi-matrix format called a register.

The Technique

First, the chemical equation is written with extra space, so that the formulas of its compounds are well separated.

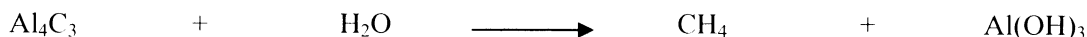


Then, the symbol for each element of the equation is written in a column beneath the yield sign. The order of the elements in this column, top to bottom, is the same as the order of the elements in the equation, left to right. If you use lined paper, skip a line between each element. Allow the equivalent space if you do not use lined paper.



4		Al		1
3		C	1	
	2	H	4	3
	1	O		3

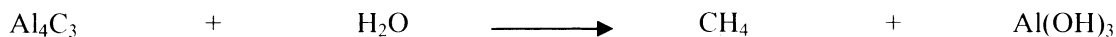
Balancing a register row means that coefficients are assigned (using the lowest common denominator) to its numbers so that the sum of the products of numbers on the left side of the element column, in that row, is equal to the corresponding sum on the right side.



(1)4		Al	(4)1
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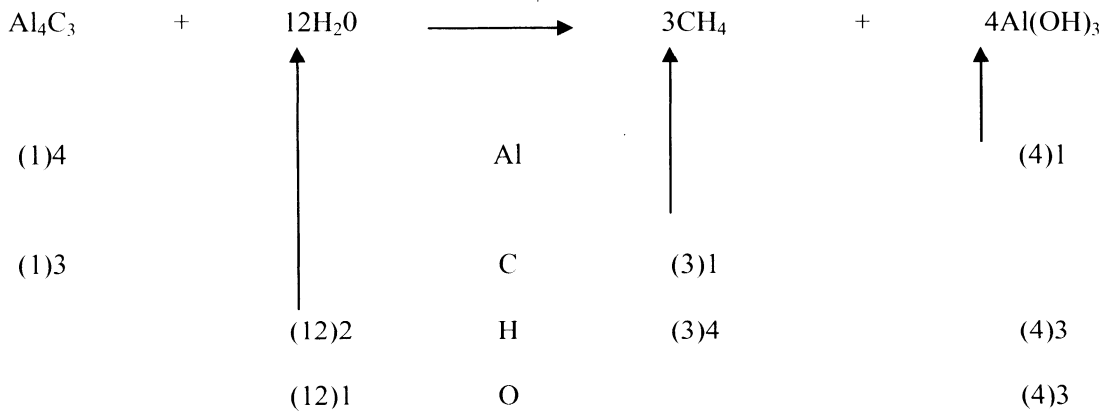
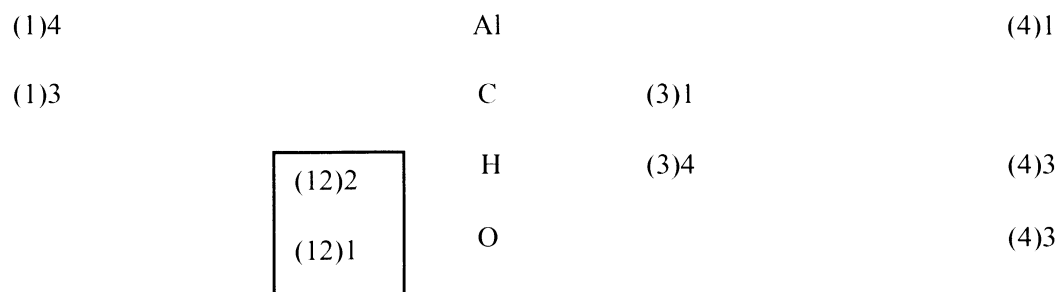
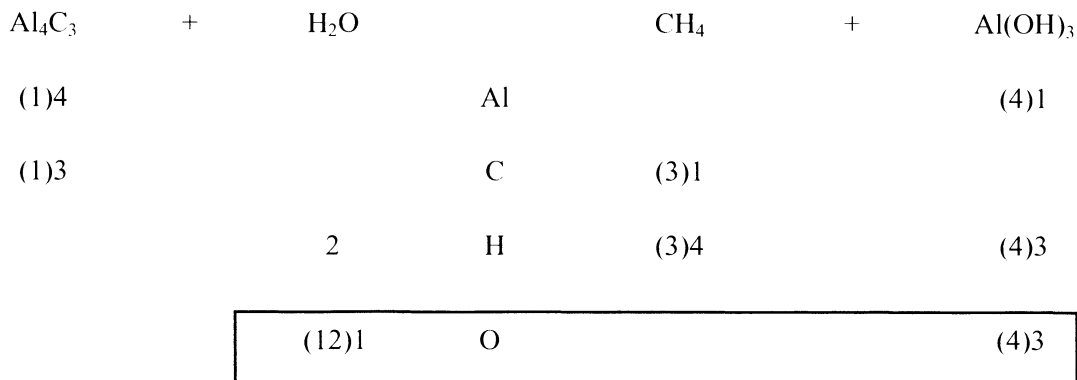
3		C	1
	2	H	4
	1	O	3

Once a row is balanced, then every number in any column having a number in the balanced row must be given the same factor as that column's number in that row. That is, all of the numbers in the column must be multiplied by equal factors. This is very easily done, but a little awkward to express. (For convenience, it might be called "equifacting.")



(1)4		Al	(4)1
(1)3		C	1
	2	H	(4)3
	1	O	(4)3

This pair of actions, balancing a row and equifacting its columns, constitutes a step in the balancing procedure. This two-part step might be called a "couplet." Once a couplet is



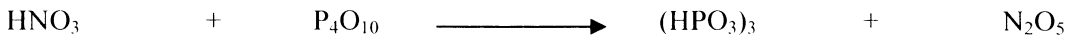
Once all couplets are completed, corresponding coefficients are placed in the original equation to complete the balancing.

It may be that equifacting the columns of a newly balanced row unbalances a previously balanced row. This is perfectly normal. Eventually, this unbalanced row will be selected for rebalancing. In theory, the same row might be balanced, unbalanced, and rebalanced more than once during this procedure. However, the row selection criteria suggest that balancing begins relatively high in the register and that priority be given to shorter compounds (number of elements) and to more complex compounds. With respect to the latter, complexity is proportional to the number of subscript coefficients distributed over some notationally defined set of elements and/or the number of elements in the set over which the subscript coefficient is distributed. Thus, $(\text{HPO}_3)_3$ is considered to be more complex than HNO_3 .

Using the example and criteria above as a case in point, please consider that the first row (Al), the second row (C), and the fourth row (O) are tied for shortness. However, the first row is associated with the relatively complex compound, $\text{Al}(\text{OH})_3$. Therefore, it was balanced first, then its columns equifacted. This completed the first couplet. A new row was selected (C) based on the original criteria, and the procedure continued until the register was fully balanced. Once completed, the factors of each column were transferred to their corresponding compounds (or elements) in the equation.

Most students respond very favorably to this technique. The method permits students to readily identify quantitative relationships. While easy balancing offers obvious cognitive advantages, it also offers subtle affective advantages (especially for uncertain or anxious students). That is, the method is simple and self-structuring, which helps students feel confident as they work thorough the problem. Haphazard guessing and desperate searching are virtually eliminated. A further example is provided below. This equation is usually perceived as more difficult than the first due to the relatively large numbers associated with its balancing.

Write the spread equation and its register.



1				H		3		
1				N				2
3		10		O		9		5
		4		P		3		

Then, proceed as explained above.

1				H		3		
1				N				2
3		10		O		9		5

(3)4	P	(4)3
------	---	------

1				H		(4)3		
1				N				2
3		(3)10		O		(4)9		5
		(3)4		P		(4)3		

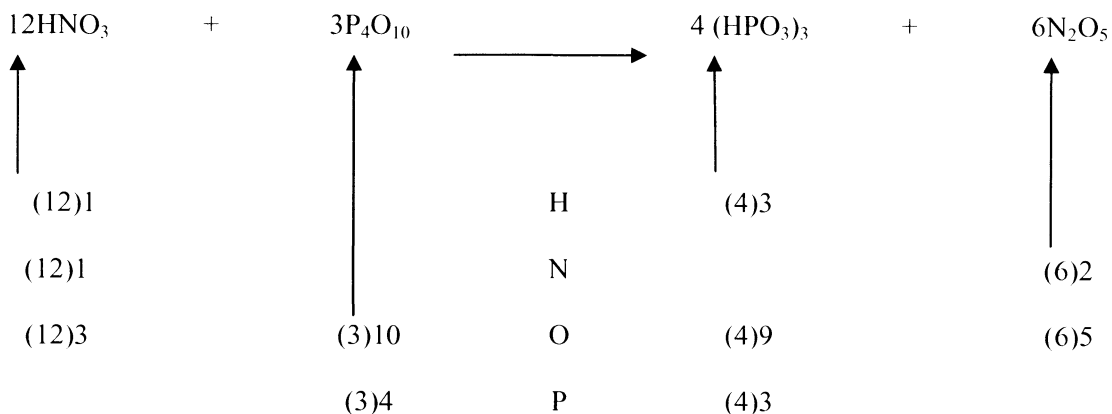
(12)1		H	(4)3	
-------	--	---	------	--

1		N		2
3	(3)10	O	(4)9	5
	(3)4	P	(4)3	

(12)1		H	(4)3	
		N	(4)9	2
(12)1		O	(4)3	5
(12)3	(3)4	P		

(12)1		H	(4)3	
(12)1		N		(6)2
(12)3	(3)10	O	(4)9	5
	(3)4	P	(4)3	

(12)1		H	(4)3	
(12)1		N		(6)2
(12)1	(3)10	O	(4)9	(6)5
	(3)4	P	(4)3	

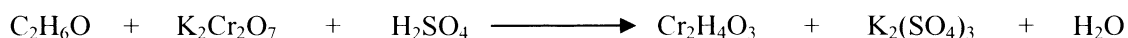


Using the register to help teach equation balancing makes this part of chemistry far more algorithmic than heuristic and, consequently, easier for students to comprehend and master. Its steps are summarized below.

- 1) Write the equation, spread out.
- 2) Write the element column.
- 3) Write the element frequencies.
- 4) Choose the first row to balance.
- 5) "Run" the first couplet.
- 6) Continue choosing rows and "running" couplets until all rows are balanced and all columns equifacted.
- 7) Transfer column factors to their corresponding equation components.

The procedure is easily extended to the balancing of redox equations. It seems especially suited to combination with a modification of the "tried and true" half-reaction approach.

As before, write the equation with terms spread out.



Then:

- 1) Separate the full-reaction equation into oxidation and reduction half-reaction equations.
- 2) Write relevant oxidation states above the appropriate chemical symbols.

- 3) Calculate and show electron imbalances at the right of each half reaction.
- 4) Add water molecules to the right of the oxidation equation and hydrogen ions to its left.
- 5) Add hydrogen ions to the right of the reduction equation and water molecules to its left.

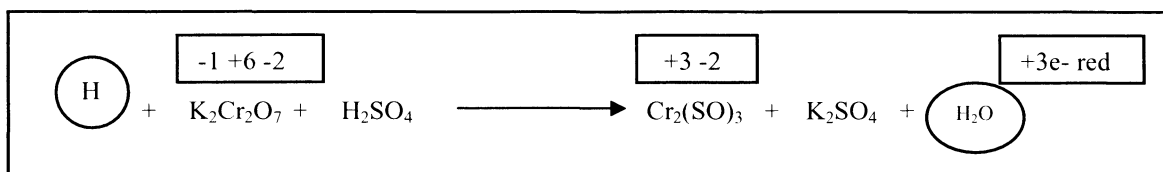
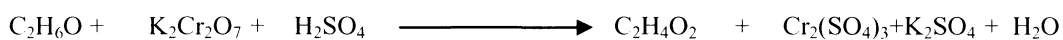
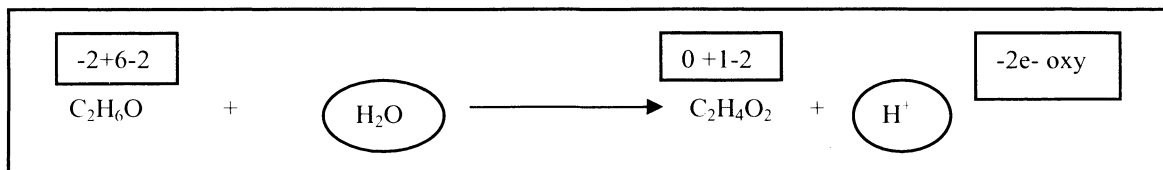
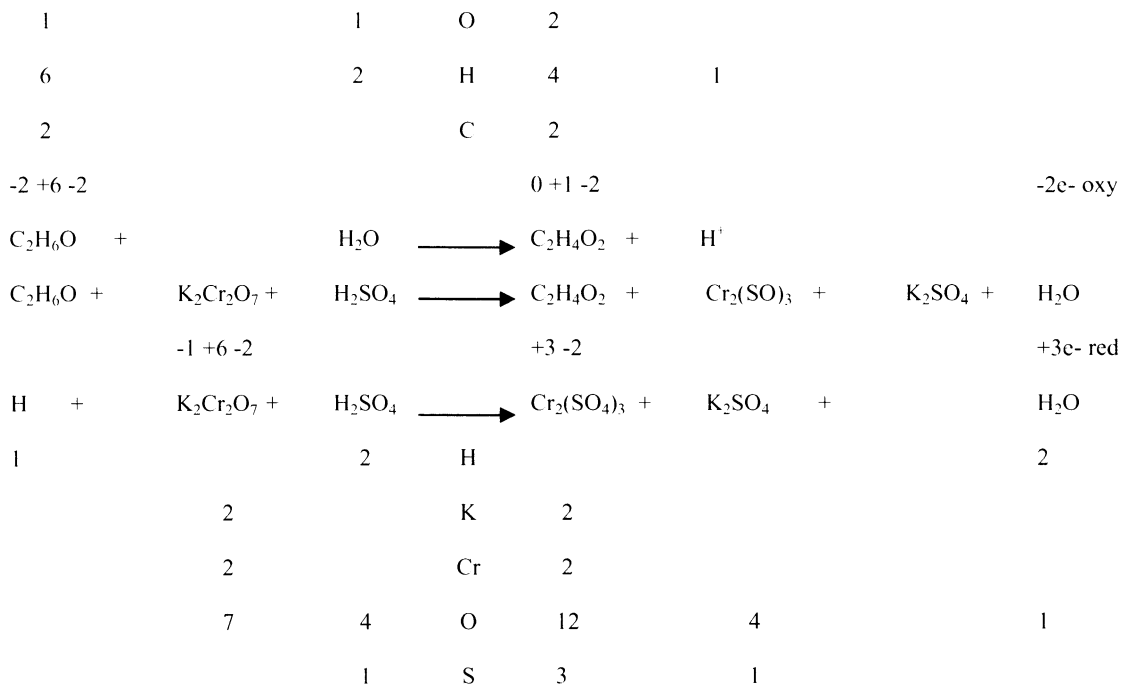


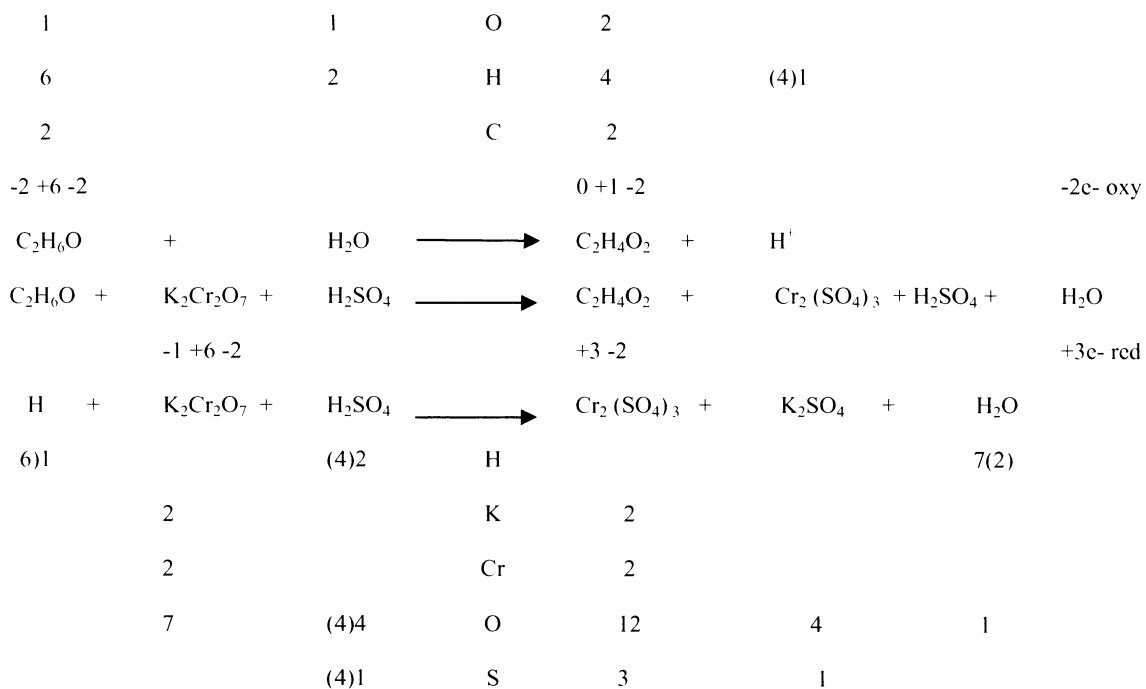
Figure 1. Oxidation.

Reduction

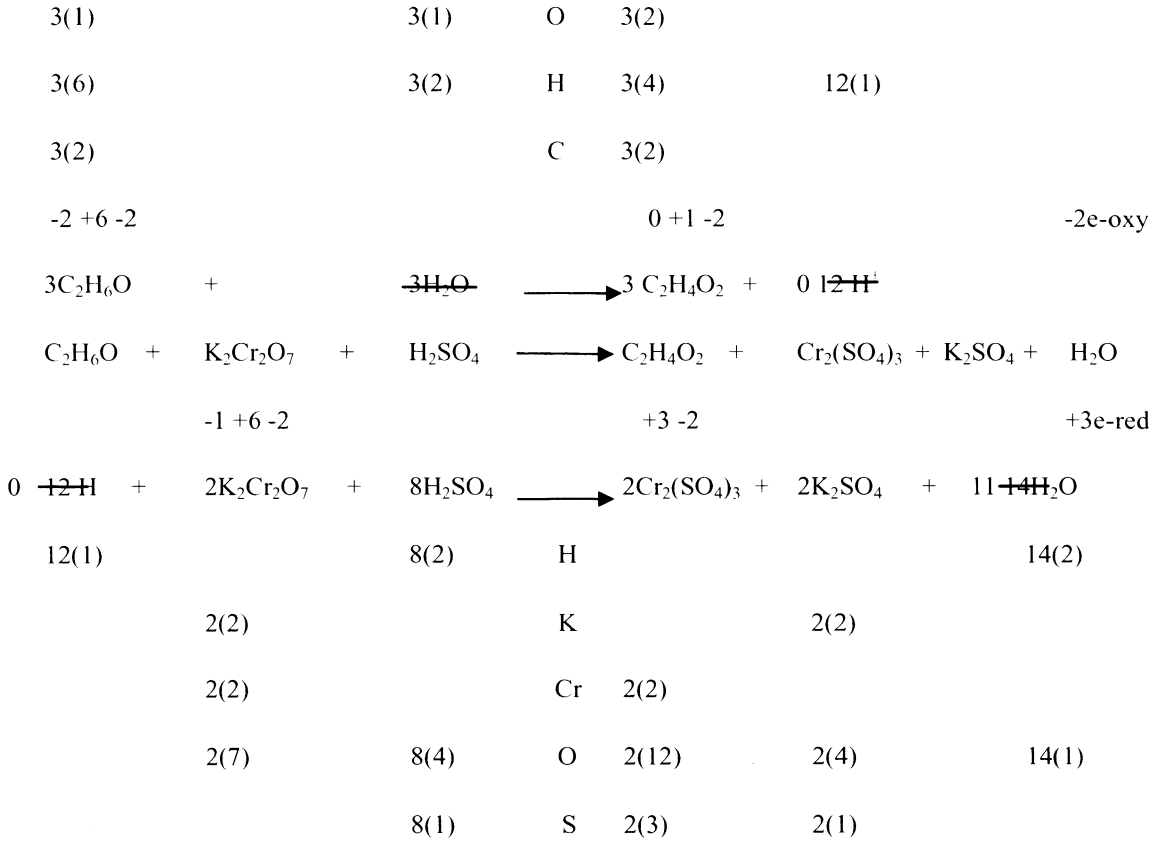
Write a reaction register for each half reaction. The reduction register is placed below its half reaction and the oxidation register is placed above its half reaction.



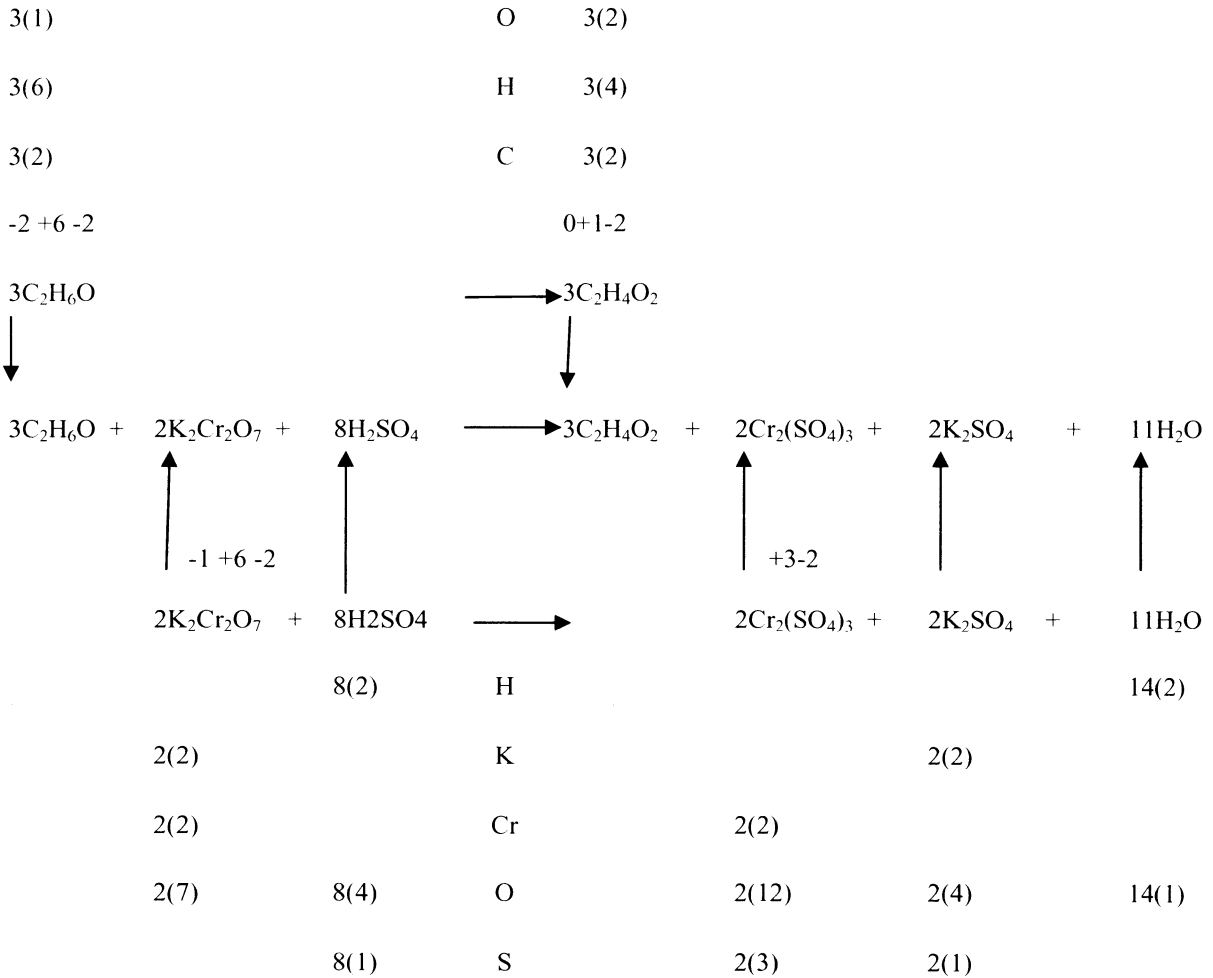
Now, chemically balance the registers for both half reactions using the new procedure.



Subtract water of the oxidation reaction (top left) from water of the reduction (bottom inset). Subtract hydrogen ions of the reduction reaction (bottom left) from hydrogen ions of the oxidation reaction (top right).



Transfer all half-reaction coefficients to corresponding components or in the full-reaction equation. Note that hydrogen ions have been eliminated from both sides and water molecules from one side.



Summary

This procedure seems to substantially facilitate the balancing of equations that, traditionally, have been considered difficult for many students. It is interesting that the more difficult the equation, the greater this facilitation appears to be. Moreover, the double registers appear to contribute to concept development in exactly the way an “exploded” assembly diagram does, by making every component relationship extremely clear.

The immediate importance of the procedure lies in the fact that it can remove the heuristic wall of haphazard inspection, replacing it with a near algorithmic procedure that virtually assures balancing success for average students and below average students. Also, it gives able students an unusual facility. A significant, but less immediate, advantage is the preparation the procedure could offer for future matrix techniques. ■

Reference

- [1] L. Peterson, et al., “Chemical Balancing,” *Project Intermath*, COMAP, Bedford, MA, 2002.

INTO THE FRAY: NOVICE TEACHERS TACKLE STANDARDS-BASED MATHEMATICS

B. SCHRODER and S. GNINGUE

*Dept. of Middle & High School Education, Lehman College, CUNY
Bronx, NY 10468*

barbara.schroder@lehman.cuny.edu , serigne.gningue@lehman.cuny.edu

Abstract

This article tracks twenty-one graduates of a reform-based mathematics teacher education program for two years as they begin teaching mathematics in public elementary schools in New York City. Using surveys, classroom observations, and interviews, it examines the extent to which these beginning teachers were able to implement standards-based mathematics instruction in their classes. Results of the study were mixed. The novice teachers generally demonstrated an adequate understanding of the underlying mathematics principles and strong intentions of teaching mathematics for understanding. They were generally able to engage children in learning, and most performed at the “beginning stages of effective instruction” in their first year. However, they still struggled to engage students in higher order thinking and knowledge construction. In their second year their abilities improved, but they were still hampered by local factors such as insufficient in-service support, the restrictions of high-stakes testing, and the overall school climate.

Introduction

The National Council of Teachers of Mathematics (NCTM) envisioned a classroom where students learn mathematics with conceptual understanding [1]. In this vision, the teacher engages students in critical, in-depth, higher order thinking about the content through the use of manipulatives, technology, cooperative learning, and other pedagogy that enable students to construct mathematics concepts on their own by reasoning, verifying, comparing, synthesizing, interpreting, using different strategies of investigating or solving problems, making connections, communicating ideas, and constructing arguments.

However, despite the NCTM’s recommendations, there is still a wide variation in content coverage and teaching practice among teachers. Many teachers are comfortable with teaching only how to perform calculations without meaning or context. Liping Ma's study of elementary teachers' understanding of mathematics in China and the United States found that participants in the United States viewed mathematics as "an arbitrary collection of facts and rules in which doing mathematics means following set procedures step-by-step to arrive at answers" [2]. Further,

prospective elementary teachers often expect to implement traditional teaching practices, such as teacher-directed lessons followed by student practice of paper-and-pencil computations, aimed at developing procedural fluency. For Timmerman, these practices send students a clear message that mathematics often does not make sense, and they do not need to or cannot understand mathematics [3].

In elementary schools, the initial focus in teaching mathematics concepts is on whole numbers built upon “counting” processes, and students do not face many cognitive difficulties until they start moving from the whole number set to the rational set. The transition to the rational set that involves complex conceptual changes unfortunately functions as a “gatekeeper,” keeping many children from advancing in their understanding. Earlier representations that worked for whole numbers are inadequate for understanding concepts in the rational number system such as fractions. Rational numbers can be variously understood; e.g., as fractions, or ratios of whole numbers, as measures of length or area, as operations involving stretching/shrinking, or as extending the integers via multiplicative inverses. These numbers may be variously represented, such as equivalence classes of fractions, “mixed numbers,” finite or repeating decimals. Each of these mathematical ideas is complicated, and a large body of research in education and cognitive science (such as, “Rational Number, Ratio, and Proportion” by M.J. Behr, et al.) addresses them [4]. Fractions provide a basis for understanding and manipulating rational expressions that occur later in algebra, units of measurement fundamental to science, and probability/statistics. The transition from the whole number system to the rational system is therefore critical, making learning for understanding crucial at the elementary school level, especially in urban schools, where many children struggle to achieve in mathematics.

Yet, the teaching of mathematics in elementary school is still geared to memorizing routine skills with little room for reflection and logical thought. For many teachers, doing mathematics is associated with following the teacher’s rules. “Knowing mathematics means remembering and applying the correct rule and having the answer ratified by the teacher” [5]. This leads students to an “unfortunately limited picture of mathematical expertise,” in which to be an expert, one merely needs to be able to remember and explain the correct rule and have the answer ratified by the teacher [6].

This situation is exacerbated in urban settings where most minority children live and attend school. Ball, Hill, and Bass found that in the third grade for instance, “...higher-knowledge teachers tended to teach non-minority students, leaving minority students with less knowledgeable teachers who are unable to contribute as much to students’ knowledge over the

course of a year” [7]. As a result, substantial numbers of urban students do not attain the mathematics skills and understanding needed for success in today's world. Other factors, which range from high teacher turnover and dilapidated schools to bureaucratic inertia, crime, drugs, and poor housing, contribute to urban students' failure in mathematics. One of the main problems, however, remains the manner in which mathematics concepts are being conveyed to students.

The consequences of this situation at the national level are that the United States faces not only a shortfall of mathematicians, but a general mathematics illiteracy. The number of mathematics Ph.D.s granted today is two-thirds the number awarded in the 1960s, and student achievement is below that of other countries. By the time students reach their college mathematics courses, they are bored, passive, hostile, and full of complaints [8].

Context of the Study

In efforts to address these issues, teacher education programs at the City University of New York (CUNY) have developed courses over the past ten years that use inquiry-based approaches to instruction, in which students have opportunities to construct their own understanding of basic concepts. These efforts were supported during 1996-2000 by the National Science Foundation's (NSF) Collaboratives for Excellence in Teacher Preparation (CETP) program, which brought together faculty members from both education and mathematics/science departments across the country to redesign core offerings for prospective elementary teachers. In most instances, pre-service teachers taking the redesigned courses were engaged in activities they could apply directly in their own classrooms. The faculty involved in these courses anticipated that they would result in graduates who would be prepared and willing to implement these same sorts of practices in their own classrooms.

The data examined here were collected as part of an evaluation study of this NSF-funded program, the New York Collaborative for Excellence in Teacher Preparation (NYCETP). The larger evaluation study focused on the teaching of both mathematics and science, and sought to evaluate the impact of NYCETP through, among other methods, collecting evidence of the classroom use of standards-based teaching strategies by teacher graduates of the CETP-reformed pre-service classes through classroom observations, surveys, and interviews.

Purpose of the Study

This article examines the classroom practices of twenty-one novice elementary teachers in New York City public schools, graduates of one CUNY college, as seen through the lens of the evaluations designed for the CETP study. The overarching purpose is to ascertain the extent to which they were able to incorporate the skills of and understandings about teaching mathematics acquired in their pre-service classes into their first two years of teaching.

Research Questions

The study's central question is: "To what extent were these teachers teaching for conceptual understanding?" Other questions are listed below.

- Were there significant changes between pre-service teachers' intentions in using inquiry-based teaching practices and their first-year self-reports of practice?
- To what extent did CUNY elementary education students provide their students with the opportunity to engage in inquiry-based mathematics activities in their first year of teaching?
- As teachers moved into their second year in the classroom, were there significant changes in their overall performance, with regard to teaching mathematics to K-6 schools?
- What factors seemed to support or detract from their teaching for conceptual understanding?

Subjects

Data were collected over a four-year period. In 2001-2002, prospective participants in the evaluation study were surveyed in the last year of their pre-service teacher education program concerning, among other things, their intention to implement a series of standards-based reform practices in the classroom, all of which were aimed at promoting students' conceptual understanding.

In 2002-2003, among the larger pool of participants were twenty-one first-year teachers and student teachers who were observed teaching a mathematics lesson. In addition to being observed in the classroom, participants completed surveys and submitted sample lesson plans. Throughout this article, the term "Year I" refers to 2002-2003.

In 2003-2004, eleven of these teachers continued in the study, and were observed a second time teaching a mathematics class. As in the previous year, they completed surveys and

submitted lesson plans, and their principals completed surveys. Throughout the article, the term “Year II” refers to this year.

Finally, in 2004-2005, six teachers participated in intensive interviews, in which they reflected upon various aspects of their experiences in the mathematics classroom the previous year.

Instrumentation

The surveys, classroom observation protocols, and lesson plan scoring rubrics were originally developed by the University of Minnesota for the CETP core evaluation study, and were either used as is or modified slightly. The interview protocol was developed by the CUNY Center for Advanced Study in Education. The instruments used are outlined below.

Teacher Surveys — Teacher surveys were administered once before participants began teaching, and then again each time that they were observed teaching. The initial survey, adapted from the CETP K-12 Teacher Survey, was administered in participants’ pre-service education classes. It asked them to predict to what extent they expected to implement a variety of standards-based teaching strategies, for example asking students to write descriptions of their reasoning or to work on problems related to real world or practical issues, in their own classrooms. Then, either right before or immediately after they were observed teaching, they completed another survey that among other things, asked them to relate the extent to which they were actually implementing these same strategies in the classroom.

Classroom Observations — Classroom observations were the essential element in determining teachers’ levels of teaching for conceptual understanding. Participants were observed by faculty members of their college as they taught a mathematics lesson, using a Classroom Observation Protocol (COP) created for the national CETP evaluation study. The COP “constructed through the selection of items from several classroom observation forms. The items selected were those that had been shown to be predictive of standards-based instruction and positive student outcomes. Sources used included: Horizon Research, Inc.; the Arizona Collaborative for Excellence in Teacher Preparation; Evaluation of the Long-Term Effect of Teacher Enhancement project; the Constructing Physics Understanding evaluation project and the Systemic Initiatives evaluation project” [9]. Preliminary estimates of the instruments’ inter-rater and intra-rater reliabilities range from 50% to 80%, while internal consistency analyses resulted in alphas of .90 or better.

The first three sections of the COP described the teacher's background, classroom demographics, and the classroom context. The fourth section collected information in the areas of, among others: **Type of Instructional Activities** (e.g., lecture, small group discussion, hands-on activities, etc.); **Levels of Student Engagement** (e.g., high, medium, or low); and **Level of Student Cognitive Activity** (e.g., "receipt of knowledge," "construction of new knowledge"). A fifth section rated **Key Indicators** of standards-based instruction, such as "The lesson encouraged students to seek and value alternative modes of investigation or problem solving," and asked the observer to comment on the effectiveness of the lesson in several categories. Finally, the sixth and last section contained an overall **Capsule Rating** of the lesson's effectiveness, ranging from 1 (ineffective instruction) to 8 (exemplary instruction).

The CUNY faculty observers were all seasoned mathematics educators, school administrators and/or teacher educators. In order to promote inter-rater reliability, two training sessions were held: a full day attended by observers across all the campuses, and a half day on each individual college campus. In these sessions, observers rated sample videotaped lessons and then compared their ratings. When differences were observed among raters during these training sessions, they were only on the order of one out of a possible seven in the vast majority of cases. Observers then discussed their differences in order to resolve them and arrive at a shared understanding of the ratings.

Lesson Plans — The teachers submitted a sample lesson plan, usually for the observed lesson. The plans were rated by teams of two faculty members, who discussed and resolved their rating differences for each plan. The rating protocol focused on essentially the same standards-based elements as the observation protocol. Ranging from 1 (not evident) to 4 (clearly evident), the ratings indicated the extent to which the lesson plans "encouraged students to manifest characteristics of students in standards-based classrooms." More specifically, they were asked if they provided students with the opportunities to: 1) engage in in-depth, higher order thinking about the content; 2) make real-world connections; 3) work together as learning community; 4) feel as though they have their needs met; and, 5) learn important concepts. A final question (6) asked the extent to which effective questioning strategies for constructing student knowledge and differentiating instruction was present. As with the Classroom Observation Protocol, raters also provided a **Capsule Rating** of the planned lesson's effectiveness ranging from 1 (ineffective lesson) to 8 (exemplary lesson).

Interviews — Six of the teachers participated in in-depth interviews concerning their experiences teaching mathematics during the winter of 2004. The intent of these interviews was to provide

additional understanding of how teachers evaluated their students' math achievement, as well as of the school contexts within which they operated. The interview protocol asked teachers to describe their classes, in general terms and in terms of mathematics instruction. It also asked them to rate their students' mathematics performance and describe their reasons for these ratings.

The pages that follow first summarize the data from the teachers' first year of teaching. We then move on to consider the experiences of the eleven teachers who were observed again teaching a mathematics lesson in their second year. The article ends with a discussion of the role of the contexts within which they taught, drawing on the surveys and interviews.

Results — Changes between Pre-Service Intentions and First-Year Self-Reports of Practice

According to the NCTM in 1991, "The constraints of the real world of schools overwhelm the perceptions these new teachers hold about what mathematics teaching and learning could be [and] ...the result is that many new teachers find it difficult to adapt what they have learned in their teacher preparation programs" [10]. The results of this study indicate that the situation has not changed significantly as of 2002. When surveyed in their university education classes prior to their observations, prospective teachers indicated a strong commitment to employing the classroom strategies consonant with helping children develop a good conceptual understanding of mathematics. When asked how often they intended to implement a list of twenty-two reform practices (e.g., "have students use or make conceptual or mathematical models") with possible responses ranging from 0 (never) to 3 (regularly), the majority of respondents chose either "2" or "3" for most items (mean of 2.45 across all items).

In their first year of teaching, however, the reported use of reform strategies dropped dramatically from the stated intentions of the previous year. The average responses dropped for all items, leading the overall average to drop significantly from 2.45 to 1.46, which when analyzed with a paired-samples, *T*-test analysis, showed a statistical significance of .000. Listed below are some illustrations of such decreases.

- Eighty-one percent of respondents intended to "have students write descriptions of their reasoning *regularly*" before beginning teaching, but only 20% reported actually having them do this *regularly* in their first year of teaching.
- Sixty-three percent of the respondents intended to "have students make connections to other fields and areas of mathematics *regularly*," but none reported doing this *regularly*, and only 33% reported doing it *occasionally* in their first year of teaching.
- Sixty-three percent intended to "engage students in data collection and analysis *regularly*," but only 7% reported doing it *regularly* in their first year in the classroom.

Results—Year I Lesson Plans

For five of the six indicators listed above, the percent receiving a rating of 1 or 2 was at least two times the percent rated at 3 or 4. The mean capsule rating was 2.86, slightly below a rating of 3 or “elements of effective instruction.” Taken together, these results indicate that overall, the raters did not see in these lesson plans strong evidence of the ability of the participants to plan for standards-based mathematics instruction.

Results—Classroom Observations

The new teachers were observed teaching a mathematics lesson using the Classroom Observation Protocol (COP) developed by the University of Minnesota. For each class, the observation time was divided into five-minute intervals, during which the observer recorded the Type of Instructional Activity, the Level of Student Engagement, and the Level of Cognitive Activity seen. The lessons observed ranged in length from twenty minutes to one hour, with the average length being forty minutes, or eight five-minute segments. In total, 164 five-minute segments were coded and analyzed.

Classroom Instructional Activities — Nineteen different types of instructional activities that could take place in a mathematics classroom were identified in the COP. For this study, we grouped them into four categories: Type I, those deemed typically traditional (e.g., those that were definitely not standards-based, such as “lecture” or “reading seat work”) were observed in forty-two of the 164 five-minute segments, or 26% of the time; Type II, activities in between “traditional” and “standards-based” (e.g., problem modeling or demonstrations) that could be used during both standards-based and traditional instruction were observed 31% of the time; Type III, inquiry- or standards-based activities, such as collaborative learning groups, were observed 37% of the time; and, Type IV, occasions when teaching was interrupted due to student behavior, administrative tasks, or other non-related learning tasks were observed 6% of the time.

Student Engagement — Three levels of student engagement were identified in the COP instrument: high (when at least 80% of students actively participated in the lesson); mixed; and, low (when at least 80% of students were off task). Of the 160 five-minute intervals with student engagement data, students were highly engaged in 58, or 36% of the time. They were somewhat engaged 49% of the time, and only minimally engaged 15% of the time.

Cognitive Activity — Five levels of cognitive activities were coded in the observations. Level 1 (Receipt of Knowledge) was noted when students were involved in the reception of information;

Level 2 (Application of Procedural Knowledge) when students applied their knowledge by doing worksheets, practicing problems, or building skills; Level 3 (Knowledge Representation) when students manipulated information by reorganizing, categorizing or attempting to represent what they learned in a different way; Level 4 (Knowledge Construction) when students created new meaning by making connections, generating ideas or solving new problems; and, Level 5 (Other) for administrative tasks, interruptions, etc. Of the 164 five-minute recordings available, Level 1 and Level 2 were recorded 84% of the time, meaning that students spent most of their time receiving and applying procedural knowledge.

Relationships Among Lesson Elements — To examine whether there were patterns of relationships among the three lesson elements recorded by observers, we first converted Type of Instructional Activity into a scale variable: a value of 1 was assigned to Type I activities, a value of 2 was given to Type II activities, and a value of 3 was given to Type III activities. Similarly, Level of Student Engagement was converted into a scale variable ranging from 1-3, and Level of Cognitive Activity was converted into a scale variable with values from 1 – 4. (It was possible for the observer to enter more than one Type of Instructional Activity into one five-minute segment. When this happened, such values were first averaged across all entries in each five-minute segment of the observation and then averaged across the entire set of 164 five-minute segments observed.)

Table 1 presents the means of the resulting measures. As seen there, observers rated the lesson taught highest in the area of Student Engagement (on average 2.4 out of 3) and lowest in the level of student Cognitive Activity (on average 1.69 out of 4). Several Pearson's Product-Moment Coefficients were then calculated, to explore the bivariate relationships among the three variables. Table 2 shows that all three correlations can be considered statistically significant at the .05 level. The strongest relationship observed was that between Type of Instructional Activity and students' Cognitive Activity, and the weakest was between Type of Instructional Activity and Student Engagement.

Table 1
Coded Classroom Instructional Activity, Student Engagement and Student Cognitive Activity Ratings, Year I

Variable	Range	Mean
Type of Instructional Activity (reform value)	1 - 3	1.99
Level of Student Engagement	1 - 3	2.40
Level of Cognitive Activity	1 - 4	1.69

Table 2
Type of Instructional Activity, Student Engagement, and Student Cognitive Activity:
Correlations

	Pearson's Product-Moment Coefficient	<i>p</i>
Type of Instructional Activity with Student Engagement	.213	.036
Type of Instructional Activity with Cognitive Activity	.581	.000
Student Engagement with Cognitive Activity	.312	.002

Ratings of Key Indicators — In the fifth section of the COP, the observer was asked to rate each of nine “key indicators” using a Likert scale ranging from 1 to 5 (“not at all” to “to a great extent”). The overall mean across the nine indicators was 2.55. This result seems to suggest that the standards-based characteristics were observed to a minimal extent. The four lowest ratings indicate:

- Students were not reflective about their learning. Seventy-one percent of the observations were given a 1 or 2 for this indicator.
- Students were not encouraged to generate conjectures. Seventy percent of the lessons received a 1 or a 2 for this indicator.
- Appropriate connections were not made to other areas of mathematics, other disciplines, or real-life contexts. Sixty-six percent of the observers gave the lessons a 1 or a 2 for this indicator.

On the other hand, the following positive outcomes were noted for the two key indicators with the highest ratings.

- Teachers satisfactorily displayed an understanding of mathematics concepts. Eighty-one percent of the observers gave them ratings of 3 or 4, and 14% gave a rating of 5.
- Teachers respected students’ prior knowledge in these lessons. Sixty-five percent of the observers gave them ratings of 3 or 4 with a mean of 2.95 (std. = .95).

The third highest rated indicator, #5, was in the area of: “the interactions reflected collaborative working relationships among students and between teacher and students.” Its mean of 2.76 was deemed inconclusive, since 57% of observers gave ratings of 1 or 2.

Three additional questions in this section of the COP asked observers to rate the “likely effect” of the observed lesson in three areas, using the same Likert of 1 (“not at all”) to 5 (“to a great extent”). These ratings were generally low: for “students’ understanding of mathematics concepts as a dynamic body of knowledge generated and enriched by investigation,” 68% received ratings of 1 or 2; for “students’ understanding of important mathematics concepts,” 55% of the ratings were 1 or 2; and, for “students’ capacity to carry out their own inquiry,” 68% received ratings of 1 or 2.

Capsule Description of the Overall Quality of the Observations — Finally, the sixth and last section of the COP instrument assessed the overall effectiveness of the observed lesson, using the same scale as for the lesson plan. Using ratings ranging from 1 (ineffective instruction) to 8 (exemplary instruction), the observers summarized their overall assessments of the quality of instruction and its likely impact of the lesson on students. Most participants (76%) were rated at least a 4, or the “beginning stages of effective instruction,” with an average score of 4.24.

Summary of Year I Observations

In summary, results of the first-year data were mixed. We concluded that, while most first-year teachers who participated in this study displayed an adequate understanding of the concepts they were teaching, they still reported using far fewer standards-based strategies in their mathematics classes than they had intended to and had lesson plans that were uniformly rated lower than their classroom observations. They seemed generally successful in the areas of maintaining high levels of student engagement, working with students’ prior knowledge and misconceptions, and establishing positive, collaborative norms in the classroom. A sizeable majority of the group—76%—was rated overall at about where we would hope beginning teachers would be, namely at least at Level 4 (“beginning stages of effective instruction”). Teachers received the lowest ratings in the areas of promoting students’ metacognitive abilities and helping them generate their own conjectures, solve new problems, and create new knowledge.

Year II and Year I Comparisons

During 2003-2004, eleven of the above twenty-one teachers were again observed teaching a mathematics lesson. Nine stayed in the same schools as in 2002-2003, and all were

observed by the same faculty member who had observed them during their first year. Eight were teaching the same grade as in the previous year. Tables 3 and 4 compare rating means for 2002-03 (Year I) and for 2003-04 (Year II) for the Lesson Plans and Observations, respectively, for several of the indicators discussed above.

For the lesson plan indicators (Table 3), the results were mixed as they were divided evenly between those that rose from Year I to Year II and those that either stayed the same or decreased. For the classroom observation indicators however, Table 4 shows that there was an increase in the presence of standards-based characteristics in the classroom. Except for one indicator (#4), all mean scores were higher in Year II than in Year I, leading us to conclude that the continuing teachers had indeed improved in their ability to facilitate students' understanding of mathematics concepts after their first year in the classroom.

Table 4 shows that observers also saw an increase in the use of activities that could be designated as standards based. The mean of the "Type of Instructional Activities Scale" rose from 1.99 to 2.17 (maximum possible rating: 3). The largest increase, however, was obtained with the rating of the "Overall Student Engagement" indicator, which rose to 2.61 from 2.40.

On the other hand, the types of cognitive activities in which students were engaged remained largely in the lowest categories of "receipt of knowledge" and "knowledge representation," despite the teachers' pre-service preparation, which had explicitly stressed inquiry-based teaching and learning, and their own stated intentions, as indicated in their surveys. (The average rating in this area did rise somewhat in Year II, to 2.15 from 1.69, out of a possible 4.) So while we conclude that their ability to deliver standards-based mathematics instruction was progressing, there was still room for improvement.

Table 3
Lesson Plan Ratings, Year I and Year Two Comparisons

Measure	Possible Range	Year I (n=21) Mean	Year II (n=11) Mean
Lesson Plans			
I. Presence of Standards-Based Characteristics			
Key 1 The lesson engages students in in-depth, higher order thinking about the content	1 – 4	2.10	2.27
Key 2 Students make real-world connections	1 – 4	2.00	2.27
Key 3 Students work together as learning community	1 – 4	2.29	2.09
Key 4 Students feel as though they have their needs met	1 – 4	2.05	2.05

Key 5	Students learn important concepts	1 – 4	2.16	2.36
Key 6	The lesson plan demonstrates effective questioning strategies for constructing student knowledge and differentiating instruction	1 – 4	2.33	2.27
II. Capsule Rating		1 – 8	2.86	3.36

Table 4
Classroom Observation Ratings, Year I vs. Year II

Measure	Possible Range	Year I Mean (n=21)	Year II Mean (n=11)	
Classroom Observations				
Classroom Instructional Activity	1 – 3	1.99	2.17	
Overall Student Engagement	1 – 3	2.40	2.61	
Overall Cognitive Activity	1 – 4	1.69	2.12	
A. Presence of Standards-Based Characteristics				
K1	Students seek & evaluate alternative modes of investigation...	1 – 5	2.38	2.77
K2	Elements of abstraction...	1 – 5	2.52	2.62
K3	Students were reflective about own thinking...	1 – 5	2.05	2.69
K4	Respect prior knowledge	1 – 5	2.95	2.83
K5	Collaborative interactions	1 – 5	2.76	3.08
K6	Promote conceptual understanding	1 – 5	2.21	2.67
K7	Students encouraged to generate conjectures	1 – 5	2.10	2.69
K8	Teacher's understanding of math...	1 – 5	3.62	3.85
K9	Connections to other areas of math, real world, etc.	1 – 5	2.11	2.42
Observation Capsule Rating		1 – 8	4.24	5.09
B. "Likely Effects" Indicators				
K10	Students' understanding of math concepts as a dynamic body of knowledge generated and enriched by investigation	1 – 5	2.32	2.55
K11	Students' understanding of important mathematics concepts	1 – 5	2.55	3.00
K12	Students' capacity to carry out their own inquiry	1 – 5	2.16	2.18
Mean of likely effect indicators		1 – 5	2.43	2.59

Factors Contributing to Teachers' Performance—the Citywide Context

At the beginning of 2003, New York City public schools underwent a major shift as all schools were required to adopt the *Everyday Mathematics* program for grades one through five, and *Impact Mathematics* for grades six through eight [11,12]. While these programs are generally consonant with the standards-based reforms, teachers struggled to implement them. Students were caught in the gap between their previous curriculum and the new programs. Frequently, for a particular grade level, the new curriculum would be aimed at a certain level, and assumed knowledge of content to which the students had never been exposed. Teachers consistently expressed their lack of preparation and training in the new programs and struggled to

understand and implement them. They reported very little support from their schools, in terms of professional development or mentoring, for making this adjustment.

Related to this issue is that of the impact of mandated assessments, sometimes those of the new mathematics programs, but also the citywide mathematics examinations. Several teachers also complained about the need to concentrate on test prep materials prior to the citywide mathematics tests in May. In the words of one:

The biggest thing that comes back to me is the amount of test prep at the end of the year. I would try and abandon the program because it was not working. Example: I was supposed to tell the students [the times of] sunrise and sunset and have them calculate the length of the day. I had students who couldn't tell time. High and low temperature. They couldn't tell temperature.

In all, ten of the twenty-one teachers specifically mentioned difficulties resulting from a lack of time and/or flexibility to teach appropriately, due to either the switch to the new mathematics programs, the demands of test preparation for the standardized exams, or both.

Factors Contributing to Teachers' Performance—School-Level Support

Of major concern to educators is the question of the general environment of particular schools, sometimes referred to as the school culture or as the school context. Through teacher surveys and interviews, we focused on three areas of school-level support for these novice teachers as they attempted to teach math for understanding: 1) that provided by their administrations; 2) that provided by their colleagues in general; and, 3) the extent to which they were engaged in conversations about teaching and learning math.

Administration — Teacher surveys asked teachers about the ways in which their schools supported excellence in math instruction, and the barriers they faced in teaching math. Nine of the twenty-one teachers found their schools to be supportive; of these, four referred to helpful staff developers or other veteran teachers, three mentioned supplies of books or manipulatives, and two mentioned feedback from assistant principals following observations. Two-thirds of the respondents in 2002-2003 and nine of the eleven in 2003-2004 identified school-based barriers, other than the ones related to the new math programs and mandated assessments that were discussed above. When asked to describe these barriers, the teachers singled out: lack of classroom demonstrations and guidance; lack of resources (books, materials); and, class size, scheduling, and time constraints.

In their second year, teachers were asked to rate their school administration on several dimensions. Responses could range from 1 (strongly disagree) to 4 (strongly agree). Table 5 reports the results.

Table 5
Teacher Ratings of Administrative Support for Teachers, Inquiry ($n=11$)

Item	Percent Responding:		Mean
	1, 2 Strongly disagree, disagree	3, 4 Agree, strongly agree	
1. The principal at this school:			
a. Promotes parental and community involvement in the school....	30	70	2.8
b. Works to create a sense of community in this school.....	80	20	2.1
c. Takes a personal interest in the professional development of teachers....	50	50	2.4
d. Is strongly committed to shared decision making.....	70	30	2.1
e. Ensures that student learning is the “bottom line” in the school....	78	22	2.2
f. Supports and encourages teachers to take risks.....	100	0	1.8
g. Is a strong leader in school reform.....	78	22	1.7
2. Teachers in this school are well-supplied with materials for investigative instruction.....	60	40	2.3
3. Assessment of student performance leads to changes in our school’s curriculum.....	54	44	2.3

As seen here, teachers generally found their principals unsupportive. None reported that their principal encouraged them to take risks; only 22% agreed that their principal ensured that student learning was the “bottom line” at the school, etc.

Colleagues — A second series of questions on the teacher survey in Year II asked teachers to measure the extent to which a shared culture of learning existed among the school faculty. Responses could range from 1, (strongly disagree) to 4 (strongly agree). Table 6 presents the results.

Table 6
Teacher Ratings of Colleagues: Shared Values, Behaviors, and Support (n=11)

Item	Percent Responding:		Mean
	1, 2	3, 4	
	Strongly disagree, disagree	Agree, strongly agree	
Shared values:			
It is important for students to have input in establishing criteria by which their work will be assessed.....	30	70	2.8
Teachers in this school have a shared vision of instruction.....	56	44	2.2
Our stance towards our work is one of inquiry and reflection.....	50	50	2.8
Behaviors:			
Teachers are engaged in systematic analysis of student performance data.....	44	56	2.7
Teachers in this school are continuously learning and seeking new ideas....	20	80	3.1
Teachers in this school are well informed about the national, state, and professional education standards, e.g., AAAS, NRC, NCTM, for the grade levels they teach.....	25	75	2.9
Support:			
I feel supported by colleagues to try out new ideas.....	10	90	3.1
Teachers in this school trust each other.....	56	44	2.4
Teachers in this school feel responsible to help each other do their best...	20	80	2.6

As seen above, teachers gave their colleagues “middling” ratings on most of the questions. While they generally found their colleagues supportive, less than half felt that their school had a shared vision of teaching and learning, and only half felt that “our stance is one of inquiry and reflection.”

Conversations About Teaching Mathematics — In the interviews conducted in 2003-2004, when discussing individual students, teachers were asked, “Did you ever discuss teaching math to this student with another teacher, a supervisor, or a math coach or mentor?” Each of the six teachers interviewed described three students in depth during the interviews; hence, this question was

asked about eighteen students. Teachers reported discussing twelve of the eighteen. However, the topic of the conversation was often one of general concern, such as getting a better class placement, or about areas other than math, e.g., reading difficulties. Only four of the twelve conversations reported had to do specifically with some aspect of the student's performance in math. The interviews give the impression that, in general, teachers discussed their students with others in the school most often when there was a problem, sometimes out of general interest and concern (e.g., checking with the current teacher of a former student to see how s/he was doing), but only rarely around specific issues related to math teaching and learning.

Summary and Conclusions

This study tracked the experiences of a cohort of novice teachers as they moved from their college classes into public elementary schools in New York City. As noted, there was a sharp decline between their pre-service intentions and their reported classroom practices in the first year. Overall, observers gave the first-year teachers mixed ratings in terms of their implementation of standards-based classroom practices. The strongest points of the novice teachers were their ability to engage students and their understanding of the content they were teaching. However, they still lacked proficiency in guiding students to higher levels of conceptual understanding by leading them to reason, examine their own thinking, and create their own knowledge.

As the teachers moved into their second year in the classroom, their abilities to teach math for conceptual understanding increased, reaching Level 5, or "solid beginning stages of effective instruction" on the capsule rating, on average. However, their average ratings on most key indicators still hovered around the mid-point of 2.5 on the scale from 1 to 5; we would have hoped to see averages of at least 3 by the second year. Their strongest ratings remained in the areas of their own content knowledge and in their ability to create a collaborative atmosphere in the classroom.

Such findings are in alignment with other recent studies of the impact of standards-based preparation of mathematics teachers. Weiss reports that even teachers who were provided with extensive in-service professional development to enhance their ability to use standards-based materials via NSF's Local Systemic Initiatives, "struggled with key elements of teaching for understanding" [13].

The school context factors listed below seem to have contributed to the ability to teach math for understanding of the new teachers in our study.

People Resources, More than Material Ones — For mathematics instruction at least, new teachers singled out the role of mentoring and coaching, and specifically requested more demonstration math lessons. Although they did mention the need for more manipulatives, computers, or other material resources, these were clearly less of an issue than was the need for ongoing professional support and development.

Difficulties Arising from the Citywide Adoption of New Math Programs — Specifically, it is quite clear that teachers would have benefited from more training in using the new math programs in 2003-2004. Many preferred more flexibility in choosing teaching materials and texts.

School Culture — School leaders generally got very low marks in terms of focusing on student learning, leading for change, and for supporting shared decision making and risk taking on the part of their staffs. While teachers generally reported higher levels of support from fellow teachers in their schools, their responses still indicate considerable room for improvement in the cultures of these schools, in terms of promoting systematic teacher inquiry and reflection about teaching and learning.

Limitations of the Study

Although the results of this study are in keeping with the results of other recent ones, caution needs to be exercised in several areas. The first concerns whether the sample was truly representative. It is probable that the most confident and able teachers self-selected themselves for the additional scrutiny that this study entailed. The second caution concerns whether only one observation each year gave a valid indication of the teachers' capabilities. Anecdotally, the designers of the CETP core evaluation study design report that in other studies increasing the number of observations per year to two did not change the ratings significantly. Additionally, we suspect that two conflicting tendencies may cancel each other out in this area. The first is the extra preparation and planning that went into these lessons because they were being observed which would have resulted in an overestimation of their daily teaching practice. On the other hand, not even the most expert teacher in the world could demonstrate his/her entire repertory of standards-based teaching strategies in one forty-minute lesson; hence, this study may have underestimated their abilities. Taken together, these two tendencies may have effectively counteracted each other.

Implications for Pre-Service and In-Service Professional Development

What circumstances are necessary, in order for these and other novice teachers to teach mathematics for understanding at the levels that they aspired to as undergraduates? Despite their training and strong belief in using standards-based practices, the level of cognitive activities engaged in by their students seldom reached the highest levels of knowledge construction and knowledge representation. Some of the obstacles the teachers faced were school based: class size, scheduling and time constraints, lack of materials and resources, and lack of sustained training and guidance in using the new mathematics programs. These were compounded by the pressure of state-mandated, high-stakes tests. However, we may also ask to what extent their pre-service education classes had adequately prepared them for and assessed their abilities to apply theoretical understandings of standards-based pedagogy in practice. Teaching for conceptual understanding not only requires addressing the school-based obstacles mentioned above, it also requires a high level of teacher skill in selecting and designing activities. As other studies previously found, beginning teachers tend to move away from their beliefs and “give up their new conceptions as they struggle to survive and to fit into the instructional norms of traditional educational practices” [14]. The consequences of this struggle could be devastating to the students they teach, especially those in urban areas who already face tremendous challenges.

Certain recommendations are therefore obvious. From both their pre-service and their in-service training, teachers need more scaffolding, more model lessons, and more specific support for engaging students at higher cognitive levels, for helping students to create their own understandings, and for implementing cooperative learning. School administrators need to be convinced that teaching mathematics for understanding cannot be accomplished by teaching to the test. Curricular materials such as *Everyday Mathematics* provide teachers with standards-based instructional activities [11]. However, teachers must be empowered to deviate from these activities in order to address their students’ needs when necessary. Finally, schools need to initiate conversations with teachers about not only teaching and learning in general, but the specific progress of individual students, and to sustain those conversations in an ongoing way throughout the school year. ■

Acknowledgment

The research upon which this article is based was supported by a grant from the National Science Foundation to the Center for Advanced Study in Education, CUNY.

References

- [1] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.
- [2] L. Ma, *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Lawrence Erlbaum Associates, Mahwah, NJ, 1999.
- [3] M.A. Timmerman, "The Influences of Three Interventions on Prospective Elementary Teachers' Beliefs about the Knowledge Base Needed for Teaching Mathematics," *School Science & Mathematics*, **104**(8) (2004) 369-382.
- [4] M.J. Behr, G. Harel, T. Post, and R. Lesh, "Rational Number, Ratio, and Proportion," in D. A. Grouws (ed.), *Handbook of Research on Mathematics Teaching and Learning*, Macmillan Publishing Co., NY, 1992.
- [5] D.A. Grouws and K.A. Schultz, "Mathematics Teacher Education," in J. Sikula, T.J. Buttery, and E. Guyton (eds.), *Handbook of Research on Teacher Education*, Macmillan Publishing Co., New York, 1996.
- [6] M. Lampert, "When the Problem Is Not the Question and the Solution Is Not the Answer: Mathematical Knowing and Teaching," *American Educational Research Journal*, **40** (1990).
- [7] D. Ball, H. Hill, and H. Bass, "Knowing Mathematics for Teaching," *American Educator*, **44** (2005) 14-16.
- [8] U.E. Wagener, "Changing the Culture of Teaching," *Change*, **23**(4) (1991) 28-37.
- [9] F. Lawrenz, D. Huffman, and K. Appeldoorn, *Classroom Observation Handbook*. CAREI, College of Education & Human Development, University of Minnesota, Minneapolis, MN, 2002.
- [10] *Professional Standards for Teaching Mathematics*, National Council of Teachers of Mathematics, in D.F. Steele, "The Interfacing of Pre-Service and In-Service Experiences of Reform-Based Teaching: A Longitudinal Study," *Journal of Mathematics Teacher Education*, **4** (2001) 169.
- [11] *Everyday Mathematics*, University of Chicago School Mathematics Project, McGraw-Hill, New York, NY, 2004.
- [12] *Impact Mathematics*, McGraw-Hill, Glencoe/McGraw-Hill, 2002.
- [13] I.R. Weiss, "Evaluation of the NSF Local Systemic Change Program: Implications for Preparing New Teachers of Mathematics," *Association of Mathematics Teacher Educators (AMTE) Connections*, **15**(1) (2005) 12.
- [14] S. Wilcox, P. Lanier, P. Schram, and G. Lappan, *Influencing Beginning Teachers' Practice in Mathematics Education: Confronting Constraints of Knowledge, Beliefs, and Context*, The National Center for Research on Teacher Learning, Michigan State University, East Lansing, MI, 1992.

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