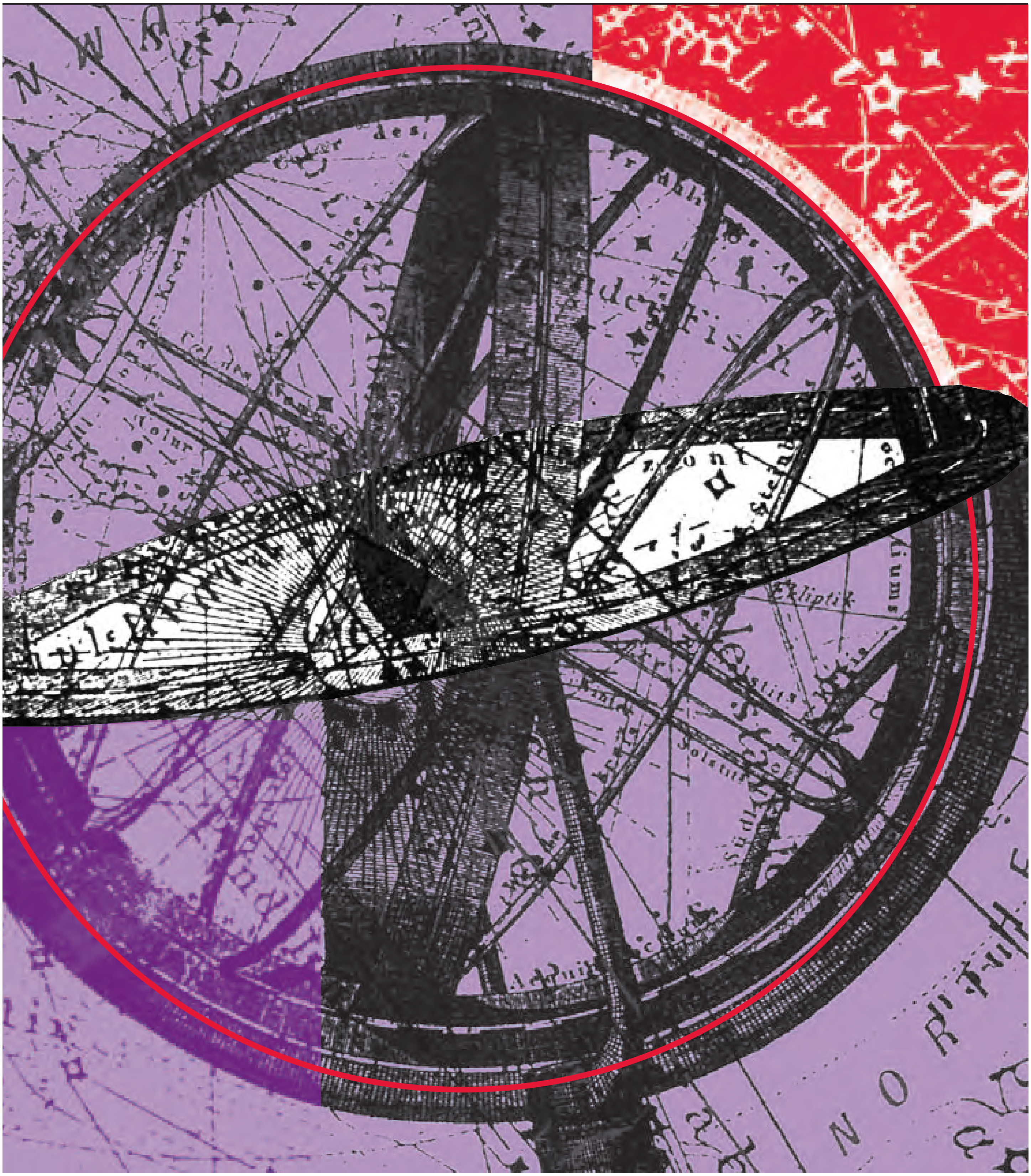
NATIONAL COUNCIL OF SUPERVISORS OF MATHEMATICS

# NCSM JOURNAL of Mathematics Education Leadership

VOLUME 9, NUMBER 1 SPRING 2006



The ***NCSM Journal of Mathematics Education Leadership*** is published at least twice yearly, in the spring and fall.



The editors of the ***NCSM Journal of Mathematics Education Leadership*** are interested in manuscripts that address concerns of leadership in mathematics rather than those of content or delivery. Editors are interested in publishing articles from a broad spectrum of formal and informal leaders who practice at local, regional, national, and international levels. Categories for submittal include:

- Key Topics in Leadership
- Case Studies
- Research Report and Interpretation
- Commentary on Critical Issues in Mathematics Education
- Professional Development Strategies

*Note: The last two categories are intended for short pieces of 2 to 3 pages in length*

## Submission/Review Procedures

Submittal of items for this publication must include three hard copies and a disk copy in text format. Do not put any author identification in the body of the item being submitted, but do include author information as you would like to see it in the ***Journal***. Items submitted for publication will be reviewed by two members of the NCSM Review Panel and one editor with comments and suggested revisions sent back to the author at least six weeks before publication. Final copy must be agreed to at least three weeks before publication.

## On the cover:

This issue's cover, created by Bonnie Katz, is a graphic interpretation of a gyroscope, a device used to measure or maintain orientation, based on the principle of conservation of angular momentum. In physics this is also known as gyroscopic inertia or rigidity in space. The essence of the device is a spinning wheel on an axle. Once spinning, the gyroscope tends to resist changes to its orientation due to the angular momentum of the wheel.



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## *Purpose Statement*

The purpose of the NCSM Journal of Mathematics Education Leadership is to advance the mission and vision of the National Council of Supervisors of Mathematics by:

- Strengthening mathematics education leadership through the dissemination of knowledge related to research, issues, trends, programs, policy, and practice in mathematics education
- Fostering inquiry into key challenges of mathematics education leadership
- Raising awareness about key challenges of mathematics education leadership, in order to influence research, programs, policy, and practice
- Engaging the attention and support of other education stakeholders, and business and government, in order to broaden as well as strengthen mathematics education leadership.

# Comments from the Editor:
## *Energizing Leadership*

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All but one of the articles in this issue concern professional development leadership. This weighting was not intentional on the part of the journal's reviewers and me. Rather, I believe that the preponderance reveals the great energy and creativity currently being committed to professional development by our colleagues all across the continent. In the articles, you will see examples of professional problem solving through professional development, of philosophically driven design and implementation, of engagement with the real world of political and social forces, and of commitment to deep engagement with mathematics and the nature of mathematical thinking.

Occasionally, public media can make it sound as if the core purpose of staff/professional development in education is to bring people up to speed or, worse, to fix. The articles in this issue demonstrate the shallowness of this perspective, and reflect far richer purposes for professional development programs, in particular, individual learning, professional growth, and collaborative problem solving. Several decades ago, Donald Schön studied the practices of various professionals, such as architects and psychotherapists, and described how effective practitioners frame problems, construct and experiment with solutions, and reframe the problems as they read the results of their experiments. (Schön, 1983, 1987). The term he used, *the reflective practitioner,* became and remains an important descriptor in the study and design of effective professional learning. I think that, over the past decade, our profession has seen a remarkable burgeoning of interest in educating practitioners to be more reflective in their practice, and I believe the following articles corroborate that impression. My own recent experience also adds to my picture of "reflective practice."

I am currently involved in an effort by New York City's Office of English Language Learners to solve a problem through the professional development and collaborative efforts of teachers, coaches, and administrators. The problem: In the city, there is an unexplained achievement gap in mathematics between English Language Learners and others. The premise on which the effort is based: From lesson preparation to interacting with students in the classroom to analyzing student work, we all need to be more effective in understanding evidence of difficulty with academic language as well as evidence of difficulty with mathematical concepts, and we need to inform the teaching and support of English Language Learners accordingly. Further, as school teams undertaking this effort, we need to learn and strategize and implement together.

Leaders of this effort do not spare messages about accountability—the next round and all future rounds of test scores will be examined, after all--but they also clearly communicate messages about trust in the power of the professional learning and collaborative problem solving of those closest to the children affected by achievement gaps. I believe the resulting effort not only is congruent with what we know about "reflective practitioners," but also fits with the notion of "mutual accountability" that some education writers refer to, and it is my impression that the school team members participating in this effort draw considerable energy from it. For that, I commend the leadership behind the effort, because leadership that energizes is a wonderful and usually invisible force.

We know that there are many such stories, among NCSM members, of energizing leadership leading to reflective practice. If you have one, please consider writing about it for the journal.

## References

Schön, D. (1983). *The reflective practitioner.* New York: Basic Books.

Schön, D. (1987). *Educating the reflective practitioner.* San Francisco: Jossey-Bass.

# What is the Focus and Emphasis on Calculators in State-Level K-8 Mathematics Curriculum Standards Documents?

Kathryn Chval, Barbara Reys, Dawn Teuscher
University of Missouri

The availability of calculators has influenced mathematics instruction, assessments, and textbooks since they were first introduced into K-8 mathematics classrooms 30 years ago. During that time, there has been a steady line of research (e.g., Hembree & Dessart, 1986; 1992; Shumway, White, Wheatley, Reys, Coburn, & Schoen, 1981; Suydam, 1979) and numerous recommendations from professional organizations (National Council of Teachers of Mathematics, 1989, 2000, 2005; National Research Council, 1990; National Council of Supervisors of Mathematics, 1988) supporting the use of calculators. Furthermore, 35 states make references to calculators within state curriculum documents and 40 states allow the use of calculators on some portions of state mathematics assessments. Many current mathematics textbooks include mathematical tasks designed for use of calculators. Even though the use of calculators has been encouraged for some time, their use in elementary and middle school mathematics classrooms remains controversial. For example, authors of a recent Thomas B. Fordham Foundation report, *The State of State Math Standards* (2005) conclude: "One of the most debilitating trends in current state math standards is their excessive emphasis on calculators." (p. 14)

This assertion in the Fordham report encouraged us to conduct our own analysis of official state mathematics curriculum standards documents so that we might understand and describe the extent to which states support use of calculators in elementary and middle school mathematics classes. In particular, we examined messages about calculators conveyed within these documents to school administrators and classroom teachers. In this paper, we report the findings from our analysis, identify contradictions with the Fordham report, and discuss leadership efforts needed to support teachers in their use of calculators.

## State-Level Mathematics Curriculum Standards Documents

The federal *No Child Left Behind* act of 2001 prompted a wave of state-level curriculum articulation with specific attention to decisions about grade-by-grade learning expectations in mathematics. In fact, nearly three-fourths of the states have published new curriculum standards since 2001 (Reys, et al, 2005). While some of these documents are intended to be "models" for local school districts to utilize in shaping their own curriculum specifications, others are mandatory, specifying the mathematics all students within the state are expected to learn at particular grades. In addition, these curriculum standards serve as guidelines for shaping annual statewide grade-level assessments. As a collection, the new state-level mathematics curriculum standards represent the mathematics students in the U.S. are expected to learn.

*This report is based on the work of the Center for the Study of Mathematics Curriculum, supported by the National Science Foundation under Grant No. ESI-0333879. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

**TABLE 1:** ***Name and publication date of state-level mathematics curriculum documents (42) analyzed for this study (as identified by a search of state education department websites as of May 2005).***

| State | Document* | Year Published |
|---|---|---|
| AL | Alabama Course of Study: Mathematics | 2003 |
| AK | Grade Level Expectations | 2004 |
| AR | Arkansas Mathematics Curriculum Frameworks K-12 | 2004 |
| AZ | Grade Level Expectations | 2003 |
| CA | Mathematics Framework for California Public Schools: K-12 | 2005 |
| CO | Grade Level Expectations (Examples) | 2000 |
| DoDEA | Mathematics Curriculum Content Standards | 2004 |
| DC | Standards for Teaching and Learning | 2002 |
| FL | Sunshine State Standards | 1996 |
| GA | Georgia Performance Standards | 2004 |
| HI | Framework and Instructional Guides–Grade Level Performance Indicators | 2004 |
| ID | Idaho Mathematics Achievement Standards | 2005 |
| IN | Indiana's Academic Standards for Mathematics | 2000 |
| KS | Kansas Curricular Standards for Mathematics | 2003 |
| LA | Grade Level Expectations | 2004 |
| MD | Maryland Voluntary State Curriculum | 2004 |
| ME | Grade Level Expectations | 2004 |
| MI | Michigan Grade Level Content Expectations (GLCE) | 2004 |
| MN | Minnesota Academic Standards–Mathematics | 2003 |
| MO | Mathematics Grade Level Expectations | 2004 |
| MS | Mississippi Mathematics Framework 2000 | 1999 |
| NC | Mathematics Standard Course of Study and Grade Level Competencies | 2003 |
| ND | Mathematics Content Standards | 2005 |
| NH* | Local Grade Level Expectations (K-8) (with RI) | 2004 |
| NJ | New Jersey Core Curriculum Content Standards for Mathematics | 2002 |
| NM | Mathematics Content Standards, Benchmarks, and Performance Standards | 2002 |
| NV | Nevada Content & Performance Standards | 2003 |
| NY | New York Learning Standards for Mathematics | 2005 |
| OK | Priority Academic Student Skills | 2002 |
| OH | Academic Content Standards K-12 Mathematics | 2001 |
| OR | Oregon Grade Level Standards and K-2 Foundations | 2002 |
| RI* | Local Mathematics Grade Level Expectations (with NH) | 2004 |
| SC | South Carolina Mathematics Curriculum Standards 2000 | 2001 |
| SD | South Dakota Revised Mathematics Content Standards | 2004 |
| TN | Mathematics Curriculum Standards | 2001 |
| TX | Texas Essential Knowledge and Skills for Mathematics | 1998 |
| UT | Mathematics Core Curriculum | 2003 |
| VA | Virginia Mathematics Standards of Learning Curriculum Framework | 2002 |
| VT | Grade Expectations for Vermont's Framework of Standards and Learning Opportunities | 2004 |
| WA | Mathematics K-10 Grade Level Expectations: A New Level of Specificity | 2004 |
| WV | Mathematics Content Standards and Objectives for West Virginia Schools | 2003 |
| WY | Wyoming Mathematics Content and Performance Standards | 2003 |

* Links to each document are available at: http://mathcurriuclumcenter.org/statestandards

** New Hampshire and Rhode Island share a common document.

School administrators, teachers, and curriculum developers are carefully considering the content in the state curriculum standards, including the grade-by-grade learning expectations, as they design, teach, and monitor mathematics learning. Therefore, these documents and the messages they convey are likely to impact, in important ways, what is included in future mathematics textbooks and how mathematics is taught. Our analysis of the state curriculum documents was guided by the following questions:

1. To what extent do state-level K-8 mathematics curriculum standards documents refer to the use of calculators? How does the extent of use differ across grade levels?
2. What expected roles of calculators are articulated in state-level K-8 mathematics curriculum standards documents? How do the expected roles differ across grade levels?
3. What general messages are conveyed regarding calculator use within state-level mathematics curriculum documents at grades K-8?

## Methods

We began by collecting the most recent mathematics curriculum standards documents from all 50 states as well as the District of Columbia (DC) and the Department of Defense Educational Agency (DoDEA) (see http://mathed-db.missouri.edu/states.php for links to the documents). We identified documents that focused on elementary and middle grades and specified grade-by-grade learning expectations (LE). At the time of our analysis several states did not specify grade-by-grade LEs in mathematics and some states were in the process of finalizing draft documents, therefore we did not include these documents in the analysis. Our analysis included a review of 42 curriculum documents (see Table 1) which convey elementary and middle school mathematics grade-level LEs.

We conducted word searches for “calculator” and “technology” in the general introductory material of the curriculum documents as well as in the specific LEs within K-8 grade-level sections of the documents. We then compiled all of these statements and used that compilation as the data source for our analysis. For the specific grade-level LEs, the three authors individually coded each LE according to the role of the calculator and then met together to discuss and reach consensus on the specific code(s) for each LE.

Table 2 summarizes state documents that include messages related to calculators/technology within the introductory material and/or within specific LEs. As noted, 20 state documents include a discussion of the role of calculators/technology within the introductory material and 32 state documents include the terms calculator and/or technology within a subset of learning expectations. Documents from six states and the Department of Defense include no use of either term in the introductory narrative or within the set of LEs. The District of Columbia document includes “technology integration standards” as a separate section of

**TABLE 2:** ***Summary of states with curriculum standards documents that include the terms “calculator” or “technology” in introductory material or within statements of specific learning expectations.***

| | | Terms “calculator” and/or “technology” used in introductory sections of document | | | |
|---|---|---|---|---|---|
| | | YES | | NO | |
| Terms “calculator” and/or “technology” used within learning expectations | YES | Arkansas<br>Kansas<br>Nevada<br>North Dakota<br>New Mexico<br>Ohio<br>Texas<br>Virginia<br>West Virginia | California<br>Mississippi<br>North Carolina<br>New Jersey<br>New York<br>Oklahoma<br>Utah<br>Washington | Alaska<br>Colorado<br>Florida<br>Hawaii<br>Indiana<br>Michigan<br>Oregon<br>Tennessee | Arizona<br>District of Columbia<br>Georgia<br>Idaho<br>Louisiana<br>Minnesota<br>South Carolina |
| | NO | Alabama<br>South Dakota<br>Wyoming<br>Vermont | | DoDEA<br>Maine<br>New Hampshire | Maryland<br>Missouri<br>Rhode Island |
| | Total | 20 | | 22 | |

the document. While some of the learning expectations within this section focused on mathematics, most were related to general proficiency with technology. Therefore, we choose not to include the District of Columbia document in the analysis.

## Summary of Findings from Analysis of Introductory Narrative

As noted in Table 2, 20 state-level mathematics curriculum documents include statements regarding the role of calculators/technology within the introductory narrative. This material ranged in length from a single sentence to an entire chapter. For example, the *Kansas Curricular Standards for Mathematics* (2003) includes the following single statement in the introductory narrative related to calculators/technology:

> Technology will be a fundamental part of mathematics teaching and learning. (p. 6)

On the other hand, the California *Mathematics Framework* (2005) includes a full chapter summarizing a perspective and policy regarding calculators. The message within the California document regarding the role of calculators/technology is clearly more guarded and oppositional in nature than in other state documents. For example, unlike other state documents, there is a stated policy restricting use of calculators in grades K-5 indicating that:

> Extensive reliance on calculators runs counter to the goal of having students practice [computational and procedural skills]. More to the point, it is imperative that students in the early grades be given every opportunity to develop a facility with basic arithmetic skills without reliance on calculators. (p. 373)

Indeed, there is no mention of calculators/technology until grade 6 in the grade-level learning expectations within the California document. However, the policy regarding calculators/technology continues:

> It should not be assumed that caution on the use of calculators is incompatible with the explicit endorsement of their use when there is a clear reason for such an endorsement. Once students are ready to use calculators to their advantage, calculators can provide a very useful tool not only for solving problems in various contexts but also for broadening students' mathematical horizons. (p. 374)

A review of the other state documents reveals strong advocacy for use of calculators and technology to support student learning with caution regarding "appropriate" use of these tools. In general, calculators/technology are described as "tools" for supporting learning and carrying out computation within problem-solving settings. Teachers are charged with being responsible for making decisions about when calculators/technology are useful in reaching goals outlined in the state curriculum framework. Likewise, statements warn against over- or inappropriate use of calculators/technology. Examples of appropriate uses of calculators/technology are provided within the documents, often delineated by particular grade levels or grade bands, and include: exploring mathematical patterns, solving complex problems, and organizing or displaying data.

The most common messages within the introductory narrative sections of the documents along with illustrative examples are summarized in Table 3. These common messages include:

1. Appropriate use of calculators/technology is encouraged.
2. Calculators/technology are commonly used in the workplace and outside of school, therefore students should use these tools to solve problems.
3. Calculators/technology are tools for learning and teaching.
4. Calculators/technology can support increased understanding.
5. The existence of calculators/technology does not diminish the need for computational fluency.
6. Calculators/technology can support effective teaching.
7. Teachers are responsible for appropriate and effective use of calculators/technology.

Many of the common messages noted within the set of documents are captured in the following statements found in the introductory sections of the *Alabama Course of Study: Mathematics* (2003):

> Appropriate use of technology is essential for teaching and learning (p. 3).
>
> Technology enhances the mathematics curriculum in many ways, but is not intended to serve as a replacement for the teacher. The effective use of technology, however, does depend on the teacher. Teachers use technology in mathematics instruction to prepare students for an ever-changing world. The teacher makes

**TABLE 3:** *Common messages regarding calculators within introductory documents.*

| Message | Example |
|---|---|
| Appropriate use of calculators/technology is encouraged. | The Mississippi Department of Education strongly encourages the use of technology in all mathematics classrooms. The learning and teaching of mathematics can be greatly enhanced when quality instructional technology is appropriately used. (Mississippi Mathematics Framework, 2000, p. 9) |
| Calculators/technology are commonly used in the workplace and outside of school, therefore students should use these tools to solve problems. | Society needs individuals who have sound estimation skills and number and spatial sense, who are competent using and interpreting data, and who can use appropriate technology resources to solve problems and make informed decisions. These skills are essential if students are to become successful citizens, life-long learners, and competitive workers in a global market place. (Nevada Mathematics Standards, 2003, p. 3) |
| Calculators/technology are tools for learning and teaching. | Electronic technologies such as calculators and computers are essential tools for teaching, learning, and doing mathematics. They furnish visual images of mathematical ideas, facilitate organizing and analyzing data, and compute efficiently and accurately. They support investigation by students in every area of mathematics and allow students to focus on decision-making, reflection, reasoning, and problem solving. (New Mexico Mathematics Content Standards, Benchmarks and Performance Standards, 2002, p. 3) |
| Calculators/technology can support increased understanding. | Technology can be used by students to strengthen and extend their understanding of concepts, explore mathematical functions, engage in problem-solving activities, employ real world applications, and verify results of mathematical activities. When technology is combined with a student's understanding of underlying mathematical concepts, learning is enhanced. (Nevada Mathematics: Content Standards for Kindergarten and Grades 1 through 8 and 12 , 2003, p. 3) |
| The existence of calculators/technology does not diminish the need for computational fluency. | The incorporation of technology in instruction enables teachers to use problems containing actual numbers from existing situations rather than numbers to facilitate hand calculations. However, students must also understand quantitative concepts and relationships and demonstrate a proficiency in basic computation using calculators as an aid rather than a crutch. (Wyoming Mathematics Content and Performance Standards, 2003, p. 1-2) |
| Calculators/technology can support effective teaching. | Technology also supports effective mathematics teaching and can dramatically increase the possibilities for engaging students with challenging content using visualization, simulation, graphing, and advanced computing. (New Mexico Mathematics Content Standards, Benchmarks and Performance Standards, 2002, p. 3) |
| Teachers are responsible for appropriate and effective use of calculators/technology. | West Virginia teachers are responsible for integrating technology appropriately in the students learning environment. Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. (Mathematics Content Standards and Objectives for West Virginia Schools, 2003, p. 8) |

instructional decisions about worthwhile investigative tasks that take advantage of technological aids. Technology influences the mathematics taught by providing exploratory opportunities and visual displays that would be tedious to generate by hand. Technology should be used to foster, rather than replace, the understanding of basic mathematical concepts. The use of appropriate technological tools provides support for all students to learn mathematics. Technology can be used by students and teachers to assess the understanding of meaningful mathematical concepts and to investigate more complex problems. (p. 6)

In summary, 20 state documents note the potential of calculators/technology tools to support teaching and learning. We did not find explicit statements regarding calculators/technology within the introductory material in the other 22 state documents reviewed for this analysis. While some of these documents include references to calculators/technology within the set of learning expectations, others do not. In the next section we summarize the analysis of the specific learning expectations which reference calculators/technology.

**TABLE 4:** *Number of calculator/technology learning expectations per grade by state (shaded rows indicate state documents that do not reference calculators or technology within the statements of learning expectations).*

| State | K | Gr. 1 | Gr. 2 | Total Gr. K-2 | Gr. 3 | Gr. 4 | Gr. 5 | Total Gr. 3-5 | Gr. 6 | Gr. 7 | Gr. 8 | Total Gr. 6-8 | Total Gr. K-8 | Mean of State |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AL | | | | | | | | | | | | | | |
| AK | | | | | 3 | 2 | 2 | **7** | 3 | 2 | 3 | **8** | **15** | **1.67** |
| AR | 2 | 2 | 2 | **6** | 4 | 5 | 4 | **13** | 6 | 13 | 18 | **37** | **56** | **6.22** |
| AZ | | | | | | | | | 1 | 1 | 1 | **3** | **3** | **0.33** |
| CA | | | | | | | | | 1 | | | **1** | **1** | **0.11** |
| CO | | 1 | 1 | **2** | 1 | 1 | 3 | **5** | 3 | 3 | 3 | **9** | **16** | **1.78** |
| DODEA | | | | | | | | | | | | | | |
| DC* | | | | | | | | | | | | | | |
| FL | | 3 | 5 | **8** | 2 | 2 | 2 | **6** | 3 | 2 | 3 | **8** | **22** | **2.44** |
| GA | | 1 | 1 | **2** | 1 | 2 | 2 | **5** | 2 | 2 | 3 | **7** | **14** | **1.56** |
| HI | | | | | | 1 | 1 | **2** | | | | | **2** | **0.22** |
| ID | | | | | | | 1 | **1** | 1 | | | **1** | **2** | **0.22** |
| IN | | | | | | | | | 2 | 1 | 4 | **7** | **7** | **0.78** |
| KS | | 1 | 1 | **2** | 2 | 2 | 1 | **5** | 3 | 3 | 4 | **10** | **17** | **1.89** |
| LA | | | | | 1 | 1 | | **2** | | | 1 | **1** | **3** | **0.33** |
| MD | | | | | | | | | | | | | | |
| ME | | | | | | | | | | | | | | |
| MI | | | | | | | | | 1 | 1 | 1 | **3** | **3** | **0.33** |
| MN | | | | | | | | | 3 | 3 | 4 | **10** | **10** | **1.11** |
| MO | | | | | | | | | | | | | | |
| MS | 1 | 1 | | **2** | 3 | 1 | 4 | **8** | 5 | | | **5** | **15** | **1.67** |
| NC | | | | | 1 | 3 | 1 | **5** | 1 | 1 | 1 | **3** | **8** | **0.89** |
| ND | | | | | 1 | | | **1** | | | 1 | **1** | **2** | **0.22** |
| NH/RI | | | | | | | | | | | | | | |
| NM | | | 1 | **1** | | | | | | 1 | 4 | **5** | **6** | **0.67** |
| NJ | | | | | 4 | 4 | 3 | **11** | 4 | 5 | 5 | **14** | **25** | **2.78** |
| NV | 1 | 1 | 1 | **3** | 1 | 1 | 3 | **5** | 3 | 4 | 7 | **14** | **22** | **2.44** |
| NY | | | | | | | 3 | **3** | 1 | 3 | 1 | **5** | **8** | **0.89** |
| OK | | | | | | | | | | 2 | | **2** | **2** | **0.22** |
| OH | | | | | 1 | 1 | 1 | **3** | 1 | 2 | 2 | **5** | **8** | **0.89** |
| OR | | | | | | | | | | | 1 | **1** | **1** | **0.11** |
| SC | | | 3 | **3** | 2 | 2 | 3 | **7** | 1 | 1 | 1 | **3** | **13** | **1.44** |
| SD | | | | | | | | | | | | | | |
| TN | | 1 | 1 | **2** | | 1 | 1 | **2** | 2 | 2 | 2 | **6** | **10** | **1.11** |
| TX | 3 | 3 | 3 | **9** | 3 | 2 | 4 | **9** | 1 | 2 | 4 | **7** | **25** | **2.78** |
| UT | | | 1 | **1** | 1 | 1 | 3 | **5** | 2 | | | **2** | **8** | **0.89** |
| VA | 1 | 4 | 2 | **7** | 1 | 7 | 5 | **13** | 3 | | | **3** | **23** | **2.56** |
| VT | | | | | | | | | | | | | | |
| WA | | 2 | 5 | **7** | 4 | 5 | 3 | **12** | 6 | 9 | 7 | **22** | **41** | **4.56** |
| WV | | | | | | | | | | 3 | 5 | **8** | **8** | **0.89** |
| WY | | | | | | | | | | | | | | |
| Total LE | 8 | 20 | 27 | **55** | 36 | 44 | 50 | **130** | 59 | 66 | 86 | **211** | **396** | **396** |
| Mean per grade level | 0.26 | 0.65 | 0.87 | **0.59** | 1.16 | 1.42 | 1.61 | **1.40** | 1.90 | 2.13 | 2.77 | **2.27** | **12.77** | **1.42** |

* The DC document includes "technology integration" LEs which span all content areas and include emphasis on learning *about* technology.

## Summary of Findings from Analysis of Learning Expectations

Thirty-one state curriculum documents were reviewed for this analysis — all those that contained references to the term "calculator" or "technology" within the set of grade-by-grade LEs, excluding the District of Columbia document. The state documents differ in their use of terms — calculator and/or technology — within statements of grade-level learning expectations with no document defining either term. For example, the Arkansas document uses "technology" exclusively, never referencing the term "calculators." On the other hand, eight state documents (AZ, CA, HI, ID, MI, OK, UT, and VA) use the term "calculator," but not "technology." Most states use both terms although they do not describe how their use of the terms differs. For this analysis, we focused on statements that pertained to use of some form of calculator — four-function, scientific, or graphing calculator — rather than computers or computer software. In the remaining sections of this paper we use the term "calculator" in summarizing the data, regardless of the choice of terms used in particular state documents.

The 31 state documents include a total of about 14,600 statements of learning expectations for elementary and middle school for a mean of 52 LEs per grade per state document (see Reys, et al., 2006 for a more complete summary of the documents). A subset of learning expectations — all those that included the phrase "calculator" or "technology" were identified from this set. This set included a total of 451 LEs or about 3 percent of all LEs. Twenty-one of the 451 LEs indicated that calculators/technology should not be used. For example:

> *Multiply and divide, without a calculator, numbers containing up to three digits by numbers containing up to two digits, such as 347 / 83 or 4.91 x 9.2. (MN, Grade 6, 2003).*

> *Convert between any two representations of numbers (fractions, decimals, and percents) without the use of a calculator. (IN, Grade 6, 2000).*

In addition, 34 of the 451 LEs focused on computer technology (e.g., software) rather than calculators. For example:

> *Identify and draw lines of symmetry in geometric shapes (by hand or using technology). (IN, Grade 3, 2000)*

> *The student recognizes and investigates attributes of circles, squares, rectangles, triangles, and ellipses using concrete objects, drawings, and/or appropriate technology. (KS, Grade K, 2003)*

The remaining LEs (396) formed the basis for our review. See Table 4 for a summary of the number of LEs referencing calculators by state. As noted, the Arkansas and Washington documents include the largest number of LEs (56 and 41 respectively) and several states (CA, HI, ID, ND, OK, and OR) include only one or two LEs referencing calculators. The mean number of LEs referencing calculators in the 31 state documents is 12.8 per state (1.4 per grade), or a little less than 3% of the total number of LEs per grade (1.4/52). If the Arkansas and Washington state documents are excluded, the mean drops from 12.8 to 10.3 calculator/technology LEs per state document or a little over one per grade.

As shown in Table 4, the number of LEs referring to calculators is greater in the upper grades than the lower elementary grades. For example, the mean number of calculator LEs per grade at grades K-2 is 0.59, at grades 3-5 it is 1.40, and at grades 6-8 it is 2.27. As might be expected, the majority of calculator-related LEs (56%) are found within the Number and Operation strand of the state documents (see Table 5 for a summary by strand).

**TABLE 5:** ***Proportion of 396 LEs that reference calculators/technology by content strand.***

| Strand | Percent of LEs; N=396 |
|---|---|
| Number and Operation | 56% |
| Algebra | 18% |
| Data Analysis and Probability | 10% |
| Geometry and Measurement | 4% |
| Other (Process Strands such as problem solving, communication, and reasoning) | 13% |

In summary, ten of the 42 states represented in Table 4 have mathematics curriculum standards documents that contain no references to calculators within the set of grade-level LEs. Another 18 of 42 states include ten or fewer references to calculators within their document. With the exception of the Arkansas and Washington state documents, no state document includes more than 25 LEs that reference calculators across grades K-8. As noted, across all the documents, the largest concentration of references to calculators is at the middle grades level. In fact, 211 of the 396 (53%) calculator-related LEs identified are found at grades 6, 7, or 8.

In addition to identifying the number of LEs that reference calculators/technology, the analysis included a review of the intended role of the calculator within the LEs. Six

**TABLE 6:** ***Summary of coding scheme for specific grade-level learning expectations.***

| Message | | Example |
|---|---|---|
| Represent | Students use calculators/ technology to represent mathematical quantities and ideas including different notations and graphs. They also connect physical models to mathematical language. | Represent and solve problem situations that can be modeled by and solved using concepts of absolute value, exponents and square roots (for perfect squares) with and without appropriate technology. (AR, grade 7)<br>Organizes, graphs and analyzes a set of real-world data using appropriate technology. (FL, grade 8) |
| Solve problems or equations | Students use calculators/technology to solve applied problems or equations. | Use calculator, manipulatives, or paper and pencil to solve addition or subtraction problems (WA, grade 2)<br>Use technology, including calculators, to solve problems and verify solutions. (NV, grades 5-8) |
| Develop or demonstrate conceptual understanding | Students use calculators/technology to build conceptual knowledge of mathematical ideas and/or demonstrate understanding of these concepts. | Uses a calculator to explore addition, subtraction, and skip counting.(FL, grade 1)<br>Understand the concept of the constant as the ratio of the circumference to the diameter of a circle. Develop and use the formulas for the circumference and area of a circle. Example: Measure the diameter and circumference of several circular objects. (Use string to find the circumference.) With a calculator, divide each circumference by its diameter. What do you notice about the results? (IN, grade 6) |
| Analyze | Students use calculators/ technology to compare, interpret, identify relationships, make predictions, interpret graphs, or make sense of data. | Read, interpret, select, construct, analyze, generate questions about, and draw inferences from displays of data. Calculators and computers used to record and process information. (NJ, grade 6)<br>Uses technology, such as graphing calculators and computer spreadsheets, to analyze data and create graphs. (FL, grade 7) |
| Compute or estimate | Students use calculators/technology to compute or estimate. | Use a variety of strategies to multiply three-digit by three-digit numbers Note: Multiplication by anything greater than a three-digit multiplier/ multiplicand should be done using technology (NY, grade 5)<br>Generating sequences by using calculators to repeatedly apply a formula (NJ, grades 7-8) |
| Describe, explain, justify, or reason | Students use calculators/technology to help them describe strategies, explain reasoning, or justify mathematical thinking. | Use technology, including calculators, to investigate, define, and describe quantitative relationships such as patterns and functions. (NV, grades 5-8)<br>The student communicates his or her mathematical thinking by representing mathematical problems numerically, graphically, and/or symbolically or using appropriate vocabulary, symbols, or technology to explain, justify, and defend strategies and solutions. (AK, grade 7) |

**TABLE 7:** ***Role of calculator/technology as specified in learning expectations within state-level curriculum documents.***

| Role of Calculator/Technology | Grade Band | No. of States | No. of LEs | Total LEs* | Percentage of Total LEs (N=396) |
|---|---|---|---|---|---|
| Solve problems or equations | K-2<br>3-5<br>6-8 | 6<br>15<br>21 | 16<br>46<br>68 | 130 | 33% |
| Represent | K-2<br>3-5<br>6-8 | 2<br>11<br>21 | 5<br>17<br>83 | 105 | 27% |
| Compute or estimate | K-2<br>3-5<br>6-8 | 2<br>13<br>15 | 3<br>31<br>45 | 79 | 20% |
| Develop or demonstrate conceptual understanding | K-2<br>3-5<br>6-8 | 6<br>8<br>11 | 19<br>19<br>26 | 64 | 16% |
| Describe, explain, justify, or reason | K-2<br>3-5<br>6-8 | 8<br>8<br>9 | 16<br>18<br>29 | 63 | 16% |
| Analyze | K-2<br>3-5<br>6-8 | 2<br>5<br>15 | 3<br>7<br>41 | 51 | 13% |

* The number of LEs does not sum to 396 because some LEs were coded in multiple categories.

different categories were identified from multiple readings (see Table 6 for a list of categories, descriptions and example LEs).

Table 7 summarizes the number of LEs assigned to each coded role. About one-third of the LEs focus on solving applied problems or equations and most of these are in the upper grades. A little over a fourth of the set of LEs focus on using calculators/technology to represent, model or graph mathematical ideas or data.

Twenty percent of the LEs reference calculators/technology as a tool for computing or estimating. That is, 79 of the 396 LEs that include a reference to calculators/technology convey an intention that the tool will be used primarily for computation and most of these (45 of 79) are at grades 6-8. These data suggest that calculators/technology are infrequently encouraged solely as a computational tool.

The most prominent role for calculators/technology in grades K-2 is for developing or demonstrating conceptual understanding, in grades 3-5 for solving problems or equations, and in grades 6-8 for representing mathematics.

In addition, two other sets of LEs referred to calculators. However, the focus was not on using calculators but rather on judgments made prior to or after use of the tool. They include choosing an appropriate method of calculation and checking the reasonableness of calculated answers. Examples of LEs in each category include:

> Solve problems using the four operations with whole numbers, decimals, and fractions. Determine when it is appropriate to use estimation, mental math strategies, paper and pencil, or a calculator. (UT, grades 5, 6)

> Use estimation as a tool for judging the reasonableness of calculator, mental, and paper-and-pencil computations. (SC, grade 5)

Ninety-six of the 396 LEs focus on checking the reasonableness of a calculated answer and/or choosing an appropriate method to calculate. Table 8 summarizes the number of instances by grade band. As noted, use of calculators for either of these roles is more frequent in the upper elementary or middle school years.

**TABLE 8.** ***Summary of learning expectations referring to choosing appropriate methods of calculation and checking reasonableness.***

| Tools | Grade Band | No. of States | No. of LEs | Total LEs* | Percentage of Total LEs (N=396) |
|---|---|---|---|---|---|
| Choose appropriate method of calculation | K-2<br>3-5<br>6-8 | 4<br>15<br>13 | 8<br>36<br>34 | 78 | 20% |
| Determine the reasonableness of a calculated answer | K-2<br>3-5<br>6-8 | 2<br>4<br>4 | 2<br>9<br>7 | 18 | 5% |

## Discussion

As noted earlier, authors of a recent Fordham Foundation report, *The State of State Math Standards* (2005), indicate that attention to calculators is a "common problem" associated with state mathematics curriculum standards. They conclude:

> One of the most debilitating trends in current state math standards is their excessive emphasis on calculators. Most standards documents call upon students to use them starting in the elementary grades, often beginning with Kindergarten. (p. 14)

Our analysis of the state mathematics curriculum standards documents does not support the conclusion offered in the Fordham Foundation report. We found only five state documents that include any references to calculators in the LEs for Kindergarten. In fact, about one-fourth of the state documents include zero references to calculators in statements of LEs at any grade level. Another 43% (18 of 42 documents) include 10 or fewer references to calculators across the set of elementary and middle grades LEs.

A close examination of the LEs that reference calculators reveals that the majority suggest calculators as tools for solving problems and/or representing data rather than as a replacement for facility with paper/pencil computation. It is also worth noting that references to calculators are concentrated at the middle grades. We found no indication that states advocate reliance on calculators at the expense of efficient mental or written procedures.

Within the introductory material of state mathematics curriculum standards documents, common messages include emphasis on appropriate use of calculators — as tools for representing and visualizing mathematical ideas and for exploring mathematical patterns. Teachers are encouraged to be responsible and selective in use of calculators and base decisions on instructional goals. There is also a clear message that computational fluency remains an important goal for students and availability of calculators/technology does not diminish the importance of this goal. While some state documents include a clear statement of philosophy regarding calculators/technology within the introductory material of state standards documents, others do not. Such as statement can clarify and make explicit official state policy and entrust teachers and administrators with making instructional decisions aligned with the policy.

Overall, our analysis does not suggest an overemphasis on or debilitating trend regarding calculator use as the Fordham Report indicates. We do concur with the authors of the Fordham Foundation report that, "with proper restriction and guidance, calculators can play a positive role in school mathematics . . ." (p. 15). We believe that additional guidance would be useful to teachers and administrators regarding the appropriate role of calculators/technology at particular grade levels.

Mathematics leaders need to develop forums and structures that support teachers as they interpret state curriculum standards, specifically regarding how to utilize the potential of the calculator as a tool to enhance mathematics teaching and learning. A recent national survey of K-8 mathematics teachers identified use of technology in mathematics instruction as their greatest professional development need (Weiss, Banilower, McMahon, & Smith, 2001). As leaders begin to develop discussion forums and professional development opportunities related to state learning expectations and standards, calculator use should be specifically addressed. For example, teachers may need:

- Examples of mathematical tasks or lessons that address specific grade-level expectations.
- Observations of effective instruction in classrooms or through the use of videos to provide images that convey the meanings of the calculator learning expectations.
- Resources such as calculators themselves or the corresponding materials that support their use.
- Help regarding discussions with parents about the purpose of calculator use.

Additionally, leaders should continue to take a proactive stance as they work to eliminate ineffective uses of calculators and provide evidence to dispel myths related to calculators.

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# UnLATCHing Mathematics Instruction for English Learners

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**ABSTRACT:**
*Mathematics teachers find it challenging to meet the range of mathematical skill levels of their students. In many schools, this challenge is increased as teachers must also adapt instruction to meet the needs of English learners. Language Acquisition through Content Hierarchy (LATCH) professional development provides teachers with the skills and tools to integrate instructional strategies for English learners with mathematics content instruction. LATCH guides teachers to differentiate mathematics instruction to address the range of student abilities as well as provide access for English learners.*

Many mathematics teachers come to professional development sessions with a basic understanding of how to teach content. Increasingly, teachers participate in professional development programs that provide awareness about second language acquisition with the intent that teachers will make connections between mathematics instruction and English learning theories. The purpose of such professional development activities is for teachers to use instructional strategies that will increase access to mathematics for English Learners (ELs). However, the theory of language acquisition is often seen as additive by teachers; just more layers of work added to their already burgeoning load. The issue at hand then, is to help teachers see how language acquisition strategies can be an integral part of content instruction. The Language Acquisition through Content Hierarchy (LATCH) model was developed to assist teachers in integrating content and language acquisition strategies and use them to differentiate instruction for English learners.

In multilingual classrooms, teachers of mathematics face two challenges: how to address the language diversity of their students; and how to address the diversity in mathematical understanding. This paper will address strategies to help teachers differentiate mathematics instruction for students with a range of mathematical and English proficiencies. The paper is divided into two parts. The first part focuses on the background and development of the LATCH model. Part two explores how LATCH can be used in staff development to help teachers differentiate instruction for their students.

## *Diversity in the Classroom*

### Language Diversity

Part of the reason English learners struggle in mathematics is that rather than being language free, mathematics uses language that is a highly compressed form of communication where each word or symbol often represents an entire concept or idea. In a literature text, readers can comprehend a passage if they are familiar with 85%-90% of the words. The other words and their meanings can often be gleaned through context. Mathematics problems, on the other hand, generally require the student to understand nearly every word as there is seldom enough context provided with the problem to assist with unfamiliar words or concepts. Another problem that English learners encounter is that sometimes they recognize a word, but the meaning they know for the word is different from the intended meaning and therefore does not help them understand the problem. An example might be this problem taken from the released items of the California High School Exit Exam.

*Sally puts $200.00 in a cliff story. Each year the story earns 8% easy attraction. How much attraction will be earned in 3 years?*

This particular version of the problem was created by replacing some of the nouns with synonyms. When the problem is understood in this way, the student has little chance of solving it and would likely just sit there or raise a hand and tell the teacher, "I don't get it." When the teacher would ask which words they don't understand, the student

*has a difficult time answering because they know that:*

*a bank is a type of cliff, like the river bank*

*an account is a story, like when you give an account of an event*

*simple means easy, but this problem is neither simple nor easy*

*interest means attraction, because two people who are interested in each other have an attraction for one another.*

But somehow, the problem still does not make sense. Without more context and vocabulary building, the student would not discern the intended meaning of the problem which was:

*Sally puts $200.00 in a bank account. Each year the account earns 8% simple interest. How much interest will be earned in 3 years?*

The issue here is not whether high school students should be able to correctly understand and solve the above problem as originally written. The issue is how to make mathematics problems accessible to all students so they have the opportunity to learn both the language and the mathematics.

The Natural Language Approach to language acquisition (Krashen & Terrell, 1983) states that the process of learning a second language often mirrors that used by a child to learn a primary language. Children first learn the names of common objects; items repeatedly introduced visually and physically. Learning through direct experiences with concrete examples provides a **context embedded** environment in that the words and their meanings are supported by physical objects or are otherwise familiar to the child. If students don't have the vocabulary or experiential background to understand interest bearing accounts in banks, then they need to be provided this information in a concrete manner that builds upon experiences that are familiar. In the above example, the teacher could discuss multiple meaning of words, use a simulation, or talk about who or where in their community people loan money for a fee.

Assigning an unfamiliar problem without any linguistic supports creates what Cummins would call a **context reduced** environment. In these cases, it is presumed the student has the experience and vocabulary necessary to understand the problem. Jim Cummins highlighted the importance of context in comprehension when he described the Socio-Linguistic Approach (1979) as including two sets of skills required for language proficiency. He calls the first set Basic Interpersonal Communication Skills (BICS). BICS refers to context-embedded communication that takes place in every day interactions between individuals. Greetings, discussions of the weather, relating what just happened on the playground are all examples of BICS.

The second set of language skills involves Cognitive Academic Language Proficiency (CALP). In the case of CALP, communication takes place in a context-reduced environment, or one in which cues, such as visuals, gestures, or a familiar topic are not present. The primary distinction between BICS and CALP rests in the extent to which the context is embedded in the communication.

Cognitive Academic Language Proficiency covers two broad areas: Cognitive proficiency and academic language. The former refers generally to mathematical reasoning including the " higher level of language development [that] includes comparing, classifying, inferring, problem solving, and evaluation" (Williams, 2001; p. 2). The academic language, as it applies to a mathematics classroom, is a broad term that encompasses the skills needed to succeed in school such as reading, writing, and the language skills required to communicate the reasoning behind a mathematical solution. It also includes the technical and specialized vocabulary and terms used in mathematics classes (Chamot and O'Malley, 1994). These higher order thinking and language skills are found in classrooms where the language is complex and the tasks are cognitively demanding (Collier, 1988; Egbert and Simich-Dudgeon, 2001). These environments can be very challenging for students who have yet to gain Cognitive Academic Language Proficiency.

Language minority students often appear to be English proficient and yet perform poorly in content areas because, while they have some proficiency in interpersonal or conversational English, they lack proficiency in the content specific vocabulary which often inhibits the development of academic skills (Cummins, 1979). As a result, students who lack English skills often find themselves falling farther and farther behind in mathematics. Thus, teachers find themselves searching for a variety of instructional strategies that will enhance learning for students at every level of English as well as mathematical proficiency.

## Diversity in Mathematical Understanding

Many classrooms have as much diversity in student understanding of mathematics content as they do in language proficiency. This disparity is perhaps greatest in mathematical problem solving. This critical area of mathematics is emphasized in The Principles and Standards for School Mathematics (2000) set by the National Council for Teachers of Mathematics (NCTM) where it states, "problem solving is not only a major goal of mathematics, it is a major means of doing so" (p.4). In fact, mathematical problem solving should play a central role in the learning of mathematics (Hiebert, et al. 1996; Hiebert, et al. 1997).

George Polya (1957) published pioneering work in the area of problem solving with his book, "How to Solve It." He outlines four steps in problem solving in the text to include: 1) Understanding the Problem; 2) Devising a Plan; 3) Carrying out the Plan; and 4) Looking Back. For English learners the greatest challenge happens in the first step, as they will not be able to solve a problem they can't understand. Once the problem is understood, the second and most cognitively challenging step is devising a plan. Polya provides many suggestions on how to help students devise their own plan as he feels the plan must be their own if they are to learn problem solving. The following section looks at ways to help students, with varying mathematical skills, devise and carry out a plan for problem solving.

There is general consensus among mathematics educators that when students engage in problem solving, they progress from concrete to more abstract representations as their understanding increases (Stevenson & Stigler, 1992; Marzano, 1998; Good & Brophy, 2003; Shapiro, 2004). The Principles and Standards for School Mathematics (2000) discusses this progression and stresses the importance of allowing students to construct conceptual knowledge by building upon what they already know. Prior experiences provide a concrete base from which new, often more abstract, concepts can be developed.

Carpenter, Fennema and Franke (1996) identified this concrete to abstract progression in mathematics in their work with students in primary grades. They found that when given a problem to solve, students use a variety of strategies. Some students use more concrete strategies such as direct modeling, drawing a picture or diagram, or using simpler numbers, while others are able to use algorithms, variables, and write equations. The strategies that students employ depend on their understanding of the problem, the difficulty of the numbers, and the set of skills, understandings and prior knowledge they bring to the situation. In effect, as students gained more experience, direct modeling strategies gave way to procedures utilizing more abstract thinking.

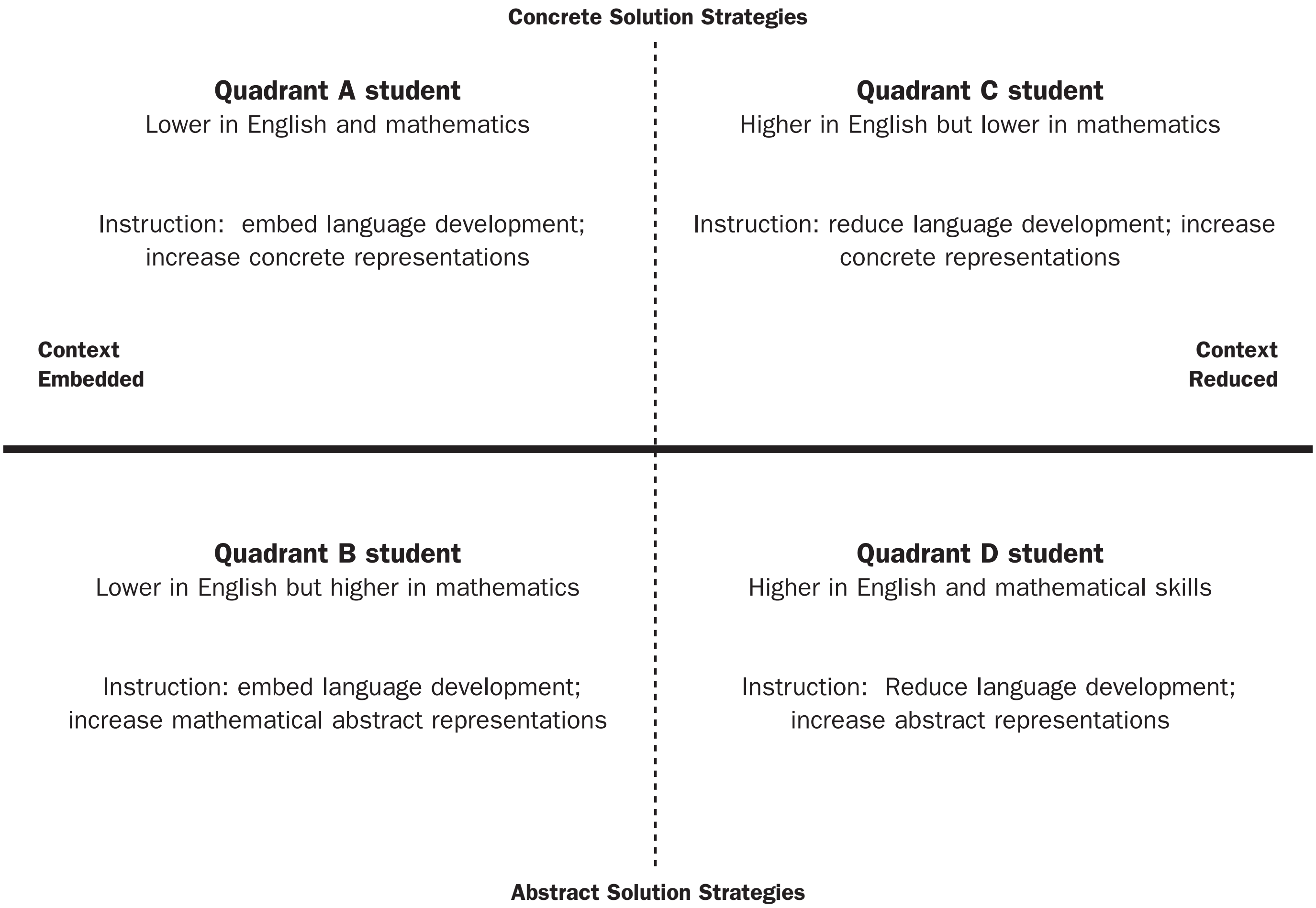
## Bridging Language Acquisition and Mathematics Content

Cummins' work (1994) provides a framework for language acquisition and how it interfaces with content area instruction. He proposed what have later come to be known as Cummins' Quadrants which graphically depict the four linguistic domains of English learners. An adaptation of these quadrants has been made for the LATCH model and appears in Figure 1.

According to Echevarria and Graves (2003), the "horizontal continuum represents contextual support, ranging from contextually embedded communication, wherein meaning can be derived from a variety of clues such as gestures, visual clues, and feedback, to context-reduced communication, which relies primarily on linguistic messages or written texts, which give few, if any, contextual clues (p. 43)". They also state that the vertical continuum relates to the cognitive demands of the task. Since cognitive demand can have a different connotation in mathematics instruction, this axis has been relabeled Concrete to Abstract to match the sequence noted by Carpenter, Fennema and Franke (1996). The Concrete end of the continuum includes solving a problem using manipulatives or drawings and is generally where the greatest number of students will have success. It is therefore the point of greatest access for students (Carpenter, Fennema, & Franke, 1996). Abstract solution strategies, such as writing equations or providing mathematical proofs, generally require the most previous knowledge and experience and therefore fewer students will be successful. In short, **for any given problem**, more students will be able to solve it using concrete strategies than abstract strategies. This does not mean that all problems using concrete strategies are easier than all problems using more abstract strategies, as the notion applies within a problem rather than across problems.

FIGURE 1

**Language Acquisition and Content Quadrants**




**Adapted from Cummins (1994)*

An example of a problem employing concrete and abstract solution strategies is one where students must fill a container with exactly 4 cups of water. All the students can use is a 5 cup container and a 3 cup container. How can the problem be solved? This problem has two solutions and a variety of solution strategies. A more concrete strategy would be to use actual containers and have students reason through the problem using trial and error. Using this strategy, almost all students would be able to work through the problem. A more abstract solution strategy that would require greater mathematical background and skill would be to make a table of all possible measures one could get using these two containers. From this table, students could sequence certain steps and arrive at an answer. While this particular problem does not lend itself to deriving a formula, it does work nicely in making generalizations. For example, will the steps you used to solve the problem work with any 3 consecutive numbers, where you have containers in the size of the largest and smallest numbers and are trying to measure the middle number? If not, what are the next three whole numbers that will work?

The value in Cummins' quadrants is their ability to link language acquisition issues to those of content instruction. This interrelationship is extremely important because it describes the task set before most teachers. The quadrants have been used to train teachers in their generic form, modified form (filled in version), and even in a form adapted to mathematics instruction (Garrison & Mora, 1999). And while all of these help describe the problem, the LATCH model provides more direction on how mathematics instruction can be adapted to meet the needs of English learners.

The Language Acquisition Through Content Hierarchy (LATCH) model helps teachers take the Language Acquisition and Content Quadrants and define each area with specific instructional strategies. Through discussions in a professional development session, teachers will use the LATCH model to construct their own LATCH instructional tool. That is, by the end of the professional development session, they will identify specific context embedded instructional techniques that will be most effective for students just learning English (Quadrants A and B) as well as specific solution strategies that can assist students who are struggling in mathematics (Quadrants A and C). All of these strategies will build on the knowledge base of the teachers present and therefore be easier for them to implement. It has been our experience in leading this professional development that participating in the creation of this instructional tool provides an 'aha' moment for most teachers.

This professional development has been based on several underlying principles: 1) knowledge is retained best when it is built upon previous knowledge (Marzano, 1998; Good & Brophy, 2003), 2) students learn best that which they construct themselves, (Stevenson & Stigler, 1992; Marzano, 1998; Good & Brophy, 2003), 3) teachers know or can devise instructional strategies to meet the needs of English learners; and 4) teachers know or can devise multiple solution strategies to mathematical problems. We have resisted giving them a list of instructional practices and instead helped them to create their own. What follows is a description of the implementation of the LATCH model and the instructional framework used during the professional development sessions.

## *LATCH Professional Development*

### Building the English Language Development (ELD) Sequence

#### THE LEVELS OF LANGUAGE PROFICIENCY

Generally, the professional-development session has taken about 4 hours, though it can be expanded. The content of the session is:

30 minutes: Introduction of Cummins Quadrants and Language Levels
90 minutes: Participants Develop the ELD sequence
60 minutes: Participants Develop the mathematics sequence
60 minutes: Discussion of the newly constructed quadrants and lesson adaptations

We illustrate how the session unfolds by recalling one particular occasion. The first task in the session was to help teachers build a sequence of instructional strategies to assist students at all levels of English proficiency understand the mathematics problem. To accomplish this goal, teachers were divided into four groups, each to represent a level of language proficiency. For example, one group of teachers brainstormed strategies for Level 1 English learners, or students who are not able to communicate in English and need support in listening comprehension. Another group of teachers addressed Level 2 students who can understand basic English (BICS) but need assistance with vocabulary development and oral skills. The third group thought of instructional strategies for Level 3 students, or students who can speak and understand basic English but need help with academic tasks such as reading. The final group addressed strategies for Level 4 students who are at intermediate fluency in English but need support in advanced communication skills such as writing. Each group was given a list of learning characteristics that described students at that level of proficiency.

The task for each group was to think about mathematics problems they had used that were particularly difficult for English learners because either the vocabulary or the context was unfamiliar. Given the context of a problem, the group listed instructional strategies that would make it comprehensible to the students at the assigned language proficiency. For example, the group that represented Level 1 students listed strategies such as acting the problem out and using visuals while the group that represented Level 3 students might list having students repeat the problem in their own words, or reading the problem aloud together. Once each group completed the list of strategies, they were asked to sequence them from the ones that provided the most support for English learners (context-embedded) to the ones that provided the least support (context-reduced). During this part of the activity, teachers were actively engaged, describing and explaining strategies they knew or could imagine and then delving even deeper into the strategies as they had to sequence them. By the end of the activity, each teacher made a deck of note cards with their group's strategies in the agreed upon sequence. These decks were used in the next part of the activity.

Once the work in each language level group was completed, the teachers were reconfigured into groups of four that included a member from each of the language groups. The task of this new group was to sequence the cards from all the decks, starting with the Level 1 group's strategies which provided the most support for English learners (context-embedded) to Level 4 group's strategies which provided the least support (context-reduced). Many of the strategies appeared in more than one group and therefore the cards could be consolidated. The goal was to form a final list of 10-15 sequenced strategies to support the learning of EL students. The expertise of the class as a whole was evident as teachers not only had to explain the strategies from their groups but also had to relate them to the others that had been presented as they sought to find the location in the sequence for each strategy. When the groups were done, teachers took a gallery walk to see how others had approached the same task. Time was allowed for any group that wanted to re-order some of their cards. The final sequence of cards was affixed horizontally (along the x-axis) to a piece of butcher paper and reserved for later use. A whole class discussion of "which sequence was right" ensued and the teachers came to an appreciation that the sequence could shift depending on the understanding of the strategies and the nature of the problem itself. While the notion of a fixed sequence (such as the one represented by the order of operations in arithmetic) was not applicable, the trend toward decreasing levels of support for English learners was evident and easily recognizable.

## Building the Math Sequence

Prior to establishing a hierarchy of skills in mathematics problem solving, teachers were given problems to solve in more than two ways. Once they completed this task, teachers were asked to share their solution strategies with the whole group. The intent of this activity was to have teachers exposed to a diversity of solution strategies that answer a math problem correctly and, more importantly, to have such strategies provide a context to assist the teachers in building a mathematics hierarchy.

Teachers were placed in the same groups that developed the sequence of ELD strategies, and were asked to make a list of all the solution strategies that can be used to solve mathematics problems. In addition to asking teachers to think back to the problem that they had just solved, they were also prompted to think about the students that they teach and the strategies that students use to solve other problems. Common strategies listed by the teachers included the use of manipulatives, writing a formula, and making a table.

When teachers select solution strategies to develop the mathematics continuum, the strategies identified by elementary teachers typically are different from those identified by high school teachers. This occurs because of the differences in the sophistication of their students, the types of problems students solve, and the instructional practices of the teachers. Even with these differences, there is still a general flow of solution strategies from those that are more concrete to those that require more abstract thought.

In helping teachers sequence solution strategies along the concrete to abstract continuum, we have been influenced by the ideas presented by the developers of Cognitively Guided Instruction (Carpenter, Franke, & Levi, 2003; Carpenter & Fennema, 1999), and suggest to teachers that solution strategies can be sorted into four categories: Physical Representations, Numbers, Variables, Generalizations/Proofs. The most concrete of these, physical representations, include the use of manipulatives and drawings. Some students at this level need to represent each number with physical objects to solve the problem. At upper grades, such students may need to make a diagram or other physical representation of the problem in order to 'see' the relationships. At a more abstract level, student will use numbers and arithmetic operations to represent and solve the problem. Students who can use variables to work with and solve the problem would fall under the next level of abstraction. The final level, generalization/proof, includes students who can go beyond the present problem and generalize the results to future problems. This continuum can be thought of as a sequence of strategies that a student might use to solve a problem.

In our session, each strategy was written on a note card and groups were directed to sequence them from the most concrete solution strategy to the most abstract. A common class list was then created to foster greater discussion and a fuller analysis of solution strategies. The justification for the placement generated rich discussions and also allowed groups to add strategies to their lists that they may have overlooked. Once the group had reached a final sequence, they were taped on the y-axis of the same paper as the ELD strategies. Figure 2 represents the completed grid of one group's work. Once the grids were constructed, the teachers were ready to understand how they could be used to guide instructional decisions.

## Defining the Domains within the Context of Mathematics Instruction

With the LATCH grids built, the connections to Cummins' Quadrants become apparent. More importantly, practical applications of presenting mathematics lessons to ELs become clear to the teacher. Each of the four quadrants of the teachers' grid describes a different type of student with specific learning needs. Students in Quadrant A (upper left) are ones who struggle with both English and mathematics. They need strong linguistic support in order to understand the problem. The LATCH grid supplies instructional suggestions (Total Physical Response (acting out), Simplify language, Preteach Vocabulary. . .) that could assist in this process. The students in Quadrant A also need support in mathematics. Their solution strategies will likely be more concrete than others in the class. While it might not be the instructional goal for them to remain in this area, they will likely be more successful if they have the opportunity to initially use more concrete strategies such as direct modeling, drawing a picture, or using an invented algorithm.

Students in Quadrant B (lower left) lack proficiency in English, but have strong mathematical understanding. This mathematical background was probably built in their first language as this is the quadrant where recent immigrants who have had strong mathematics instruction in their native tongue are located. Quadrant B students may need strong instructional supports to understand the problem, but once they do, they can use more sophisticated strategies to solve it, a key difference from students in Quadrant A.

Quadrant C (upper right) students have greater proficiency in English, and while they may still need support, it will more likely be in reading and writing. This group of students does need support in mathematics, however. They will be more successful with concrete problem solving methods such as direct modeling and finding patterns.

Students in Quadrant D (lower right) are the ones who need fewer supports in English and are able to make abstract associations in mathematics. They will likely understand the problem at hand and can solve the problem in the specific as well as the general case. They may only need linguistic support in writing the justification of their solution.

## How to Use the Language Acquisition through Content Hierarchy

The classroom teacher can use the grid to differentiate instruction for a classroom of students who are diverse in both English language proficiency and mathematical skill. Strategies to help students understand the problem are found along the language or x-axis of the grid. The mathematics content or y-axis indicates strategies that students are likely to use when solving a problem. In general, students should be allowed to solve problems using the methods that make sense to them, but should also be exposed to more sophisticated (or abstract) solution strategies so their thinking can advance. The end of the lesson debrief is an ideal place for this type of exposure. Here, the teacher can select students to share their methods of solving the problem with the class. In fact, a rich sharing of ideas should occur at the close of the lesson when students from each quadrant share their problem solving strategies with the other students. (Hiebert, et al. 1997; Stevenson & Stigler, 1992; Marzano, 1998; Good & Brophy, 2003)

For example, assume that a teacher asks the students to solve the following problem:

> *A farmer put all her ducks and sheep in a pen. When she counted the heads, she tallied 20. When she counted the feet, they added up to 54. How many ducks and how many sheep did she have?*

A teacher could use the LATCH grid to differentiate instruction as follows:

**Differentiation for Quadrant A:** The teacher could help the beginning English speakers understand the problem by using pictures of the animals mentioned in the problem. Even the word pen can be misleading as many English learners will think of a writing instrument. Pictures of an animal pen would also need to be included. A simplified version using 3 of each animal could be depicted visually and the students asked to determine the number of heads and feet shown in the picture. This would allow the students in A to visualize what the problem is asking, and to solve it initially by using a direct model strategy (counting actual heads and feet). From here, they could make their own drawings or charts to solve the problem with larger numbers.

FIGURE 2

**CONCRETE**

Direct Model

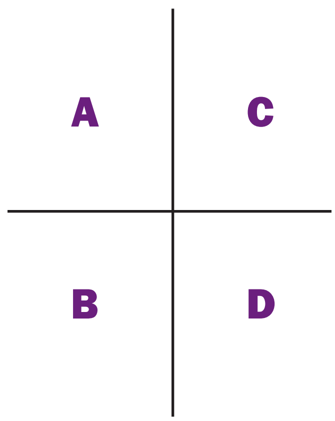
Draw a picture, diagram, table

Find a pattern

Solve using invented algorithm

Write number sentence

Solve using smaller numbers




Solve using standard algorithm

Use mental or relational math

Solve with variables

Graph an equation

Make generalizations

Write an equation or formula

Provide mathematical proof

**ABSTRACT**

- Students restate problem in own words
- Preteach Vocabulary, Word Wall, Math words
- Simplify language of problem, Discuss problem
- Change the problem context
- Student groups for language support, Think, Pair, Share
- Visuals, Pictures, Picture Dictionary
- TPR, Voice Intonation, Act Out
- Translation into primary language, Study Buddy

- Graphic Organizer, Charts, Grids, Webs
- Ask key questions – What do we know? What are we trying to find out?
- Teacher, students, read problem aloud
- Explain reasoning through Journal Writing,
- Students Write Their Own Problem
- Teacher, Text selected problem in written form without review
- Isolated problems such as on a standardized test which don't allow review

**Differentiation for Quadrant B:** Students could be introduced to the problem using the pictures as in A, and once they understood what was being asked, could employ large numbers. Particularly adept students could be asked to make a table showing the results for all even numbers between 54 and 64 and asked to look for a pattern. They could demonstrate their thinking through a chart or equation.

**Differentiation for Quadrant C:** Students would likely understand the problem, but be at a loss on how to solve it. It could be modified for this group by reducing the numbers to 8 heads and 24 feet. If they still have problems, they should be encouraged to solve the problem through direct modeling or drawing pictures.

**Differentiation for Quadrant D:** These students will need little if any support in understanding the question. After they solve the problem as stated, they should be challenged to construct an equation that would always work, no matter how many sheep and ducks were in the pen.

An assumption in the content strand is that students working at a more abstract level can solve a problem using concrete methods as well. However, this is not always the case, especially among teachers who have not learned mathematics using the concrete models. For them, the sequence can be in reverse order. This brings up three important points:

1) when instruction fails to include the models that underlie a concept, the students will not necessarily develop them on their own.

2) teachers need to know and understand the concrete models that underlie concepts so they can help students to use them to create conceptual understanding.

3) the opportunity to use non-linguistic representations (ie. concrete representations) increases student achievement (Marzano, Gaddy & Dean, 2000). Therefore they should be included in mathematical instruction.

The professional development of the LATCH model described here allows teachers to draw upon their previous knowledge of teaching and mathematics to develop a personal instrument for instructional differentiation. This provides teachers with a meaningful tool to use in instructional planning and as a reminder of strategies at their disposal to meet the needs of all the students in the classroom. It can help answer the question heard by teachers across the nation, How can I teach mathematics to a student who is not fluent in English?

## Field Test for LATCH Professional Development

The LATCH model was developed as an enhancement to the English Language Development Institute – Mathematics Content (ELDI-MC) summer professional development institute offered to Jr. High and High School teachers in Imperial Valley. The ELDI-MC curriculum was piloted in six sites across California, and a study was conducted to determine the effectiveness of ELDI-MC in increasing the knowledge of teachers about strategies to serve English Learners in the content area. All sites taught the same curriculum which consisted of English language development techniques and mathematics pedagogy to use in a pre-algebra course. The use of the LATCH technique was the major difference between the ELDI-MC curriculum taught at Site A and the other five sites. For Site A, LATCH was a half day session toward the beginning of the institute, but it provided a common language and context for later discussions of curriculum development and lesson modification.

A total of 120 teachers were pre-tested at the beginning of the 80 hour institute on their knowledge of instructional strategies for ELs. Test items posed common problems that might appear in a Pre-Algebra book and also asked teachers to elaborate on the kinds of modifications they could make to accommodate English learners. After participating in 80 hours of professional development provided by the respective institutes, these participants were presented similar problems in a post test. A teacher's score was determined by a count of the viable EL strategies that they offered in each test question. Table 1 shows the mean pre and post scores for each of the six sites. While this measure was not designed specifically to determine the impact of the LATCH model, the growth shown by teachers from site A (where LATCH was implemented) was the highest among the six sites. Using a matched-pair t confidence interval, the estimated mean difference in test scores is 4.285 points per site, with a margin of error of 1.528 for 95% confidence, i.e. the 95% interval is (2.757, 5.813). These two results, site A with the highest gain and the gain being outside the confidence interval, suggest that the LATCH model is an effective tool for helping teachers understand how to modify instruction for English learners. While the growth for teachers at Site A was significantly different (p-value < .001), further research should be conducted to determine if the results are consistent across groups and to document which aspects of LATCH improve teacher understanding.

**TABLE 1:** ***Pre- and posttest results for ELDI-MC Institutes.***

| Site | N | Pre Test ELD | Post Test ELD | Change |
|---|---|---|---|---|
| Site A * | 17 | 7.53 | 13.59 | +6.06 |
| Site B | 23 | 5.39 | 8.3 | +2.91 |
| Site C | 24 | 3.88 | 8.67 | +4.79 |
| Site D | 23 | 5.04 | 7.26 | +2.22 |
| Site E | 24 | 5.04 | 10.33 | +5.29 |
| Site F | 9 | 5.78 | 10.22 | +4.44 |

## Conclusion

This paper presented a response to the challenge faced by mathematics teachers of how to address the range of both mathematical and linguistic proficiencies of their students. By using the Language Acquisition through Content Hierarchy (LATCH) instructional tool, teachers identify strategies that integrate both mathematical and linguistic development. These strategies can be used to differentiate instruction and therefore increase access to powerful mathematics instruction for all students, including English learners.

We believe the LATCH model can be readily adaptable to mathematics professional development sessions. If the teachers or the mathematics professional developer do not have a strong background in English Language Development, it can be co-presented with someone who does. It should be stressed, however that both facilitators be present and participate throughout the session in order to highlight how both ELD and mathematics can be integrated. Also, a LATCH session can be an excellent format to offer a joint professional development session between teachers who work primarily with language learners and mathematics teachers. The session draws upon the expertise of each group and can initiate rich discussions and increase understanding.

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# The Courage To Be Constructivist Mathematics Leaders

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**ABSTRACT:**
*In this paper, we consider The Teaching Principle outlined in The Principles and Standards for School Mathematics (NCTM, 2000) and the importance of teacher learning and continuous development in mathematics learning and pedagogy. We pose the question, "How might a professional development experience that invites teachers to become 'autonomous learners' (NCTM, 2000, p. 5) be organized?" In responding to that question, we begin, as narrative researchers, by sharing a story of collaboration in planning a summer institute about mathematics for K – 3rd grade teachers. We then unpack this story of the planning and implementation of the institute thinking about the tenets of constructivism, as outlined by Brooks and Grennon Brooks (1999), and about how these tenets contribute to the development of autonomous teacher learners.*

The Principles and Standards for School Mathematics (NCTM, 2000) describe the importance of teacher learning and continuous development. The Teaching Principle states, "Teachers need to increase their knowledge about mathematics and pedagogy, learn from their students and colleagues, and engage in professional development and self-reflection" (p. 4). While many professional development activities inform teachers about mathematics or the teaching of mathematics, they may not attend to the importance of teachers learning from one another and engaging in self-reflection. In this paper, we consider the role of the mathematics leader in planning professional development experiences which honor teachers learning from one another and engaging in self-reflection. When professional development experiences invite teachers to become "autonomous learners…eager to figure things out on their own, and flexible in exploring mathematical ideas" (NCTM, 2000, p. 5) teachers enact the stance of a learner both within the professional development activity itself and within their lives in classrooms and schools. We address the question, "How might a leader organize a professional development experience that invites teachers to become 'autonomous learners' (NCTM, 2000, p. 5)?"

In a 1999 article in Educational Leadership, Brooks & Grennon Brooks wrote about teachers' courage to be constructivist in their teaching. Here, we invite mathematics leaders to be courageous and implement constructivist tenets in their planning and delivery of professional development. As narrative researchers, we start by sharing a story of collaboration in planning a summer institute about mathematics for K – 3rd grade teachers. We then unpack this story of the planning and implementation of the institute thinking about the tenets of constructivism, as outlined by Brooks and Grennon Brooks, and about how these tenets contribute to the development of autonomous teacher learners.

## Story of Collaboration

In the province of Saskatchewan, Canada, until recently, there has not been a culture of measured accountability around student achievement in mathematics. As this culture shifted in the province, in response to a greater emphasis on national and international student achievement comparisons in mathematics, curriculum leaders from geographically-connected school divisions in and around Saskatoon gathered in conversation about the early identification of children experiencing delay or difficulty with numeracy development and about enhancing teachers' numeracy and mathematics education practices within classrooms. Having switched from an earlier focus on literacy to one on numeracy, the network of curriculum leaders invited us, professors from the University of Saskatchewan, to join them in exploring professional development possibilities for early numeracy teachers.

We spent nine months in conversation with the network of leaders (called the planning team from here on in) focused on planning and implementing a meaningful summer institute about mathematics for K – 3rd grade teachers. At one meeting in March we, the two authors, proposed the following agenda for a two–day summer institute which reflected the conversation:

| August 16, 2004 | |
|---|---|
| 8:00 – 9:00 | Registration and Breakfast |
| 9:00 – 9:20 | Opening Remarks & Welcome |
| 9:20 – 9:45 | Whole Group Session: The Value of Professional Conversation |
| 9:45 – 10:55 | Professional Conversation Groups – Meeting #1 |
| 11:00 – 12:30 | Key Note Talk #1 |
| 12:30 – 1:15 | Lunch |
| 1:15 – 2:00 | Professional Conversation Groups – Meeting #2 |
| 2:00 – 3:30 | Key Note Talk #2 |
| 3:30 – 4:15 | Professional Conversation Groups – Meeting #3 |
| 4:15 – 4:45 | Facilitators' Meeting |

| August 17, 2004 | |
|---|---|
| 8:00 – 9:00 | Breakfast |
| 9:00 – 10:00 | Whole Group Session: Teacher Identity |
| 10:00 – 10:15 | Break |
| 10:15 – 11:45 | Key Note Talk #3 |
| 11:45 – 12:30 | Lunch |
| 12:30 – 1:30 | Professional Conversation Groups – Meeting #4 |
| 1:30 – 3:00 | Key Note Talk #4 |
| 3:00 – 3:30 | Whole Group Session: Closure |
| 3:30 – 4:00 | Continuing the Conversation |

This agenda purposefully included space for professional conversation (Glanfield, 2003) around teaching and learning mathematics. As the planning team discussed this agenda in the meeting, we talked about the abundance of professional development experiences that highlight expert knowledge and leave teachers feeling deficit in both their mathematical knowledge and their teaching practices; and we talked about the features of professional development that encourage ongoing, interactive, mathematics teacher development for teachers who are not mathematics specialists. Although the conversation made sense in the moment, for many people at the table the agenda was a step away from professional development they had typically experienced.

Shortly after the meeting we received an email from one of our colleagues on the planning team:

> I would like to share a concern I have after reflection on the weekend. I was trying to put myself in the shoes of a young mother who has paid $175.00 and arranged day care for her little ones to attend the institute. She then spends till 11:00 a.m. in children's literature and discussion groups — almost the entire morning. Will we have lost her? Do we need to get input from the keynote speaker more quickly than this?
>
> I worry that discussion groups at this stage might be a pooling of ignorance. I do not mean to sound disrespectful, but I feel that might be an appropriate way to describe what my contribution at this stage might be, without a sound philosophical basis to use for the math discussion.
>
> These are just some musings that I offer from one perspective. (email, March 16, 2004)

In response, we invited our colleague to suggest how she would rearrange the schedule to reflect her perspective expressed in the email.

Our colleague's response to our invitation was:

> Day one: Plug the keynote speaker in right after the opening remarks, and then go with the optional plan — share the value of professional conversations as well as spend time with the professional conversation groups. I think the conversations will be richer working with info from both the keynote speaker and the value of professional conversations.
>
> After lunch start with the keynote speaker — we will have been involved in professional conversations during

lunch anyway — and then perhaps move to professional conversation groups. It would be helpful to end with a half hour recap with the keynote speaker perhaps sharing some gems from the conversations he and his co-presenter have heard in the conversations.

I'm still thinking about day two, and I guess it will depend in large part on how day one evolves. (email, March 16, 2004)

Learning from one another in the exchange, we shared the following thoughts with our colleague in response to her suggestion:

As we've been thinking about this institute, we would really like to model an approach that reflects the constructivist theory of learning.

In framing our comments, we refer to a wonderful article that we read the other day, "The Courage to be Constructivist" (written by M. G. Brooks and J. Grennon Brooks, Educational Leadership, November 1999, pp. 18-24). In the article, the authors identify five central tenets of constructivism. Two of the tenets are:

1. that constructivist teachers seek and value students' points of view. Knowing what students think about concepts helps teachers formulate classroom lessons and differentiate instruction on the basis of students' needs and interests, and

2. that constructivist teachers structure lessons to challenge students' suppositions. All students, whether they are 6 or 16 or 60, come to the classroom with life experiences that shape their views about how their worlds work. When educators permit students to construct knowledge that challenges their current suppositions, learning occurs. Only through asking students what they think they know and why they think they know it are we and they able to confront their suppositions.

So, when we were discussing what the institute schedule might look like, we really wondered how we might help the keynote speaker come to know his "students" points of view. It was in this notion, that we considered the nature of the whole group sessions and then the professional conversation groups (PCG). In the first PCG experience, teachers would be sharing, essentially what they know about who they are as teachers of mathematics and their understandings of mathematical ideas. We hope, that in circulating among the professional conversation groups, the keynote speaker will come to make sense of what the teachers know and who the teachers are. We planned for the first hour or so in the groups because of the number of people in the group. For example, if there were 15 people in the group, one hour means only about 4 minutes per person to share. . . We believe this conversation and the act of writing in the journal (introduced in the whole group session) will help teachers become aware of what they know and who they are as mathematics educators at this point in time.

When the keynote speaker begins to talk then about his ideas, we are hopeful that he will be able to "challenge his students' current suppositions" so that "learning occurs" (to quote Brooks & Grennon Brooks). The movement back and forth between the keynote talks and talks with colleagues will help teachers to regularly 'reconnect' with their own thinking. (email, March 24, 2004)

From the email, we recognized there was greater dissonance with this proposed new structure for the professional development experience than we initially perceived. We returned to the next planning team meeting looking forward to further conversation about the proposed agenda. Within the team, we found a need to ask each other to say more about our beliefs about teacher learning and to go more deeply into our own thinking about valuable professional development experiences. Without consciously intending to do so in this conversation, we answered the questions for one another, "Who am I as a mathematics leader? What do I do as a mathematics leader? Why do I do what I do as a mathematics leader?" As we did this, we realized that not only was it important that we make explicit to each other our own thinking on which our proposed agenda was based, but that we make explicit to the teachers who would be participating in the summer institute why we planned the program in the way that we did. Out of this conversation we agreed on a Program Rationale that we would share in all advertisements for the summer institute, "Coming to Know: Numeracy in the Early Years:"

### Program Rationale

This two-day institute has been purposefully structured to promote and support teacher knowledge. We strongly believe teachers are holders and constructors of knowledge and come to this institute knowing much about early numeracy and about teaching mathematics to young children. We want this time to be an opportunity for educators to:

- reflect on their beliefs and practices,
- puzzle over those aspects of mathematics teaching which cause them tension or uncertainty,
- affirm and extend their understanding within a knowledge community of fellow educators,
- develop a support network,
- consider their identities as mathematics teachers.

We will strive to honor constructivist principles of learning which are foundational in the design of classroom experiences for children — principles such as beginning with what the learner knows, honoring the learner's lived experiences, connecting what is known with what is unknown, promoting active engagement — in the structure of this two day institute for educators.

As the planning team collectively reflected on our Program Rationale, we recognized that we wanted to be courageous and embrace the constructivist principles of learning in our summer institute. As mathematics leaders we realized that we constantly expect teachers to embrace and enact constructivist principles of learning in their classrooms and yet we do not see these very same principles embraced in mathematics teacher professional development.

While the Program Rationale and proposed agenda made sound philosophical and pedagogical sense to the planning team as a collective, we were all aware of the tension and unease that some individual team members felt. Not only did team members have to trust constructivist principles of learning, we also had to trust that teachers would see value in this professional development experience. Thinking about our colleague's wonders and concerns, the planning team had to further trust that we would not "lose teachers," that teachers would have knowledge to share, that they would come to the institute with questions arising from their own practice, and that they would feel comfortable posing their questions. This was a courageous moment for the planning team as we stepped away from what we'd known as mathematics professional development into something many of us had not yet experienced. Once the team made the decision to go ahead, we carefully planned the activities for the institute, in alignment with the Program Rationale, to promote and support teacher learning. Following, we describe the types of activities that the planning team used to enact the program rationale for the summer institute.

## Types of Institute Activities

**Whole Group Sessions.** The whole group sessions were a place in which all participants came together in one large professional community. They were a place in which personal reflection and professional conversations were framed and initiated, using children's literature and metaphor(s) from that literature.

As an example, on the first morning, after introducing the value of professional conversation (Glanfield, 2003), we read the story, *Wilfrid Gordon MacDonald Partridge* (Fox, 1984), to the large group. In this story, a young boy named Wilfrid Gordon lives next door to an "old people's home." He is friends with all of the people who live there but his favorite person is Miss Nancy Alison Delacourt Cooper because she has four names just as he does. One day he hears his parents saying that Miss Nancy has lost her memory. This prompts Wilfrid Gordon to set out to discover what a memory is. In asking his elderly neighbors what a memory is, Wilfrid learns much about memories. A memory is "something warm," "something from long ago," "something that makes you cry," "something that makes you laugh," "something as precious as gold" (unpaginated). With these ideas in mind, he then puts together a basket of his most precious treasures and presents them to Miss Nancy. As she explores each of Wilfrid's items, Miss Nancy recalls a corresponding memory of her own. With Wilfrid Gordon's help, Miss Nancy's memory is found!

In response to the story, we invited participants to recall corresponding memories of their own relating to numeracy teaching and learning — possibly a 'warm' memory of a child's learning or growth, or of their own; a 'long ago' memory of their beliefs and practices when they began teaching numeracy; a sad memory of a challenge or difficulty they experienced in their teaching or with a child's learning; a happy memory of a success or discovery they had made, or observed a child making; a memory they cherish from their lives as numeracy teachers which is as 'precious as gold' to them. We gave them time within the whole group setting to individually reflect and then depict their memory(ies), in their institute journals, through words, pictures, symbols, or schema. The memories they pulled forward then served as an entry point to their first professional conversation group and their conversation about their knowledge as mathematics educators.

There were many reasons the planning team chose children's literature as a way to frame the professional conversations. Literacy had been a central focus in each of the school divisions for a significant period of time and we knew teachers had strong knowledge, skills, and confidence in regard to literacy practices. We also knew these teachers, typically, did not have the same confidence in their mathematics knowledge and teaching practices. As expressed in the Program Rationale, the planning team wanted to start with something familiar, something teachers knew, connecting what was known with what was unknown (or, perhaps, less comfortable).

Further, reading a story together creates an experience that everyone then shares. It provides something that each individual at the institute has in common; something that each individual can reflect upon, make connections to, work outward from. Literature appeals to people on an affective level as it evokes an emotion; it creates an opening — a desire to know — which the intellect can then fulfill. Literature is rich with metaphor. It gives people a new way of perceiving or thinking about something because it reframes it. Thinking about 'a numeracy teaching life' as 'a memory basket' — a collection of memories that are current and long ago, that evoke laughter and tears, that are precious for what they teach us — teachers move away from seeing themselves in singularity to seeing themselves in their multiplicity and their complexity. Teachers move away from thinking of themselves as good or bad, knowing or unknowing, experienced or inexperienced, to seeing themselves as individuals who are "shaping a professional identity" (Connelly & Clandinin, 1999) from the many educative moments of their lives. In carefully selecting children's literature for the whole group sessions, the planning team believed we would bring the conversations easily and naturally to teacher knowledge, to identity, to community, and to reflection and wonder.

*Wilfrid Gordon MacDonald Partridge* and the metaphor of a memory basket continued to be woven into professional conversation throughout the first day. We opened day two with a whole group session as well, this time using the story Mirror (Day & Darling, 1997) to deepen our thinking and our conversation around teacher identity. The metaphor of a mirror helped teachers to think about how who they are as early numearcy teachers and learners is mirrored back to them by the children in their classrooms, the children's parents, and their colleagues. It also helped teachers to think about what they mirror to others about who they are as teachers and learners of early numeracy. The questions the team addressed in our planning sessions, "Who am I as a mathematics leader? What do I do as a mathematics leader? and Why do I do what I do as a mathematics leader?", were reframed as, "Who am I as an early numeracy teacher? What do I do as an early numeracy teacher? and Why do I do what I do as an early numeracy teacher?" and were explored explicitly with teacher participants. We ended day two, and the summer institute, with a final whole group session and a story entitled, I Wish I Were a Butterfly (Howe, 1987), another selection about identity; one which reminded us to celebrate the gifts we have as early numeracy teachers and to consider how we will share those gifts with our students and within our professional communities.

**Professional Conversation Groups.** Conversation within the professional conversation groups flowed naturally out of the whole group sessions. They were a place in which teachers could tell stories of their experiences as numeracy teachers and explore their own unfolding knowledge. "If one's knowledge is to be useful, one must feel free to examine it, to acknowledge one's confusions, and to appreciate one's own ways of seeing, of exploring, and of working through to a more satisfactory level" (Duckworth, 1997, p. 3). We wanted these spaces to be a place for teachers to talk about what they had figured out in their teaching and to puzzle over the questions that persisted for them. We wanted them to be a place where teachers could learn from one another.

The team planned a facilitation guide for the professional conversations and we arranged to have a facilitator, a curriculum leader, within each group of approximately ten teachers. Because many of the teacher participants did not know one another, we wanted to have a way to begin the professional conversations and an individual who could facilitate introductions and the development of a sense of community within the group.

As an example, in the first professional conversation group after sharing the story *Wilfrid Gordon MacDonald Partridge* as a whole group, teachers introduced themselves, responding to the questions, "Who am I?, What do I teach?, and What brought me to this summer institute?" Facilitators provided space to talk about and clarify the purpose of the professional conversations. Teachers then partnered with someone in the group they didn't know and shared the memories that had been evoked for them in the whole group session. Following this, teachers individually made note of the things they felt they knew about early numeracy teaching and the things they were wondering about and hoping to know more about by the end of the institute. Together as a group, teachers shared and discussed their knowledge and their hopes for expanding that knowledge. Facilitators charted key points from the conversation so that this information could guide the keynote talks and professional conversations to follow.

The planning team encouraged facilitators to see the facilitation guide as exactly that — just a guide — and to let their group of participants shape the way the conversation unfolded or the direction it took. The facilitators used their teaching knowledge and skills in enacting principles of learning within their group such as beginning with what the learners know, honoring the learners' lived experiences, connecting what is known with what is unknown, and promoting active engagement. The purpose of the professional conversation groups was always to have teachers exploring their own 'coming to know.'

**Keynote Talks.** During our planning sessions, the team talked a lot about the positioning of a keynote speaker within the summer institute. We did not want the institute to be a professional development experience in which a keynote speaker was seen to be the holder of knowledge and teachers the receptacles of that knowledge. The team did not want this to be a professional development experience where teachers listened and processed passively while a speaker talked. We invited a speaker who would join us as a member of our professional community, who would disrupt our ways of thinking about mathematics and mathematics teaching and learning, who would stimulate questions and wonders, and who would challenge us to see new possibilities. In the invitation the team extended to the keynote speaker we shared our intentions, the program rationale, and the plans for the two days.

The day before the institute started, a portion of the team met with the keynote speaker and shared the children's literature that had been selected and the facilitation guide for the professional conversation groups. Together we talked about how the speaker would move in and out of the professional conversation groups throughout the institute to get to know the teachers and to get a sense of their teacher knowledge and their wonders. We agreed that charted information from the professional conversation groups would be brought into the keynote talks and shared with the whole group to give the speaker a sense of where to begin and where to focus the talk.

Keynote talks were a second type of whole group session that shaped the professional conversations that followed them. After each talk, teachers had the opportunity to go back into their professional conversation group to discuss thoughts that were emerging for them, connections they were making, questions that were arising, and common understandings they were developing. There was a reciprocal sense-making as teachers moved between whole group sessions and professional conversations with each space influencing the other.

**Continuing the Conversation.** This element of the program provided an opportunity for all the teachers from each school division to gather together to discuss how they might continue their conversation about numeracy teaching and learning throughout the rest of their school year. It was a place to determine how they could continue to support one another's learning. While the institute was a stimulus, the planning team knew the important work was going to happen in classrooms as new ideas were enacted with children.

## Unpacking this Story of Collaboration

In reflecting on the program format for the summer institute, *Coming to Know: Numeracy in the Early Years*, we believe there are a couple of elements that were particularly significant in distinguishing this summer institute from other professional development experiences. There was a balance between time spent by teachers in professional conversations and time spent with a speaker in whole group talks. Approximately half of the participants' time was spent engaged in professional conversation, in the large community or within their smaller groups, while the other half was spent in whole group talks with the keynote speaker or engaged with children's literature. Further, the first whole group talk with the keynote speaker did not occur until late morning on the first day of the institute, rather than being first on the agenda of the institute. This scheduling speaks to Brooks & Grennon Brooks (1999) five tenets of constructivism:

> …first, constructivist teachers seek and value students' points of view…second, constructivist teachers struc-

> ture lessons to challenge students' suppositions…third, constructivist teachers recognize that students must attach relevance to the curriculum…fourth, constructivist teachers structure lessons around big ideas, not small bits of information…finally, constructivist teachers assess student learning in the context of daily classroom investigations, not as separate events. (p. 21)

In our unpacking, we have substituted the phrase "constructivist leaders" for the phrase "constructivist teachers" in each of the tenets.

### Constructivist Leaders Seek and Value Teachers' Points of View

Within the program of this summer institute, the professional conversation groups provided the space for teachers' points of view to be expressed. This is not typical in most professional development experiences. Generally, there is no planned space for teachers to describe their lived experiences nor is there generally space to connect teachers' lived experiences and their points of view with the content of the keynote presentations. Teachers who participated in the summer institute saw that their points of view were valued when the keynote talks and subsequent professional conversations were built upon what they, in their first professional conversation, said they knew and what they said they wanted to know about early numeracy teaching.

### Constructivist Leaders Structure Activities to Challenge Teachers' Suppositions

Teachers' questions and ponderings, expressed in the professional conversation groups, framed the keynote talks. The keynote speaker focused his presentations around what the teachers knew and, through his interactions with teachers in his talks, he asked teachers to question what they knew and how they knew it. For example, one of the mathematical topics that teachers raised in their professional conversations was that of children being explicitly taught the procedure to add or subtract. The keynote speaker indicated that, in his classroom, he would have children working in small groups to solve problems around addition and subtraction. By having the children share their solutions to the problems, all children in the class would come to know there are multiple ways in which one can add or subtract. This notion of multiple procedures challenged many teachers' suppositions about teaching the "correct way" to add or subtract. In this way, through his continued interactions with teachers, the keynote speaker challenged many suppositions about early numeracy and what it means to teach and learn mathematics in the institute.

### Constructivist Leaders Recognize that Teachers Must Attach Relevance to the Curriculum

Following each keynote talk teachers participated in a professional conversation group in which they were able to talk about what they had heard in the keynote talk, how what they heard in the talk could translate into their practices, and what questions continued to persist for them. For example, teachers talked about how they might structure their classrooms in order to encourage the type of problem solving that would encourage each child, or group of children, to develop their own solutions. Teachers also talked about the types of questions that they would have to learn how to ask in order to invite children to share their solutions. In addition, teachers talked about focusing their teaching around number sense, the sense of "ten-ness," and the importance of spatial visualization for young mathematics learners. These conversations lead to further questions around student assessment, talking with parents, and reporting student learning. In this moving back and forth between keynote talks and professional conversations, teachers were attaching relevance to the curriculum of the institute and the curriculum being lived in their own classrooms with children. In other words, teachers were beginning to re-imagine their early numeracy classrooms in light of the sense they were making from having their long-standing suppositions challenged and in light of the way they were now looking to big mathematical ideas instead of the multitude of mathematics objectives cited in the mandated curriculum.

### Constructivist Leaders Structure Professional Development Around Big Ideas

The rich metaphors (the memory basket, the mirror, and the butterfly) depicted in the selected children's literature reflect the big idea around which the institute was organized, that of early numeracy teacher identity. Flowing from our numerous conversations as a planning team, we recognized that the summer institute was not just about teachers knowing mathematics or the pedagogy of mathematics but that it was also about who they saw themselves as being as teachers of mathematics – and as teachers outside of mathematics, about the complexity of their particular classrooms and the communities in which they teach, and about the impact and complicity of their teacher judgment in each and every decision and action they take (Davis, Sumara, & Luce-Kapler, 2000). As teachers embraced the multiple metaphors, they were given an opportunity to move away from seeing themselves in singularity as early numeracy teachers following a prescribed curriculum to seeing themselves with multiple identities in that role – as teachers, as learners, as curriculum-makers, as supporters, as risk-takers, as knowing, as wondering. They were given the opportunity to reflect on these multiple identities as situated within the complexity of their classrooms, and they were invited to make, with an ownership for their complicity, teacher judgments and decisions within their early numeracy classrooms.

As a planning team, we believed that teachers participating in the summer institute, through reflecting on their lived experiences and laying those experiences alongside those of other teachers and of the keynote speaker, would come to see themselves as individuals who are "shaping a professional identity" (Connelly & Clandinin, 1999) — individuals with a strong sense of who they currently are as early numeracy teachers, of what they do and of the suppositions underlying what they do, of what is yet possible for them and of new suppositions to consider, and of who they want to become as early numeracy teachers.

## Constructivist Leaders Assess Teacher Learning

Mathematics leaders on the planning team were the facilitators of the professional conversation groups. Through their participation as facilitators in the institute they came to see the importance of assessing teacher learning in the context of teachers' daily unfolding practice. Throughout the two days in the professional conversation groups, the leaders observed that as teachers shared who they were and who they were becoming, thoughts about implications for practice, and emerging wonders, the leaders could think about the assessment of teacher learning as "enlarging the space of the possible" (Sumara & Davis, 1997, p. 303). That is, the mathematics leaders saw themselves as assessing teacher learning by listening to teachers' stories about the implementation of new practices and about how teachers were making sense of the multiple identities they now recognized they were living out. The leaders took on a role, similar to that of the keynote speaker at our institute, to find out what teachers within their school divisions knew, what suppositions they were acting on, and to consider ways in which to challenge, or affirm, teachers' suppositions. The leaders took responsibility, beginning with "Continuing the Conversation" at the institute, to structure further activities to keep professional conversation an integral part of the life of a classroom teacher engaged in "daily classroom investigations" (Brooks & Grennon Brooks, 1999, p. 21).

In interacting with one another, with their colleagues and with the children in their classrooms, we believe teachers consciously generate new interpretations of curriculum and new practices, and link curriculum and practice together in new ways. It is through being engaged with these interactions and through listening to teachers' stories of these interactions that mathematics leaders are able to assess teacher learning and to determine how to provide continuous professional development for teachers that will increase their knowledge about mathematics and pedagogy, enable them to learn from their students and colleagues, and promote self-reflection and ownership for learning.

## Conclusion

The Professional Standards for Teaching Mathematics suggest that teachers should be given the opportunity to "examine and revise their assumptions about the nature of mathematics, how it should be taught, and how students learn mathematics; reflect on learning and teaching individually and with colleagues; and participate actively in the professional community of mathematics educators" (NCTM, 1991, p. 160, 168). Like Clark and Florio-Ruane, we believe "the time has come for a radical shift in thought and action in support of sustainable teacher learning and teacher research. This shift is needed to engage teachers as reasoning and responsible professionals in the process of refining their knowledge" (2001, p. 6). This shift for us requires a shift to tenets of constructivism enacted within professional development experiences.

This summer institute, *Coming to Know: Numeracy in the Early Years,* was a courageous attempt by mathematics leaders to embrace NCTM's (1991, 2000) teaching and learning principles by creating a professional development experience which provided a space for teachers to share and explain their thinking about teaching mathematics in the early years in authentic conversation (Clark, 2001). "[This] reconstitution of experience through personal narrative allow[ed] for safe exploration of uncharted territory and imagining the possible" (Clark & Florio-Ruane, 2001, p. 12). This institute began a process of continuous professional development; a process continuing to be lived in teachers' daily classroom work and in their ongoing conversations with colleagues about the "possible."

To create a professional development experience for teachers that positioned teachers as autonomous learners in "control of their own learning" (NCTM, 2000, p. 5), we, too, as mathematics leaders had to reconstitute our own sense of what it means to live out leadership in ways that reflect the tenets of constructivism (Brooks & Grennon Brooks, 1999), to explore uncharted territory in professional development experiences, and to imagine what is possible for continuous teacher learning within a community of mathematics educators.

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# When "One Shot" Is All You've Got:
## *Bringing Quality Professional Development to Rural Mathematics Teachers*

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**ABSTRACT:**
*Criteria for "powerful" professional development in mathematics have been well documented by researchers and organizations. Unfortunately, barriers of distance, time, and expense impede rural teachers from attending conferences, workshops, and college courses built on these recommendations. This paper proposes a professional development model that has successfully addressed these criteria, resulting in change in teacher knowledge, skill, and practice, with positive results for student learning. In particular, the model is analyzed against five curricular and structural criteria identified by research as essential for effective professional development: a focus on* ***content knowledge****, the use of* ***active learning*** *strategies,* ***coherence*** *with other learning experiences, sufficient* ***duration*** *of the experience, and* ***collective participation*** *by teachers.*

The defining characteristics of "ideal" or "powerful" professional development in mathematics and science have been well-documented by researchers and organizations who publish recommendations for high-quality professional development (Easton, 2005; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Schwan Smith, 2001). These characteristics have in some cases been identified through repeated experience and hands-on expertise, while others arise from research efforts ranging from case studies to meta-analyses of dozens of programs. Often, an underlying goal of these recommendations is the establishment of an embedded culture of professional development based on the individual school climate; enacting this culture frequently depends on ongoing collaboration among teacher groups (Easton, 2005).

In an urban or suburban school district, it is possible to embed professional development if teachers, administrators, and professional development designers and facilitators commit to creating and following through on appropriate experiences. But what if the district in question includes only one school? What if that school employs only one or two secondary mathematics teachers? What if the nearest colleague of similar discipline and grade level is fifty miles away, as is the case in many rural schools? Ensuring collective participation and ongoing collaboration among teachers within a content area becomes not merely challenging, but nearly impossible. The questions posed above suggest the need for an alternative model that incorporates the key characteristics of effective professional development while respecting the limitations and restrictions imposed by rural realities. This paper proposes a professional development model that has successfully addressed these characteristics, resulting in change in teacher knowledge, skill, and practice, with positive results for student learning.

In 1999, reviewers for the National Research Council called for research to "determine the efficacy of various types of professional development activities, including pre-service and in-service seminars, workshops, and summer institutes....[in] order to identify the processes and mechanisms that contribute to the development of teachers' learning communities" (Bransford, Brown, & Cocking, 1999, p. 240). In response, Garet, Porter, Desimone, Birman, and Yoon (2001) conducted a large-scale study of over 1,000 teacher participants in Eisenhower-funded professional development programs. Five characteristics of professional development emerged that have "significant positive effects on teachers' self-reported increases in knowledge and skills and changes in classroom practice" (p. 916).

The first three characteristics, related to the professional development curriculum, include a focus on *content knowledge*, the use of *active learning* strategies, and *coherence* with other learning experiences. In addition, the researchers identified key structural aspects that contribute to the success of professional development activities. These include the *duration* of the activity (in terms of both contact hours and span over time) as well as the "*collective participation* of groups of teachers from the same school, department, or grade level, as opposed to the participation of individual teachers from many schools" (Garet et al., 2001, p. 920).

## Rural Realities

Loucks-Horsley et al. (1998) consider "equal access for all teachers to quality professional development" (p. 192) to be a critical issue. They note that equity in professional development is not merely about offering equal access to opportunities; equity also encompasses the design and content of professional development experiences. High-quality professional development ensures that all teachers are fully engaged and learning and that ultimately they will be able to provide the same experiences for their students.

Unfortunately, district-wide staff development with a content focus is unrealistic in a small rural district where an entire content discipline at several grade levels may be covered by one teacher. The lone mathematics teacher may find support within her/his own building or district for everyday matters involving students, parents, classroom management, and general instructional practices. But guidance in the tasks of a mathematics educator—locating and designing worthwhile mathematical tasks, orchestrating meaningful discourse, analyzing students' mathematical thinking, and using tools and alternative methods to present concepts (National Council of Teachers of Mathematics, 1991)—is more difficult to find.

Seeking out such guidance and accessing outside resources presents another challenge. Barriers of distance, time, and expense impede rural teachers from attending conferences, workshops, and college courses offered in more populated areas. Furthermore, whereas new ideas and practices adopted by teachers in larger districts tend to "trickle down" into the awareness of their colleagues through casual conversation or formal dissemination, there is no such potential for the lone rural teacher.

Colorado is a prime example of a state caught in a rural-urban tension. Based on 2000 census estimates, nearly 80% of the state's population of more than four million resides in the counties that include the Denver metro area and the satellite cities stretching from Fort Collins to Pueblo. The remaining 20% are spread across vast reaches of mountains, prairies, and near-desert terrain. The urban center of Colorado offers multiple opportunities for teachers to increase their mathematics content knowledge, experience new instructional and assessment strategies, and learn how to implement new curricula. However, teachers in rural regions can rarely afford the time or expense of participating in site-based urban opportunities.

Professional development in Colorado became a critical issue in the late 1990s as the state formally implemented a new testing and accountability system based on recently revised standards. Along with defining a body of required content knowledge, the Colorado State Assessment Program (CSAP) called for assessment of students' mathematics knowledge through open-ended problems and performance tasks. Teachers across the state became concerned about teaching appropriate content and emphasizing reasoning, problem solving, and communication. In order for new standards to make a difference, they must be accompanied by professional development that focuses on procedures for implementing standards (Guskey, 2005). The inception of the CSAP served as a powerful impetus to develop and deliver professional development built around the new standards and assessment criteria.

The five largest universities in Colorado are all located in the highly populated north-south corridor bracketing Denver. Given that the majority of the teacher population is located within commuting distance, outreach to rural communities has not been a primary focus of those institutions. Mathematics educators at the University of Northern Colorado in Greeley (UNC) were concerned about including rural mathematics teachers in the reform efforts sweeping the state. UNC had previously experienced success in working at a distance with rural mathematics teachers in northeastern Colorado. As an experiment, two faculty members (the author and a colleague) determined to improve upon those efforts by bringing on-site professional development to teachers in the mountain and mesa communities of western Colorado. The result was the Western Slope Project (WSP), a two-year program for rural mathematics teachers designed to enhance their content knowledge, improve their ability to recognize and integrate mathematical processes, and provide them with alternative assessment strategies. Supported by higher education Eisenhower funds, the project ultimately sought to improve students' learning experiences and prepare them for success on the CSAP exam.

## A Professional Development Model for Rural Mathematics Teachers

As an intervention directed specifically at rural mathematics teachers, the Western Slope Project (WSP) was challenged to creatively incorporate research-identified criteria of high-quality professional development in a setting that resists implementation of those criteria. On a more practical note, the first design challenge was to find a way to assemble a group of isolated teachers whose districts spanned half the state of Colorado. Our solution was to bring the program to the teachers. Rather than housing WSP at the University of Northern Colorado, we collaborated with the privately operated Colorado Mountain College system to provide dormitory rooms, meals, and classroom and computer lab space at its Leadville and Glenwood Springs campuses, both in rural western Colorado and over 150 miles from our home campus.

At those locations and with the assistance of Colorado Mountain College staff, we offered credit-earning courses during a two-week summer institute and two academic year workshops. Many professional development experiences have been similarly structured; the Western Slope Project was unique in the demographics of our audience and the framework we created to address their needs, maximize their engagement, and embed accountability into their experience. One of the critical issues in designing professional development is the need to "recognize, study, and apply the knowledge base of professional development theory and practice" (Loucks-Horsley et al., 1998, p. 206). The following discussion matches key components of the Western Slope Project against the criteria for effective professional development identified through research by Garet et al. (2001) and describes the means by which we adapted these general recommendations to a rural context.

### CRITERION 1: CONTENT KNOWLEDGE

Research has consistently confirmed the importance of a content focus in effective professional development (Cohen & Hill, 1998; Garet et al., 2001; Kennedy, 1998). This finding is reflected in the professional development standards of national organizations. Cohen and Hill (1998) promote the use of curricular materials in professional development experiences as one way to directly affect teacher content knowledge and enhance student learning. Such efforts also enhance teachers' pedagogical content knowledge, or "knowledge about how students learn subject matter knowledge" (Kennedy, 1999, p. 4). Furthermore, Kennedy claims that "programs that focus on subject matter knowledge and on student learning of particular subject matter knowledge are likely to have larger positive benefits for student learning" (1999, p. 4).

Western Slope curriculum planning began with a needs assessment conducted with rural mathematics teachers in the target region, comprised of thirty-nine rural districts in western and southwestern Colorado. District superintendents and directors of rural BOCES (Boards of Cooperative Educational Services), sensitive to the limited professional development available locally for their mathematics teachers, enthusiastically supported our data collection efforts. As expected, concerns about imminent changes in state-mandated mathematics testing brought assessment to the top of the needs list. Other areas of need included appropriate use of technology; mathematical process skills (problem solving, reasoning, modeling/representation, and mathematical connections); geometry and spatial reasoning; and data analysis, statistics, and probability.

Experienced teachers (two middle school, two high school) from the Western Slope region were consulted to help convert the broad spectrum of identified needs into a manageable format. The program eventually emerged as a one-year professional development cycle launched by an intensive two-week summer institute designed to improve areas of weakness in content knowledge. Week One focused on statistics and probability, embedding the use of TI-83 calculators as a tool for data collection, analysis, and interpretation. In Week Two, a study of geometry and extensive use of Geometer's Sketchpad® software provided the context for developing problem solving skills and incorporating other mathematical processes into instruction. Performance assessment was also featured daily.

### CRITERION 2: ACTIVE LEARNING

Teachers' classroom practice tends to reflect their own experiences as students; therefore, professional development needs to provide "the opportunity to experience firsthand a form of teaching that facilitates and supports learning" (Schwan-Smith, 2001, p. 43). This includes "posing worthwhile tasks, engaging teachers in discourse…and expecting and encouraging teachers to take intellectual risks" (NCTM, 1991, p. 127). Loucks-Horsley (1998) refers to "immersion in inquiry" as a means for teachers to "broaden their own understanding and knowledge of the content" and to be "better prepared to implement the practices in their classrooms" (p. 49), and Clarke (1994) considers it a basic principle of professional development that mathematics teachers experience model teaching strategies as active classroom participants.

The Western Slope summer institute modeled content delivery based on active learning and constructivist principles. Teachers worked in pairs and in groups on activities that called for the collection and interpretation of data, problem solving, and reasoning about geometry. Calculator and computer technology played a significant role throughout the two weeks. Many activities were drawn from modules in standards-based curricula (*Interactive Mathematics Program®* and *Connected Mathematics™*), allowing teachers to experience new approaches to teaching and to explore mathematical concepts through active learning as their own students might. They replicated these experiences in their classrooms and reported in their journals such successes as using software to teach lessons, changing questioning strategies to a more open-ended, probing style, and developing assessments in which their students had to explain their solutions in writing.

## CRITERION 3: COHERENCE AND CONTEXT

Garet et al. (2001) identified three aspects of coherence: how new knowledge builds on previous knowledge; alignment of content and pedagogy with standards; and support for sustained, ongoing communication with like-minded colleagues. The National Resource Council observes that teachers bring "varying degrees of experience, professional expertise, and proficiency" to the table (1996, p. 70). In the context of rural professional development, each teacher also brings an entirely different school experience. Designers of effective professional development try to acknowledge the existing beliefs and practices of participants (Richardson, 2003) and take teachers' contexts into account (Schwan Smith, 2001). Consideration of school context, including availability of instructional resources, district and state mandates, and school structure, is essential in designing meaningful experiences for teachers (Loucks-Horsley et al., 1998).

Western Slope teachers were challenged to link new ideas to old as they were confronted with new approaches to teaching and learning content during the summer institute. During the institute, teachers matched the content they were learning to state content standards and experienced how content can be introduced through activities that incorporate mathematical processes and different ways of thinking. During Week Two, aligning standards and assessment became the unifying theme as teachers became familiar with alternate ways to assess students' conceptual understanding through the use of performance tasks and open-ended problems. Teachers carried this knowledge into the classroom and reported on efforts to implement it:

> "Designing a performance assessment forces me to use the standards as a guide. Hopefully, this helps students meet the standards in a hands-on applied setting… Designing a performance assessment with a rubric was challenging for me. I wanted to make sure I was measuring the right things… It's challenging to ask questions that foster problem solving, and it's difficult for students to justify solutions to problems."

Creating a climate of sustained, ongoing communication after the summer institute proved to be a challenge. The limited availability of technology in some rural schools made us wary of depending on Web-based communication. Likewise, expecting teachers from more than a dozen different schools to collaborate on projects outside of the summer institute seemed unfeasible. Instead, participants created individual action plans for the academic year, and made a commitment to carry out and report on their activities. Teachers kept journals and submitted samples of student work, and each cadre met twice during the academic year to report on their action plans and share progress. As another measure, all participants were required to share Western Slope assessment materials with one district or regional colleague and to mentor one less experienced teacher in their schools or districts. These "second tier" teachers reported that mentoring by Western Slope participants helped them in areas of content, assessment, and technology. One wrote: "My mentor provided much needed information on CSAP-type questions, which is lacking in our Saxon textbooks. Also, her enthusiasm about your program and about teaching math based on standards has been inspiring!"

## CRITERION 4: DURATION

Teacher growth requires time, and effective professional development must be of sufficient duration, both in terms of total contact hours and the length of time spanning those hours. In a report to the Glenn Commission, Susan Loucks-Horsley advocated for a process that is "continuous and sustained over time" with "adequate amount of time for teachers to learn and make meaningful changes in their practices" (Kimmelman, 2003, p. 2). She further noted that up to 100 hours of contact is desirable for a high-quality experience. In a review of 93 studies of professional development effectiveness, Kennedy (1999) observed that total contact hours appeared to be unrelated to student benefits, while distribution of time did appear to matter. In general, however, researchers agree that sustained and extended experiences are most effective (Garet et al., 2001; Richardson, 2003; Sparks, 2002).

Building in sufficient contact hours was not a problem for the Western Slope Project. Our choice to host the summer institutes in-residence at small, local campuses rather than through classes offered at the University of Northern Colorado allowed us to make maximum use of time. Besides meeting formally for eight hours each day, the Western Slope teachers spent two weeks establishing lasting professional and personal relationships through shared meals, recreational activities, and organized social events.

Professional development that continues over time requires a new model for rural teachers from far-flung rural schools who cannot be expected to meet together regularly. To compensate, WSP built in assignments with academic year follow-up to keep participants focused on the project goals. Teachers were asked to design an enrichment unit or series of activities to be integrated into an existing course. The activities and their assessments had to incorporate problem solving, statistics, and/or geometry and align with Colorado and NCTM standards. At an October face-to-face meeting, teachers presented their action plans for implementing new technology, teaching problem solving skills, and/or introducing new statistics and geometry concepts in their classrooms. As a group, they also selected a set of performance assessment tasks to administer and score for later comparison. In April, they reconvened to analyze their students' work on those tasks and to report progress on their action plans.

The academic year sessions also provided a forum for teachers to share classroom "success stories." Most evident among the teachers' self-reports were a significant increase in problem solving activities, greater emphasis on written responses and explanations from students, better understanding of statistics concepts, and instructional use of Geometer's Sketchpad®. One teacher shared that he was teaching more statistical analysis and problem solving, adding "I've become well versed on State Standard #3! I feel more confident!" Another came to the summer institute with a goal "to start using the *Connected Mathematics*™ series with my 8th graders." WSP gave him confidence to try a standards-based unit in his regular curriculum. By spring, he had used several *Connected Mathematics*™ modules in 7th and 8th grade. He later reported that his students did exceptionally well on the CSAP exam. "I have used the knowledge I've learned about performance assessment and scoring to set up the tests I've given… Because of this, I'm more aware of the way that I am teaching—so that I teach in a way to help them be successful on the assessment."

## CRITERION 5: COLLECTIVE PARTICIPATION AND COMMUNITY OF LEARNERS

Collaboration among teacher learners has been found to positively affect teacher outcomes (Garet et al., 2001; WestEd, 2000), and is accordingly given high priority in nationally recognized professional development guidelines and standards (Loucks-Horsley et al., 1998; National Research Council, 1996; National Staff Development Council, 2001; Schwan Smith, 2001). Schwan Smith (2001) cites research suggesting that participation in "communities of collaborative practice where teachers are able to work with colleagues toward shared goals" provides valuable support to teachers in terms of their own practice (p. 45). The issues of collaboration and community building have also received significant attention in the distance learning literature (Berge & Mrozowski, 2001).

Teachers in the Western Slope Project experienced a two-week immersion not only in worthwhile mathematics and high-quality instruction, but also in the company of like-minded professionals. The context of preparing students to succeed on the standards-based state assessment provided a shared goal. Participants from some small districts expressed excitement about their first-ever collegial experience with other mathematics teachers, even though they came from different schools. Two weeks of working together, eating together, living together, and sharing leisure activities established a professional learning community in a way no summer course on a university campus ever could. Permanent relationships were forged—in fact, one couple became engaged in the year after they met through the Western Slope Project!

## Results

The Western Slope Project directly served 37 secondary mathematics teachers from rural western Colorado (18 in the first cadre, 19 in the second), while other teachers were reached indirectly through the mentoring component. Most of the participants worked in communities of less than 5,000. More than half of them were responsible for teaching the entire mathematics curriculum for grades 9-12. Roughly one-fourth were in their first or second year of teaching.

A substantial body of data collected over the two-year life of the project documents success in increasing the participants' content knowledge, influencing their classroom practice, and improving their ability to assess achievement of standards.

Quantitative data were drawn from pre- and post-tests based on content learned during the summer institute and from pre- and post-surveys of perceived preparedness to teach mathematics. The content test consisted of ten multiple-choice items on statistics and probability and ten open-ended items on geometry and problem solving, compiled from text sources and released assessment items. Open-ended problems were scored using a rubric (1.0 = meets expectations, 0.5 = partially proficient, 0 = unsatisfactory or blank); multiple choice problems were worth one point. Mean scores for the 35 participants who completed both pre- and post-tests increased from 5.64 to 7.70 for the data/probability portion, and from 5.76 to 7.79 for the open-ended portion. The pre- and post-tests revealed significant gains in the form of large and medium effect sizes for statistics/probability, geometry, and the use of technology.

The preparedness survey was adapted from a 1999 teacher enhancement instrument designed by Horizon Research, Inc. Using a Likert scale, teachers were asked to rank their preparedness level along ten dimensions of pedagogy relevant to mathematics. Calculation of effect sizes on subscales of the survey revealed the largest gains in teachers' preparedness to develop their students' problem solving skills.

Qualitative data included journal entries submitted by participants throughout the academic year as well as self-reports and feedback forms indicating changes in practice and observed effects on student behavior and performance. Analysis of the textual data indicates that teachers applied their newly obtained content knowledge and skills, made substantial changes in classroom practice, and witnessed improvements in their students' conceptual understanding and ability to communicate ideas. Self-reports from 29 of the teachers indicated that all but one had transformed knowledge gained from the Western Slope Project into classroom practice. Significant practices included teaching problem solving processes and skills, using technology more effectively, and actively preparing students for the constructed-response items on the CSAP (e.g., assigning open-ended problems, scoring with rubrics, and asking students to explain their thinking).

## Conclusion

Although obstacles still exist, it is possible to design "powerful" professional development for isolated rural teachers. The key characteristics of effective programs can be adapted for the unique context of rural mathematics teaching, with positive results for classrooms and students. The outcomes are further enhanced when teachers who work as individuals in their profession, but share similar contexts and experiences, are brought together in an immersion experience that allows them to share stories, learn from each other, and form professional bonds. The Western Slope Project motivated many teachers to make substantive changes in their classroom practice, with documented effects on student learning:

- "I am making a special attempt to incorporate technology, which I haven't done in the past. I am also having my kids practice for the CSAP, and they are assessing each others' work; this way they'll have an idea how they will be graded."

- "It has made a difference in the way I teach and assess students. Lessons are more activity-oriented and students are more interested and engaged."

- "I have been focusing on students constructing their own understanding. I have been using problem solving daily and working on my questioning techniques and requiring…written explanations/responses that explain their strategies or 'why.'"

- "I have implemented the problem solving strategies …with much success. The students are writing in words the strategies and steps used to solve certain problems."

The Western Slope model bears replicating, and indeed is now being implemented in a Montana Mathematics and Science Partnership project funded by the U.S.

Department of Education. Similar in structure but of larger scope, the COMET Project serves 70 teachers from across the state, roughly two-thirds from distinctly rural communities. Three grade band groups (K-5, 6-8, and 9-12) attended a two-week residential summer institute in 2005. Following the Western Slope model, teachers set goals and wrote action plans for the following academic year, and attended two academic year workshops. In an extension of the model beyond teaching mathematics content and modeling appropriate pedagogical approaches, COMET is also educating participants about how to use self-assessment and reflection to improve instruction. Teachers were introduced to a set of observation instruments at the summer institute and are expected to videotape and assess their own teaching throughout the year; some of these tapes will later be shared and analyzed with other participants. Reflection will be the centerpiece of another week-long summer institute in 2006, along with continued expansion of content knowledge. The Montana project has shown great promise in its first several months. We encourage others to adapt and report on similar models for rural professional development.

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# Balancing Accountability and Staff Development in Urban School Reform

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Students learn best when their teachers are themselves also learning. There is an accumulating body of evidence that supports this common-sense belief. Engaging teachers and administrators in collaborative professional learning focused around mathematics content and pedagogy can improve student achievement (U.S. Department of Education, 1996; Darling-Hammond, 1997; Elmore, 1997). Quality professional development that translates into student achievement must address rigorous mathematical content, how children learn that content, and effective instructional strategies to teach that content (Sparks & Richardson, 1997; Ball & Bass, 2003). Moreover, there is a growing consensus in the field about what constitutes effective professional development (Supovitz, 2001; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003).

At the same time, the national movement for standards-based reform in mathematics (NCTM, 2000), fueled by the Third International Mathematics and Science Study (Stigler & Hiebert, 1999), has increased emphasis on accountability. Although it may appear that there is a contradiction between the accountability movement and intensive staff development, the experiences reported here support the idea that accountability and staff development are intertwined in standards-based reform. Establishing and communicating clear expectations, providing adequate support to help staff meet the expectations, and monitoring the expectations to ensure that they are met, demonstrate commitment to standards-based reform.

In one small urban district, Plainfield, New Jersey, balancing support for staff and accountability (e.g., communicating clear expectations and providing regular feedback) resulted in improved student achievement in mathematics in every elementary school in the district. The purpose of this article is to share some of the tools and techniques used in this district for supporting teacher learning in the context of raising expectations for students, teachers, principals and central office staff. Other district leaders reading about strategies used in Plainfield to implement standards-based elementary mathematics program may gain an image of how such reform might occur in their own situations.

The article is organized chronologically. After describing the district and the initial reform efforts in the background section, the first-year staff development and accountability strategies are described. Then, the staff development and accountability work in Years Two and Three are addressed. A topically oriented chart that summarizes the strategies appears in Appendix A.

## Background

Plainfield, located in central New Jersey, enrolls 8500 students in grades PreK-12. Seventy percent of the students qualify for free or reduced lunch and the student population is almost entirely African American or Latino. There are ten elementary schools, two middle schools and one comprehensive high school. Since Plainfield is one of the districts designated for additional aid as part of the Abbott v Burke case in New Jersey, three- and four-year olds are served by full-day, full-year, high-quality preschools, primarily through subcontracts with the community child care centers in the city.

A new administrative team arrived in the district in 1995 to find low student achievement and a culture of low expectations for students and teachers. The vision of the board and the new administration was summarized in a document that was widely circulated and discussed throughout the district. "The 12-Step Framework for Reform in the Plainfield Public Schools," included the following:

1. *Re-thinking of district vision, mission, and beliefs to ensure the success of every child.*
2. *Development of student learning and performance standards that clearly indicate what students should know and be able to do.*
3. *Development of assessment and accountability systems to measure student progress and school/district effectiveness.*
4. *Implementation of policies, procedures, and practices to decentralize decision making to the school site to the maximum extent possible.*
5. *Re-definition of roles, responsibilities, and functions to support and empower staff to make the major decisions affecting the teaching and learning process in the school.*
6. *Utilization of research-driven, data-based approaches to give direction to initiatives to improve teaching and learning processes.*
7. *Expansion of the role of technology in all school district operations (instructional, administrative and management, student data management).*
8. *Establishment of a partnership between union and management to promote and expect shared responsibility for the education of children and the establishment of relationships based upon mutual respect, trust, and accountability.*
9. *Partnerships with parents, community, social and health service agencies, businesses, churches, government at all levels (municipal, county, state, and federal) to ensure comprehensive support for students and their learning needs.*
10. *Improvement of communication strategies and systems to engage all internal and external stakeholder groups in the ongoing work and mission of the public schools of Plainfield.*
11. *Organization and maintenance of systemic efforts to engage parents in the education of their children and the work of the schools and district.*
12. *Establishment of a comprehensive staff development system aimed at the professionalization of teaching and learning in the public schools of Plainfield.*

To begin to put the vision into practice, the Board of Education and the administration negotiated a new contract with the Plainfield Education Association (PEA) that included a joint partnership for school reform. As the preamble to the agreement reads:

> *The parties are committed to developing a collaborative working relationship at all levels of the system. A collaborative relationship is one in which the parties work together with mutual respect, reliability, clear and direct communication and a willingness to understand and consider a different point of view....The Board, The Association, and Administration, at all levels, will act as professional colleagues who sometimes differ about how to solve a problem but who share a common purpose and dedication to the educational achievement of Plainfield students. (Collective Bargaining Agreement, 1995)*

The contract established the Leadership, Innovation, and Change Council (LINCC) to manage reform efforts in the Plainfield Schools. The district LINCC was co-chaired by the superintendent and the association president. Represented on the district council were teachers, the collective bargaining associations for all staff, the parent organization and the high school student organization. School LINCCs were formed to function within parameters established by the Plainfield Board of Education, and federal and state law and regulation. School LINCCs were involved in the following areas of decision-making: staff development, budgeting, accountability, staffing, curricula and instructional materials, disciplinary practices, and others. The district LINCC and the school LINCCs served as forums for debate, venues to hash out concerns and to address "push backs" (resistance) to the reform efforts from staff and parents.

To support school-based decision making, the roles and responsibilities of Plainfield's central office staff were redesigned. If staff were to be empowered at the school level, the district curriculum staff had to play a less directive, more collaborative role. The central office staff partnered with school staff to build capacity for school reform and to facilitate change. There was recognition that change required both a "bottom-up" and a "top-down" strategy at the same time.

For the first few years, the systemic reform efforts in the district did not have an impact on the classrooms. The district and school LINCC members learned about collaboration, staff engaged in conversations around the need for high expectations and efficacy on the part of staff and students, parent and community outreach improved, and staff development increased. However, the activities were too diffuse. There was a growing recognition that all the activity and conversation were not deliberative enough or focused enough to affect teaching and learning.

In order to accomplish the vast changes needed in curriculum and instruction, the district leadership looked to the experience of Community School District #2 in New York City. Research on the reform experiences of Community School District #2 (Elmore & Burney, 1997; Stein & D'Amico, 1998) documents the development and implementation of a standards-based system in the area of language arts literacy. The themes identified by Elmore and Burney (1997) in the District #2 systemic reform efforts that were most applicable to the Plainfield situation included: introduction of instructional changes in one content area at a time; treating staff development as an integral part of system management; balancing central office and site-based decision-making; and hiring external consultants with expertise consistent with the district's strategy.

The reform efforts directly addressing teaching and learning in Plainfield were modeled on the District #2 experience. When the New Jersey State Department of Education required each district school to adopt a whole school reform model as part of the Abbott requirements, nine of the ten elementary schools and both middle schools selected America's Choice, a whole school reform model from the National Center for Education and the Economy that perfectly complemented the district's reform agenda. Plainfield organized a focused, sustained initiative to improve teaching and learning in the area of language arts literacy. As a result of this work over a three-year period, student performance on the New Jersey State fourth grade assessment in language arts literacy significantly improved (Muirhead & Collum, 2004; Supovitz, Poglinco, & Snyder, 2001). The assumption behind this strategy of content-area focus is that, over time, changes in teaching and learning in one content area can reach more content areas and more staff. As teachers are engaging in sustained professional growth and renewal activities, they act as catalysts to cause other teachers to move in new directions. An increased sense of efficacy, experienced by many Plainfield staff members based on the successes in improving teaching and learning in language arts literacy, made the culture of the schools more receptive to addressing the next content area: mathematics.

Building on the approach used in language arts literacy, Plainfield moved in 2001 to implement NSF-developed, standards-based mathematics programs in every classroom. In the elementary schools, the district adopted *Investigations in Number, Data, and Space*; in the middle schools, *Connected Mathematics*; and in the high school, *Interactive Mathematics Program* (IMP). The aim was to bring about district-wide improvement by aligning curriculum and instruction to standards, providing extensive staff development, and monitoring to ensure practice consistent with the standards (Briars & Resnick, 2000). What staff learned from the language arts literacy reform could contribute to more effective and efficient change in mathematics teaching and learning.

From the beginning of the mathematics focus, the district provided intensive and on-going staff development, and designed and communicated clear expectations for teachers, as well as for principals and central office staff. The remainder of this article highlights some of the strategies successfully used over a three-year period as the district implemented the new program, *Investigations in Number, Data, and Space.* The strategies for professional development and accountability during the first year are discussed separately from those in the second and third years to highlight the changes in the balance between accountability and staff development over time. The chart in Appendix A summarizes the accountability and staff development strategies discussed in this article.

## Professional Development of Teachers, Coaches and Principals in Year One

In the first year of the new mathematics program, staff commitment and confidence were fragile. Although staff members throughout the district engaged in discussions around the need for standards-based mathematics reform before the move to the new curricula, the comfort level of staff with mathematics as a content area was clearly lower than with language arts literacy. Therefore, the support provided to both classroom teachers and school administrators had to be intensive.

• **Creating the position of mathematics coach.** Mathematics coaches were selected the previous spring from among teachers who were most successful in teaching mathematics and who expressed interest in assuming this role. District supervisory staff and higher education partners from Rutgers University and Kean University began providing support to the group of coaches as soon as they were appointed.

A detailed job description outlined the role of the mathematics coaches. The emphasis during the first year was on providing model lessons in classrooms, helping teachers plan, trouble-shooting related to program implementation, and delivering parent workshops. In order to carry out their responsibilities, the coaches needed to learn about the content and pedagogy of standards-based mathematics, the change process, facilitation skills, and working with adult learners. Along with higher education partners, district supervisory staff and various outside consultants furnished by the National Center for Education and the Economy (the whole school reform model) mentored the coaches on site and met weekly with the coaches. At these weekly meetings, coaches engaged in professional growth activities, collaborated to solve problems that arose, and coordinated the work across the district.

• **Modifying the leadership team.** As part of the whole school reform model adopted by the schools, America's Choice, each school had an existing leadership team consisting of the school administrator(s), a full-time whole school reform coach, a full-time literacy coach, and a parent liaison. To this group, the full-time mathematics coach was added. The school leadership team met weekly to identify needs and solve problems. During the first year of the program implementation, the team focused on addressing nuts-and-bolts issues and creating a mathematically rich environment in each classroom. The leadership team worked to ensure that teachers had the materials required and began to use the rituals and routines of the *Investigations* program. When the leadership team members conducted mathematics focus walks in classrooms, they were careful to select elements of the program to look at that were most neutral in terms of teacher accountability. For example, a focus walk during the first year might look at each classroom to ensure that there was an adequate supply of manipulative materials available. Members were regularly in classrooms, helping teachers and students. In subsequent years, the leadership team took on a stronger accountability role.

The work of the leadership team was supported by both district administrative staff and a cluster leader provided by the National Center for Education and the Economy, the parent agency of the whole school reform model, America's Choice. As principals worked more collaboratively, so did district administrators. A reorganization of the district curriculum and instruction staff ensured that every school had a liaison who attended leadership team meetings regularly and consulted with principals around the work of the team.

• **Providing staff development workshops.** Every elementary teacher in the district was invited to participate in five days of paid staff development in the summer before the program began. The workshops prepared the teachers for the rituals and routines of the Investigations program and engaged them in sample activities from the key instructional modules. TERC, the developers of Investigations, provided workshops for primary and upper elementary teachers. Both district and school administrative staff, and mathematics coaches participated along with the teachers. Over a third of the elementary teachers participated in this initial training. Those who did not attend the summer training, received some initial training from the mathematics coach in the school and/or the district mathematics supervisor, and principals ensured their attendance at monthly workshops discussed below.

All elementary principals and assistant principals, as well as district supervisory staff, attended a three-day summer institute that was focused on mathematics instruction. The emphasis of the sessions was on introducing the administrative staff to the differences between a standards-based program and the traditional textbook-driven, whole-class instruction that they were used to. In addition, about half of the monthly administrative meetings during Year One included professional development related to the mathematics program.

Workshops for teachers across the district were offered regularly during the school day on various topics identified by the leadership teams. Within the schools, weekly grade-level meetings during the school day, led by the mathematics coaches and the principals, focused on nuts-and-bolts issues such as learning the rituals and routines of the program and creating the appropriate classroom environment for standards-based mathematics. There was some limited review of student work and analysis of children's mathematical thinking and discourse. However, it was not until Year Two that these activities became predominant in teacher meetings.

## Accountability Strategies in Year One

At the same time that there was a heavy investment in supporting staff, the district leadership team structured conversations among the stakeholders that laid the basis for a shift to more accountability for classroom instruction in future years. The message from the district administration was clear from the beginning—standards-based mathematics reform in every classroom in every school. However, expressing expectations is only the beginning of an accountability system; documenting how the expectations are being met is key. In Year One, teachers, principals, and district administrators all had opportunities to contribute to crafting the description of what would be monitored and documented beginning in Year Two.

• **Drafting indicators and implementation rubric for standards-based mathematics classrooms.** Early in Year One, a draft was developed that described clearly what a classroom that is implementing standards-based programs should look like. District leaders distributed the draft among the stakeholders and engaged in debate with staff at meetings of leadership teams, site-based management teams, the teacher's union, and school faculty. Based on the feedback from stakeholders, modifications to the indicators were redrafted in the form of a checklist.

When the checklist was finalized, it was widely shared in the spring of Year One. Leadership teams began to informally use the checklist as they visited classrooms during their focus walks. However, leadership teams and administrative staff were careful not to use the checklist in Year One in any way that could be construed as evaluative of teacher performance. In fact, elementary principals were encouraged to do no formal evaluations in the area of mathematics instruction during the first year of the program. However, principals were expected to be in classrooms every day during the mathematics block. Appendix B contains a copy of the final checklist.

Based on the finalized indicators, district leaders developed a draft of a rubric to rate the level of teacher implementation of the program that was also circulated for feedback. This rubric made explicit the expectations of the district leaders for the development of teachers as they learned how to use the new program. Appendix C contains a copy of the rubric.

• **Developing a pacing guide.** During Year One of the program, central office staff provided teachers with a limited number of instructional modules from Investigations to be used and an outline of the order in which they should be used. However, teachers were given a clear message that the first year was for learning the new program and that a clear pacing guide would be developed for Year Two based on their experiences. Therefore, principals and district administrators did not pressure teachers based on their pacing.

• **Revising the target assessment process.** For several years, the district had been administering open-ended assessment items that sampled the standards at each grade level three times during the year. Teachers were provided with summaries of the class data on the target assessment process. The results were reviewed by the teacher and the principal with an eye to improving student outcomes, student by student and class by class. During Year One, the format and content of the target assessments were revised to better align with the new program. Although principals continued to review results on the formative assessments, the emphasis was on using student results on the assessments to support staff learning during the transition to a standards-based mathematics program.

## Professional Development of Teachers, Coaches and Principals in Years Two and Three

In Years Two and Three, the support provided for staff continued and intensified. As Elmore (1997) notes, "Setting standards … does not, by itself, address the problem of knowing how to do the right things." (p. 66) In order for teachers to teach differently, professional development must "permeate the work of the organization and the organization of the work." (Elmore & Burney, 1997, p. 15)

• **Developing coaches.** To be an effective mathematics coach, a teacher needs to rethink subject matter and pedagogy. The coaches had limited background in mathematics so there was a need to deepen content knowledge. In addition, a coach needs excellent interpersonal and facilitation skills (Costa & Garmston, 2002).

Higher education partners provided graduate courses and facilitated study groups designed to address issues of mathematics content. The district expected coaches to enroll in these courses and provided support for other teachers as well to attend. Tuition costs were paid by the district.

The weekly meetings of the coaches complemented the course work by involving the coaches in the regular review of student work, exploration of children's thinking about mathematics, model lessons, role playing, professional reading, collaborative problem solving, and planning for workshops. Between meetings, coaches communicated frequently via e-mail and telephone. The math supervisor regularly visited the schools to assist the coaches.

Each year, coaches attended several days of training that specifically addressed coaching strategies and facilitation. At the weekly meetings, coaches analyzed the inherent dilemmas faced in their role, e.g., how to build collegial relationships of trust, how to avoid being used or viewed as a "spy" for the principal, how to provide feedback without being evaluative.

• **Providing tools in response to identified needs.** Lesson plan templates were drafted and revised to assist teachers in their planning. Teachers were not required to use these templates. Rather, the purpose was to provide a tool that could make the teacher's job easier. In some schools where the climate encouraged collaborative work, teachers developed lesson plans together.

Another tool that proved useful for the teachers was a chart developed by one school leadership team to encourage accountable talk in the classroom. The chart had sentence starters for students to use in explaining their strategies and engaging in collaborative problem solving. This chart was shared among the schools and was posted in many classrooms.

Other tools developed in response to needs identified by teachers, principals, and parents included: observational checklists for specific components of the program (e.g., accountable talk); a question-and-answer letter to help explain the new program to parents (provided in both English and Spanish); child-friendly rubrics for the primary grades; parent booklets summarizing what all students should know and be able to do at the end of each school year in mathematics; a portfolio format and forms for student and teacher feedback on the work selected for the portfolios; and standards-based report cards for communicating student progress.

• **Providing staff development workshops.** In the summers before Year Two and Year Three, teachers were again invited to attend paid summer training in the program. New teachers were provided with the Year One training.

There continued to be half-day workshops offered for every elementary grade level to specifically address mathematical pedagogy and content needed to implement the program. However, increasingly, workshops were provided at the school level by the coaches in response to specific identified needs of teachers or of students. Strategies for professional growth other than workshops became more common such as: observing in other classrooms for a particular purpose (e.g., to see how a teacher used effective questioning skills); study groups; review of student work; review of data; and common planning). Resources such as *Bridges to Classroom Mathematics*, a standards-based training program developed by TERC and the Consortium for Mathematics and its Applications (COMAP, 2003), provided coaches with workshop agendas, videotapes, and student work on a variety of mathematical content. On average, each elementary teacher of mathematics participated in 45 hours of staff development workshops related to mathematics during Year Two and 35 hours during Year Three.

Staff development for principals intensified in Years Two and Three. In the summer institute for administrators, clinical assignments involved the participants in observing in summer school classrooms where the new program was being used and in interviewing students about their mathematical thinking. During the monthly administrative meetings, discussion focused on the supervision of mathematics instruction. Principals watched videotapes of classroom instruction in elementary mathematics and discussed how to provide feedback to teachers based on their observation. Reviewing student work in mathematics and analyzing results on various assessments in mathematics helped the school administrators learn how to observe standards-based mathematics classrooms. Where possible, these administrative meetings were held at different elementary schools to provide opportunities for discussion of student work in classroom math folders and posted in classrooms and halls. Each elementary school administrator engaged in at least 30 hours of professional development in elementary mathematics during each of the two years.

At the end of Year Three, higher education partners provided Lenses on Learning training for the district administrators (Grant, et al., 2003). The combination of videotaped lessons, professional reading, and discussion about student thinking helped participants think about the need to have a deep understanding of the content in order to observe teachers and provide useful feedback to them. As one principal commented during the session on June 10, 2004, *"Supervisors have to get teachers to think about their practice. Don't just go into the classroom for a snapshot. You have to determine what kids are understanding. … What was the teacher's intent? What was driving the teacher's thinking? This is what you could discuss with the teacher."*

• **Growing other professional development initiatives.** Leadership teams in each of the ten schools carried out various other professional development activities. One school had a study group where the entire school read a professional article or book related to mathematics instruction and discussed the assigned reading in small groups at a regular staff meeting. Another school used the staff meeting time to engage teachers in a walk-through of all the classrooms in their own school to encourage idea sharing. In addition, inter-class and inter-school visitations supported learning from each other.

With the support of faculty from Rutgers University, lesson study groups (Lewis, 2002) were organized and approximately 20 elementary teachers and mathematics coaches participated. The teachers were grouped by grade cluster and each group addressed an area of focus in mathematics with a research lesson. They observed each other teaching the lesson and worked to improve the lesson based on the feedback.

## Accountability Strategies in Years Two and Three

At the beginning of Year Two, the superintendent sent a letter to every elementary school staff member conveying the clear expectations for the implementation of the mathematics program. In his message, he announced the beginning of the walk-through process for mathematics as follows:

> *At the end of this month, we are beginning our walk-throughs. This year, the first walk-through will focus on the implementation of the new mathematics program. The rubric that has been shared with your school indicates the developmental continuum that teachers follow as they learn to use the Investigations program.*
>
> - *I do not expect to see classrooms that are fully implementing and integrating the program at this time.*
> - *I do expect, however, to see all classrooms at least scoring at the beginning level on the rubric.*
> - *I do expect to see a classroom environment that reflects the Investigations program.*
> - *I do expect to see every teacher putting in the effort needed to help students achieve standards in mathematics.*
> - *I do expect to see that teachers are trying to engage students in accountable talk around mathematical ideas. (Letter dated September 23, 2002)*

This clear communication of the expectations for Year Two conveyed a shift from mostly supporting staff in the first year to providing more pressure on classroom teachers and principals. However, the purpose of the walk-through process was improving teaching and learning and therefore required support mechanisms. The superintendent ended his letter with a commitment to the development of staff:

> *The purpose of the feedback is to use it to improve. We want the Plainfield Public Schools to be a place where continuous learning is the norm — for students, for teachers, for administrators, for parents, and for the superintendent. I look forward to learning with you how to implement the rigorous new standards that our students must reach to be successful. (Letter dated September 23, 2002)*

• **Conducting district walk-throughs.** In the fall and the spring of Year Two, and the fall of Year Three, every elementary classroom was visited by at least two observers, one from the district administration and one from the school leadership team. The two raters observed a math block in each classroom and reached consensus in completing the checklist and assigning a rubric score on the level of implementation (see Appendices B and C). Observers held a brief conference with each teacher after the visit and shared the completed checklist and rubric score to provide non-judgmental feedback. In addition, after all the teachers were visited, the walk-through team met with the leadership team to identify school-wide areas for growth.

The purpose of the walk-throughs was not evaluative, and principals were cautioned not to use data collected as part of teacher evaluation. However, the data were to be used to identify areas of need. Data from the walk-throughs determined workshop topics offered by the district and school as well as the nature of classroom assistance provided by the mathematics coach and principal at the school.

As indicated by the superintendent's message, the focus of the first walk-through was on the nuts and bolts of the program implementation. In order to score at the "Beginning" level on the rubric, a teacher would need to have established a classroom environment with all required materials and elements, a one-hour mathematics block, and the program routines and procedures (see Appendix C).

In subsequent walk-throughs, the expectations for the teachers were higher. Visitors observed how teachers encouraged collaboration and reflection among the students. How did teachers document individual student concept development and provide feedback to students about their thinking? How did teachers use data in instructional decision making? Were students reflecting on their own work and building on the thinking of others? Could students engage in accountable talk, that is, talk about their mathematical ideas and strategies? How did portfolios of student work demonstrate progress towards meeting the standards? Most importantly, teachers were expected to be more able to act as facilitators of students' mathematical learning.

• **Monitoring program pacing.** The new pacing guide was used by the leadership teams to monitor the pacing of program implementation. A range of dates was given to indicate when a module should be finished and the module assessment completed. The leadership team, as well as teachers during the weekly grade-level meetings, reviewed the results of the module assessments to identify areas of need. Feedback from teachers resulted in modifications to the pacing guide, as needed.

• **Conferencing around results on the target assessment process.** In many schools, principals met several times a year with each teacher or with each grade level team to discuss student results on the target assessments. The conversations focused on strengths and needs of the class and individual students, strategies for improvement, and support that the teacher might need to carry out the improvement strategies. These results-oriented conferences sent a strong message that the principal expected all students to reach the standards and also that the principal recognized his or her responsibility in making that happen.

• **Growing school-based accountability.** School leadership teams were encouraged to develop their own accountability strategies. The district accountability system required each school to present an end-of-the-year report to the community. In one school, where the level of trust was high, the end-of-the-year report included data on implementation of the program and student achievement by classroom. In another school, the leadership team organized parent walk-throughs using the same indicators as a mechanism for parents to better understand the mathematics program. Many schools developed strategies for documenting and celebrating student learning. In most schools, the leadership team decided to reorganize classes in grades 3-5 so that teachers specialized; teachers who were stronger in mathematics taught more of the students in that subject area. The growth of school-based responsibility for student learning is part of becoming a learning community.

## Conclusions

By Year Three, after years of flat, poor performance in mathematics on the state's fourth grade assessment, 54.4% of the students met the proficiency level in mathematics, an increase of 19 percentage points from spring 2003 to spring 2004. In the following year, there was a further increase of 6 percentage points. For the first time, the district had more than 10% of the students scoring at advanced proficient, a considerable increase. Moreover, the data from the walk-throughs indicated that almost 45% of the teachers were rated at the high end of the rubric, as "implementing" or "integrating" (see Appendix C). The teachers with higher ratings on the rubric also had a higher percentage of students passing the state test and scoring at advanced proficient. These results provide evidence that a well implemented, standards-based mathematics program can have significant influence on student achievement on the high-stakes state tests.

The goal was to implement the program consistently in every classroom in every school through balancing the pressure teachers feel from increased expectations and accountability with support strategies to encourage teacher efficacy. Just as teachers become more engaged as they perceive themselves to be more successful, so do students work harder when they can see that they are learning. As Elmore (2004) notes, "The teacher's sense of efficacy comes from the observed effects of her work with the student." (p. 285) Just as the teacher in a standards-based classroom is explicit about what students need to achieve in order to reach the standard, so was the district administration clear about the expectations for teachers. Just as teachers must support student learning if every student is to reach the standard, so must district leaders support teacher learning. Accountability and professional development are intertwined.

Over the three years of program implementation activities outlined in this article, emphasis shifted between accountability and professional development, pressure and support. Some of the shifts were planned; others occurred in response to feedback from stakeholders. The experiences in Plainfield demonstrate that a district-wide initiative to improve mathematics achievement through standards-based reform can work. However, the story also shows the importance of involving stakeholders from the beginning in decision making. What works in one context is not directly transferable to another. The groundwork done in the first few years of the district's efforts, before the specific focus on content area reform, began the change in culture that occurred in Plainfield. This culture shift made it possible to make improvements in teaching and learning. The willingness of the district leadership to engage in debate with teachers, with parents, with principals, and with students, while at the same time, maintaining a commitment to standards-based reform and improved student outcomes, resulted in progress.

The specific strategies for accountability and professional development that worked for the Plainfield community may not work in other contexts. However, if a district leadership is committed to developing a learning community where administrators, teachers, parents and students are learning at the same time, the specific strategies that will be effective will emerge from collaborative inquiry. The district's mission quoted below includes the phrase, "whatever it takes." What it takes to reform a district is to build a community of learners with a shared commitment to the mission:

> *The Plainfield Public Schools, in partnership with its community, shall do whatever it takes for every student to achieve high academic standards. No alibis. No excuses. No exceptions.*

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## APPENDIX A
### *Summary of Accountability and Professional Development Strategies*

| Accountability Strategies | Professional Development Strategies |
|---|---|
| **Communicating high expectations**<br>• Collaborative development of standards-based indicators and rubrics for implementation of the mathematics program<br>• Pacing guide to communicate expectations for program implementation | **Providing external experts consistent with the program**<br>• Workshops and coaching from consultants from America's Choice, the whole school reform model adopted by the schools<br>• Workshops and coaching from higher education partners<br>• Workshops from TERC trainers on *Investigations in Number, Data and Space* |
| **Establishing school-based leadership**<br>• Creation of School Leadership, Innovation and Change Council (site-based management team)<br>• Creation of the school leadership teams | **Developing mathematics coaches and school-based leadership team members**<br>• Staff development workshops and graduate courses about mathematics content, how children learn, and pedagogy<br>• Weekly meetings of coaches with district supervisors for problem solving<br>• Learning how to facilitate and coach<br>• Understanding the change process<br>• Lesson study<br>• Study groups<br>• Coaching from district supervisors and higher education partners |
| **Developing and administering a target assessment process**<br>• Collection of data on progress towards the standards at three points during the school year to use in instructional decision making at the school and district levels<br>• Conferences between teachers and principals about the results | **Providing district-wide and school-based professional growth opportunities for teachers in response to identified needs**<br>• Half-day workshops by grade level for teachers across the district on content and pedagogy<br>• Use of weekly grade-level meetings in the schools for professional development activities<br>• Observing in other classrooms and working with coach in own classroom |
| **Monitoring program implementation**<br>• Focus walks by leadership team members in schools<br>• Monitoring program pacing and reviewing results on module assessments by leadership team members<br>• Principals visit classrooms every day during the mathematics block<br>• District walk-throughs using the implementation indicators and rubric | **Providing staff development for principals and supervisors**<br>• Summer institutes for principals including clinical experiences with summer school students and teachers<br>• Math-focused staff development at monthly administrative meetings, including review of student work, viewing videotapes of lessons, exploring teacher evaluation strategies for standards-based mathematics<br>• Coaching from district staff<br>• *Lenses on Learning* training |
| **Encouraging school-based accountability strategies**<br>• Disaggregated data by classroom made public in the school<br>• Parent walk-throughs to learn about the program<br>• Celebrating and documenting student learning<br>• Teacher specialization in the upper elementary grades based on data analysis | **Developing customized tools in response to identified needs**<br>• Templates for lesson planning<br>• Templates for summary of classroom data<br>• Observational checklists for specific program components (e.g., accountable talk)<br>• Booklets for parents with grade-level expectations in English and Spanish<br>• Q&A document in two languages to explain Investigations to parents<br>• Portfolio formats and forms for student and teacher feedback on work selected<br>• Standards-based report cards for communicating student progress |

## APPENDIX B

## *Standards-Based Mathematics Instruction Checklist*

Teacher: ______________________________

School: ______________________________

Date: ____________________ Time: ____________________

**N** = not evident; **P** = in progress; **E** = evident; **NA** = not applicable

| N | P | E | NA | |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | **Designated area for math materials and artifacts (e.g., word wall) and sufficient supply of materials available for use.** |
| ☐ | ☐ | ☐ | ☐ | **Procedures, routines/instructions displayed and students demonstrate knowledge of them.** |
| ☐ | ☐ | ☐ | ☐ | **Lesson plans reflecting one hour Investigations block, 10-minute math, and standards-based homework.** |
| ☐ | ☐ | ☐ | ☐ | **Student work with teacher commentary/feedback displayed on a standards-based bulletin board.** |
| ☐ | ☐ | ☐ | ☐ | **Math notebooks/journals/work folders that should include: Investigations activity sheets, standards-based homework, student problem solutions that include pictures, numbers and words, teacher feedback that is standards based.** |
| ☐ | ☐ | ☐ | ☐ | **Evidence of all components of Investigations lesson—introduction, exploration and summary.** |

Notes:

| N | P | E | NA | |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | **Evidence of regular assessment and documentation of student progress** |

1. anecdotal notes kept on each student
2. standards-based commentary/feedback evident on student work
3. portfolios for every student
4. student reflections evident on student-selected work in portfolio
5. end of unit assessments administered, scored and documented

Notes:

| N | P | E | NA | |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | **Evidence of cooperative learning group dynamics** |

1. students working in a variety of groupings
2. students sharing materials
3. students noting and building on the work of others
4. students considering their own reasoning and respecting that of others

Notes:

**N P E NA**

☐ ☐ ☐ ☐ **Evidence of student discourse**

1. accountable talk
2. students describing their work
3. students using standard math terms
4. students creating their own descriptive words

Notes:

☐ ☐ ☐ ☐ **Teacher as facilitator**

1. supports an environment of inquiry (asks good questions — "say why", observes and orchestrates oral and written discourse)
2. gives students the tools to construct meaning in their encounters with academic and social tasks in an ever-changing world
3. encourages students to be responsible for their learning and their behavior
4. helps all students to make connections among key areas in mathematics and the real world

Notes:

GENERAL NOTES

**Student is able to respond to questions posed.**

E.g., What do you do during math? How do you know what to do? How does your teacher help you?

**Summary feedback**

Implementation Level on Rubric ______________________________

**Please note:** This feedback is given for the sole purpose of supporting continuous growth and improvement.

Visitors: ______________________________

## APPENDIX C
## *Implementation Rubric*

| PRE-IMPLEMENTING | RESPONSE TYPE 1 | EVOLVING | IMPLEMENTING | INTEGRATING |
|---|---|---|---|---|
| Teacher has:<br>• attended Investigations training<br>• determined routines and procedures necessary to support Investigations<br>• established a place in classroom for math materials<br>• all teacher materials available<br>• established an area for standards-based student work (e.g. bulletin board)<br>Teacher has:<br>• attended Investigations training<br>• determined routines and procedures necessary to support Investigations<br>• established a place in classroom for math materials<br>• all teacher materials available<br>• established an area for standards-based student work (e.g. bulletin board) | Teacher has demonstrated all traits for pre-implementing and has:<br>• prepared the classroom environment for Investigations<br>• established a 1-hr. math block<br>• assessed whether the class has internalized the routines and procedures of the math block<br>• incorporated some of the elements of the investigations lesson into the math block | Teacher has demonstrated all traits for beginning and has:<br>• included 10 minute math in lesson plans<br>• established a system for recording anecdotal notes<br>• used end of unit checklists to create class profiles<br>• maintained established routines and procedures<br>• established an environment of inquiry (e.g. why, how do you know....)<br>• begun to assume the role of facilitator, modeling accountable talk<br>• begun to use standards and rubrics to review student work<br>• actively and continuously participated in building-based math articulation<br>• made all components of lesson (introduction, exploration, summary) part of daily routine | Teacher has demonstrated all traits for evolving and has:<br>• effectively incorporated all components of lesson as part of daily routine<br>• included daily 10-minute math in plans and instruction<br>• regularly documented anecdotal notes for each student<br>• incorporated standards-based feedback on student work<br>• demonstrated effective classroom management (e.g. students know and use routines and rituals for the math block)<br>• used observations of student work during explorations to guide summaries<br>• established a clear expectation for student accountable talk (e.g. student accountable talk is evident in the classroom) | Teacher has demonstrated all traits for implementing and has:<br>• integrated Investigations as a natural part of classroom instruction<br>• exhibited skill and confidence in implementing all aspects of Investigations sessions<br>• established a learning environment where student accountable talk is the norm<br>• selects appropriate work to be shared during summary, showing a variety of strategies and representations<br>• posted student work with standards-based commentary/ feedback<br>• established student portfolios<br>• uses standards-based feedback regularly to focus and support the mathematical development of all students |

# A Framework for the Strategic Use of Classroom Artifacts in Mathematics Professional Development

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The use of classroom artifacts as a way to ground teacher professional development in the practice of teaching mathematics is generating considerable interest among teacher educators and researchers. Teacher educators have developed professional development around written student work, print and video cases, and videos of teachers' own classrooms. (Ball & Cohen, 1999; Driscoll et al., 2001; Kazemi & Franke, 2004; Schifter et al., 1999a, 1999b; Seago et al, 2004; Sherin, 2004) While many educators are enthusiastic about the use of these different artifacts of classroom practice in professional development, it is also important to recognize that artifacts, by themselves, do not guarantee teacher learning any more than having manipulatives in the classroom ensures that students will develop deep mathematical understanding (Ball, 1992; Ball & Cohen, 1999). Like manipulatives, classroom artifacts are only tools for learning; their effectiveness depends on how they are used.

The Turning to the Evidence (TTE) research project took on the challenge of articulating a framework to describe effective use of classroom artifacts in professional development and to connect that framework to teacher learning. By classroom artifacts, we mean materials that come from the classroom and that can serve as evidence of student and teacher thinking during the classroom lessons from which they are drawn. Video snippets and/or audio transcripts of students working, video of class discussion, or samples of written student work are all examples of classroom artifacts. TTE studied the use of classroom artifacts in two different professional development contexts, and the Strategic Use of Classroom Artifacts framework grew out of a need to articulate the nature of the use of classroom artifacts under study in these two contexts.

The first step is to define the purpose for their use. Classroom artifacts in a professional development setting can be used in many different ways, with many different purposes. For example, many teachers look at student work to assess students' learning or as a springboard for discussing issues of curriculum or instruction (Allen, 1998; Falk, 2000; Project Zero, 2001; Weinbaum et al., 2004). In the TTE study, classroom artifacts were used as data about students' mathematical understanding. In both of the professional development programs we studied, the purpose of the artifacts was to help teachers learn to use the data to inquire into the mathematical ideas that students were working on, students' understanding of these ideas, and the tasks of teaching that help promote deeper student understanding. An explicit goal of both programs was to help teachers internalize such an inquiring stance toward classroom artifacts and to begin to use them to better understand their students' mathematical thinking (Driscoll & Moyer, 2001; Driscoll, et al., 2001; Seago, et al., 2004).

*This project was funded by the National Science Foundation as grant REC-0231892. The findings and opinions expressed in this article are not necessarily those of the National Science Foundation. The authors would like to thank Judith Mumme, Daniel Heck, Joseph Maxwell, and Mark Driscoll for their contributions to the ideas in this paper.*

## The Professional Development Programs

The two professional development programs used in the TTE study, Learning and Teaching Linear Functions (LTLF: Seago, Mumme, & Branca, 2004) and the Fostering Algebraic Thinking Toolkit (ATT; Driscoll et al., 2001), were both designed specifically around the use of classroom artifacts. Teachers participating in LTLF seminars work primarily with video cases of classroom mathematics discussions that were selected to highlight different aspects of student thinking about linear relationships. Teachers participating in ATT seminars work with a wider variety of classroom data (written student work, transcripts of students working in small groups to solve problems, records of teachers' questions to students in the classroom), which come primarily from their own classrooms. In the TTE study, seminars for each program were facilitated by the lead author of those professional development materials, thereby assuring that the seminars would be implemented with a high degree of fidelity (Seago, 2006).

These two programs share an underlying philosophy and a number of critical design features that are characteristic of the class of practice-based professional development programs: they offer coherent and extended opportunities for teacher learning (specifically, monthly, three-hour sessions for up to two years), focus on understanding and promoting student learning, connect to classroom practice, involve teacher collaboration, and seek to promote and support deep changes in both cognitive and behavioral aspects of teaching (Ball & Cohen, 1999; Hawley & Valli, 1999; Loucks-Horsley et al., 1998; Thompson & Zeuli, 1999). Both programs focus on algebraic thinking, aim to help teachers develop greater sensitivity to their students' mathematical ideas, and gain a deeper understanding of the algebra they teach. They seek to promote teacher learning by centering professional development activities around analysis, discussion, and reflection on classroom records and artifacts. Both programs also broadly organize professional development activities into two major activities: (1) opportunities for participants to explore and discuss the mathematics problems that they will encounter in the artifacts, and (2) inquiry into the artifacts themselves.

A major goal of both programs we studied is specifically to use classroom artifacts to help teachers develop the mathematical knowledge necessary for teaching (Ball & Bass, 2003; Ma, 1999) by promoting deep, sustained inquiry into both the mathematics underlying the problems used in artifacts and the student thinking embodied in them (and, where relevant, also the teacher thinking). To this end, activities are structured (and facilitated) to help teachers do the following: generate and recognize different solution strategies, make connections between different solutions and the underlying mathematics of the problem, compare and contrast different representations in terms of the mathematical ideas they highlight, and explore the mathematical thinking embodied in the artifacts. In addition, the programs seek to cultivate a disposition toward inquiry by encouraging a curiosity about the thinking captured in the artifacts and a tendency to generate and consider alternative interpretations.

## Strategic Use of Classroom Artifacts

In order to study the teacher learning in these professional development contexts, we needed to articulate the facilitators' specific goals and strategies for using classroom artifacts. The result of this effort is the Strategic Use of Classroom Artifacts framework. We began the process of developing the framework by tapping the program developers' many years of experience in using artifacts in professional development. We then refined the framework through analysis of videotapes of the two professional development programs as they were implemented during the TTE study.

This paper describes and illustrates the Strategic Use of Classroom Artifacts (SUA) framework (see Table 1). In addition to its research application, we have found that the SUA framework can be used by people involved in the design and implementation of professional development centered on artifacts of classroom practice. The framework highlights the importance of helping teachers establish a disposition to attend to both the mathematical content captured in the artifact and the nature of the thinking (and understanding) that it captures.[1] These two ways of looking at classroom artifacts (i.e., with an attention to the thinking they capture and with an attention to the mathematical content) certainly overlap at times, and often are intentionally integrated. We have separated them for the purposes of explicating the framework because each serves

[1] Because the context of the TTE study was mathematical (algebraic) thinking, the framework is organized in terms of mathematical content. However, we believe that the general focus of the framework (on attention to content and attention to thinking) could be modified to address examination of classroom artifacts in other content areas.

**TABLE 1:** ***Strategic Use of Classroom Artifacts Framework***

| Attention to Thinking | Attention to Content |
|---|---|
| 1. expressing curiosity about the thinking behind artifacts | 1. considering the mathematical ideas underlying the work represented in the artifact |
| 2. distinguishing between description of work represented in artifacts and interpretation of it | 2. using a guiding framework to discuss the mathematics content in artifacts |
| 3. grounding interpretations of thinking in evidence from artifacts | 3. making connections between the mathematical ideas represented in the artifact and related mathematical ideas |
| 4. generating plausible alternative interpretations of thinking, and supporting these with evidence | 4. comparing/contrasting different representations of mathematical ideas represented in artifacts |
| 5. seeing strengths (not just weaknesses) in the thinking and understanding captured in artifacts | 5. using the exploration of the mathematics represented in the artifacts to develop/engage norms of mathematical argument |
| 6. developing plausible story lines about the student or teacher thinking behind the work | 6. comparing/contrasting mathematical arguments and solution methods represented in artifacts |
| 7. making connections to previously studied artifacts to compare/contrast the thinking in the artifact currently under study | 7. making connections to previously studied artifacts to compare/contrast the mathematical ideas under consideration |
| 8. using discussion of the thinking represented in artifacts to connect with issues of one's own teaching practice | 8. using discussion of content represented in artifacts to connect with issues of one's own teaching practice |

| Links to Practice: Teachers think about and discuss |
|---|
| 1. their own and others' classroom dilemmas |
| 2. the kinds of student reasoning and understanding they see (and don't see) among their own students |
| 3. how to promote deeper understanding among students |
| 4. the mathematical ideas elicited by different mathematical tasks and problems |
| 5. how different mathematical tasks and problems will generate evidence of student thinking in the classroom |

as a somewhat different lens on the use of classroom artifacts.

To briefly illustrate the kinds of attention to student thinking the framework is meant to highlight, consider the following excerpts from transcripts of conversations among teachers in one of the ATT seminars. These are taken from the final (13th) session of the seminar, during which time teachers studied three students' solutions to the Crossing the River problem. In the following excerpted conversation Linda, a high school teacher, and Tara, a fifth grade teacher, are working together, trying to follow the thinking of "Student A" (see Figure 1).

Linda and Tara are focusing on question 5c, which asks what happens to the rule if [any number] of adults and 11 children need to cross the river.

Linda: Oh wait a minute, they're saying repeat this nine times, so two kids across and one kid comes back, you repeat that nine times that's eighteen, one adult crosses, one kids comes back, two kids cross, one kid comes back, repeat that A -1 times, so let's say we have eleven kids, and let's just say five adults, which would be 5 x 4 would be 20 trips to cross, and the kids were 22 – 3, which would be…

Tara: 19

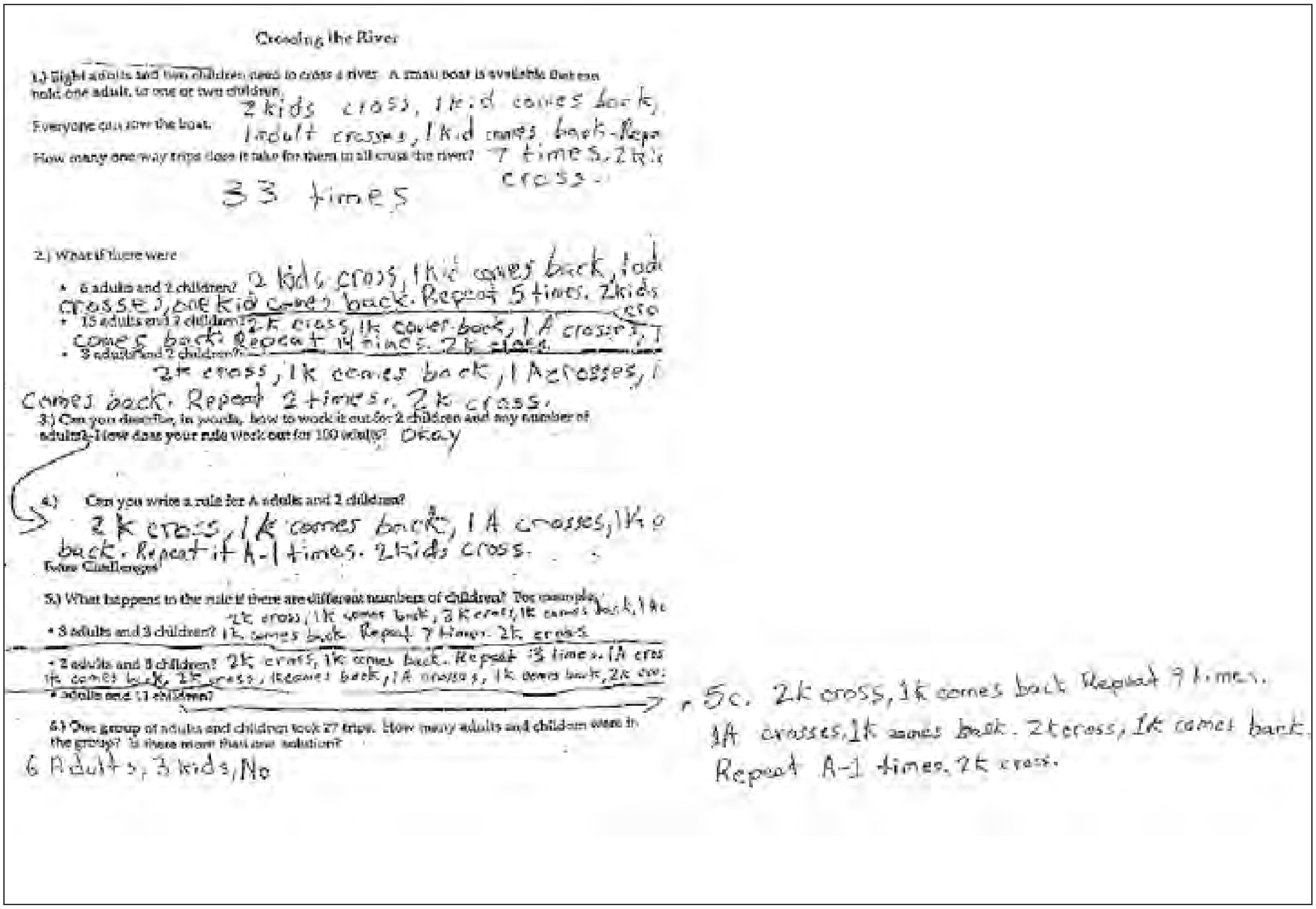
Linda: thank you, that would give us 39 trips, so this is 18, yeah, they're off one. But then…

Tara: Because they forgot that the kid needs to go back. Is that why they're off?

Linda: I don't know.

[2] All names of teachers are pseudonyms.

**FIGURE 1:** ***Student A's work on Crossing the River***




Tara: Two kids across one kid comes back [mumbles] see the kid needs to get back again.

Linda: This is off too though — "repeat A-1 times" to get the adults across. [mumbles] which would be four times, and then two kids cross which would be one time. Now they seem to realize in the end that two kids have to come back across. I think that's what that is. So that's 23.

Tara: I'm trying to think what their strategy would be. They did chunk that by trips. You know what I mean? By words, they chunked by words.

*Here, the teachers begin to move slips of paper representing children and adults back and forth to help follow the student's solution*

Tara: Now they're starting to get the adults.

Linda: Right, but they're trying to get the kids across….Now to get an adult across. One adult crosses, one kid comes back. Two kids cross. This person comes back. One kid comes back. Why are two kids crossing now, why are they not sending an adult? Two kids cross, one kid comes back, then repeat that. One adult, there's one trip, two trips, three trips, four trips.

Tara: Are they the same? Subtract here? Repeat…

Linda: Would that work? Three adults we would make one, two, three, four. One, two, three, four trips. For each. No, that doesn't seem right. . . .

In this excerpt, Linda and Tara both express curiosity about the thinking behind the piece of student work they are examining (Attention to Thinking #1), asking questions about what the student could mean by the instructions for moving A adults and 11 children. As they do so, they try to re-enact the students' solution methods, grounding their interpretations of Student A's thinking in the written evidence (Attention to Thinking #3). The teachers alternate between stating parts of the rule that the student wrote on his or her paper, and offering interpretations of how that rule might make sense to the student and/or as a problem solution. Furthermore, Tara attends to the mathematical content (Attention to Content #2) when she hypothesizes about the student's use of chunking. (Chunking is an element in the algebraic habits of mind framework that guides the ATT seminars.)

When the teachers convene as a whole group, they work together to reconcile their various interpretations of the student's thinking.

> Linda: We were just trying to figure out. . .where that was coming from, the nine times, the A-1, the two kids across, just what exactly was the logic going on here. . . . We kind of figured out where the '9 times' comes from but I don't think we figured out where the A-1 came from, and then the two kids cross was the two kids coming back at the very end. But to get the 5c — to get the eleven kids across they needed to do a repeat of that first 'two kids across — one kid comes back' nine times.
>
> Tara: At first we thought they forgot that last trip but then we saw at the very end of the problem they remembered those two kids need to come back.
>
> Mikki: Wasn't their A-1 the number of adults minus one? Because they acted out getting the first adult over, so there's your four trips, and then repeat it A-1 times.
>
> Darcy: If there is, because if there's only one adult — so 'one minus one.' you repeat it zero times and then two kids cross.
>
> Linda: Oh! Yeah maybe because it got cut off on that one. Maybe they were thinking there weren't any adults. Is that what you're saying?
>
> Darcy: Yeah, because it just says, it doesn't say adults, wait, what was the original problem…adults A and eleven children, so maybe they knew it was a variable and any value can go in and if it is that's what you need to do…
>
> Linda: But it should be adult, repeat A times — not A-1…
>
> Darcy: But no, they already got one adult over.
>
> Linda: Where?
>
> Darcy: After it says repeat 9 times, then it says, 'one A crosses, one kid comes back, two kids cross, one kid comes back, repeat A-1 times,' and then two kids cross.
>
> Linda: So then you're defining repeat as not including the first round. So when they repeat that other thing nine times they've actually got two kids, they have an extra step in there.
>
> Facilitator: So if repeat means include the first step they've got too much?
>
> Linda: Exactly.
>
> Facilitator: And if repeat means just don't cross the first one then…
>
> Linda: Then they're short.
>
> Tara: They mean don't count the first one, I think, because in [problem] number 4 they do the same thing, 'repeat it A-1 times.'
>
> Cammy: I took it to mean this is the pattern, repeat it A-1 times. […]

Here, we can see teachers calling on the evidence from the written student work to support their different conjectures about what Student A means by "repeat 9 times" (Attention to Thinking #3 and #4). Tara's last comment (". . . in [problem] number 4 they do the same thing, 'repeat it A-1 times' ") seems to be an effort to develop a plausible story line for this student's thinking by looking for consistency in how the student approached different problems (Attention to Thinking #6). She reasons that, if Student A's meaning of "repeat" was reasonably clear in problem 4 (i.e., "don't count the first set of instructions as part of the repeat), then the instructions probably mean the same thing in problem 5.

The final portion of transcript, also from the whole group discussion, illustrates ways the teachers attend to the mathematical content of the artifact. Here, teachers use the algebraic habits of mind framework to shape their discussion (Attention to Content #2) and consider the representations of mathematical ideas used by the students (Attention to Content #4).

> Facilitator: Often, going into student work provides me a new way of looking at the mathematics, some insights into the mathematics itself, was any of that going on, I think you said it was happening for you, Mikki?

> Mikki: We had solved the problem, and we came up with for when they changed the number of children 4A for the adults plus 2 x the number of children minus three, and the numbers worked out and I accepted that as the answer but I didn't know where the minus 3 came from until I looked at student B who was looking at it separately as the going and returning … the way that the child broke it up into 2a for one way and 2a for the other…the way his or her formula was very explanatory of the actual process, and he was the one who actually drew the model that went along with his thinking.

> Wally: . . .Student A, he chunked the cycle times the number of times it was repeated then brought the kids back. Whereas. . .Student B was very much into, he built this model, and he compared the number of trips to go over across the river and the number of trips to come back, so there was one more trip to cross the river then there were coming back in all of them, and the third fellow did a very different approach…Student C comes in and it's like, six adults times 2, times 2. Now, I don't know if that was a different approach to chunking because 2 x 2 is the 4. A different way to basically put the chunking down or…

These transcript excerpts illustrate two categories of the SUAs: how teachers' discussions of classroom artifacts focus on student thinking and on the mathematical ideas represented within them. In addition, the framework includes a "Link to Practice" category, which makes explicit the connection to classroom practice.

## Using the Framework as a Tool for Professional Development

While we originally developed this framework as a research tool, it soon became apparent to us that it could also serve as a professional development tool, offering a coherent articulation of goals to guide professional development experiences that are grounded in the use of classroom artifacts. By identifying areas of attention that teachers don't necessarily gravitate to on their own, the framework can help provide guidance for developers, facilitators, and participants regarding effective use of classroom artifacts. Facilitators can model, highlight, and elicit the kinds of behavior and thinking included in the framework. For example, in the final transcript excerpt above, it is the facilitator's question about mathematical insights that initiates the conversation about representing the solution in different ways.

The idea of the framework is to provide a lens for focusing the work of the facilitator, as well as for interpreting the participants' thinking: both play an active role in shaping the discussion of the classroom artifacts. Facilitators may choose to explicitly share the framework with teachers so they can examine their own lenses on analysis of classroom artifacts, and also have a guide for the kind of discussion in which they should be engaging. Furthermore, facilitators and researchers can use the framework as a guide for examining teachers' learning over the course of practice-based professional development.

Having explicit guidelines and strategies can be useful both for creating new professional development materials and for helping facilitators to effectively use classroom artifacts in professional development settings. In terms of creating new materials, we hope that our articulation of guidelines and strategies will encourage discussion among developers regarding goals for teachers' use of artifacts as data for inquiry and the challenges involved in producing professional development programs that do so. Though there are currently a number of very thoughtfully constructed programs available (e.g., Barnett, 1998; Lampert & Ball, 1998; Driscoll & Moyer, 2001; Driscoll et al., 2001; Merseth, 2003a, 2003b; Miller & Kantrov, 1998; Seago, Mumme, & Branca, 2004; Schifter et al., 1999a, 1999b), for the most part their developers have not been explicit about the principles that guided their creation.

Additionally, a potentially promising use for these strategies is an articulation of the kinds of artifacts are useful for different kinds of inquiry. Just as not all manipulatives are useful or good for teaching every mathematical idea, it is likely that different kinds of artifacts are useful for helping teachers examine (and develop) different aspects of their practice. This kind of analysis would lead to more judicious and targeted use of artifacts in professional development. By providing a starting point for this line of thinking about the use of different types of classroom artifacts, and by articulating the specific ways that classroom artifacts can be used in professional development, the SUA framework can be used as a jumping off point for examining more closely the goals and learning outcomes of using classroom artifacts in professional development.

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