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Ben Saylor

June Apaza

Vicki Kapust

Susan Roth

Becky Carroll

*See next page for additional authors*

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## A Partnership's Effort to Improve the Teaching of K-12 Mathematics in Rapid City, South Dakota

### Authors

Ben Sayler, June Apaza, Vicki Kapust, Susan Roth, Becky Carroll, Pam Tambe, and Mark St. John

**A Partnership's Effort to Improve the Teaching of K-12 Mathematics  
in Rapid City, South Dakota<sup>1</sup>**

Ben Sayler<sup>2</sup>, June Apaza, and Vicki Kapust  
Black Hills State University

Susan Roth  
Rapid City Area Schools

Becky Carroll, Pam Tambe, and Mark St. John  
Inverness Research Associates<sup>3</sup>

**Abstract:** Over the span of ten years, a National Science Foundation-funded partnership effort has collected and analyzed multiple forms of evidence, both direct and indirect, about improved teaching of mathematics within Rapid City Area Schools. This article describes the project's impact on K-12 teaching and factors contributing to that impact. The authors argue that improvements in teaching are attributable largely to a robust infrastructure established to support teacher growth. Direct evidence includes classroom observations conducted by the project's external evaluation team. Indirect evidence exists in the form of data on student outcomes: achievement on the state's multiple-choice accountability measure and achievement on project-administered performance assessments.

**Keywords:** (K-12 mathematics education, teacher professional development, partnership, systemic reform)

*Project PRIME (Promoting Reflective Inquiry in Mathematics Education)* began in 2002 with funding from the National Science Foundation (NSF). A member of the initial

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<sup>2</sup> Correspondence concerning this article should be addressed to [Ben.Sayler@bhsu.edu](mailto:Ben.Sayler@bhsu.edu)

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cohort of NSF-funded Math and Science Partnership programs, *PRIME* was originally funded for five years. The award period has been extended several times and is now slated to conclude in 2013, 11 years after its inception. *Project PRIME* has been working to improve the teaching and learning of K-12 mathematics within Rapid City Area Schools, South Dakota's second largest school district, and to improve the preparation of teachers at Black Hills State University, South Dakota's largest producer of teacher education majors. Project partners include Rapid City Area Schools (RCAS), Black Hills State University (BHSU), Technology and Innovation in Education (TIE), a nonprofit education service provider, and Inverness Research Associates, the external evaluator.

### **Definition of Effective Teaching**

Key elements of effective mathematics teaching as defined by *Project PRIME* include:

- Providing students with rich, meaningful, challenging mathematical tasks;
- Focusing on big mathematical ideas and on connections among them;
- Creating a safe and productive classroom culture -- one that fosters a community of learning;
- Paying attention to conceptual understanding, procedural fluency, student discourse, mathematical representation, and student dispositions; and
- Drawing from a depth of pedagogical content knowledge to recognize patterns of student thinking, anticipate and diagnose misconceptions, and guide the learner in productive directions, especially through asking questions.

*PRIME* has arrived at these key elements by drawing from the mathematics education literature. Resources used early within the project to develop a common vision among the project's leadership team, district math teacher leaders, building principals, university

faculty, and other project staff included *Adding It Up* (Kilpatrick, Swafford, & Findell, 2001) and *Making Sense: Teaching and Learning Mathematics with Understanding* (Hiebert et al., 1997).

### **District Profile**

Rapid City Area Schools includes 15 elementary schools (kindergarten through grade 5), 5 middle schools (grades 6 through 8), and 3 high schools (grades 9 through 12). It employs approximately 450 teachers of mathematics (including elementary and special education teachers), and it has a K-12 enrollment of approximately 13,000 students. Thirty-seven percent of students qualify for free or reduced-price lunch, and 24% are non-White (15% American Indian, 7% other non-White, 2% two or more races). Rapid City represents the largest off-reservation population of American Indian students in South Dakota.

### **Project Goals**

*PRIME*'s two overarching goals are: 1) to improve student achievement for all K-12 students within Rapid City Area Schools, and 2) to increase and sustain the quality of K-12 teachers of mathematics. Central to goal one of serving *all* students is a commitment to educational equity, seeking in particular to meet the needs of American Indian students and those who are economically disadvantaged. Project sub-goals include reducing the achievement gap between American Indian and non-American Indian students and improving high school graduation rates.

### **Project Design**

At its core, *Project PRIME* is a teacher professional development initiative. The project was initially designed to allow every teacher of mathematics within Rapid City Area

Schools to participate in approximately 100 hours of professional development over the span of five years. Teacher participation has been voluntary throughout the project, but the majority of eligible teachers within the district have now far exceeded the envisioned 100 hours of professional development, with some having completed many hundreds of hours. Some have even earned a master's degree in curriculum and instruction at Black Hills State University, with an emphasis in mathematics education, and received a state-level endorsement as a K-12 Mathematics Specialist. Both the master's degree, with emphasis in mathematics education, and the state endorsement were created as a result of *PRIME*.

When the project began, it was the *partnership* that offered the professional development. Over time, what was once a "project within the district" has become the district's mathematics program. Thus, the language has changed such that it is now the *district* that offers the professional development, but still with support of the partnership. In aggregate, the district currently provides approximately 10,000 to 15,000 hours of mathematics professional development per year<sup>4</sup>. The two primary categories of teacher professional development are 1) district-wide offerings, including graduate-level coursework, and 2) building-based offerings, including classroom coaching and lesson study.

In addition to professional development for teachers, the project has provided professional development for building-level administrators and has supported the adoption and implementation of new instructional materials. Also, throughout its 10-year duration, the project has made abundant and strategic use of student-level, classroom-level, and system-wide data to motivate and sustain change, to highlight successes, to raise

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<sup>4</sup> The accounting is such that if 200 teachers participate in 40 hours of professional development each, then the district has provided a total of 8,000 hours of professional development.

awareness about areas in need of additional attention, and to refine the project design (Sayler & Apaza, 2006).

Project components fit together as a coherent whole, with each element supporting the others. For example, the graduate-level coursework for teachers has helped to build a common vision for quality instruction across the district and to motivate change. New instructional materials have helped teachers to put the common vision into practice. Math teacher leaders have helped classroom teachers to implement new instructional materials and to refine their practice. Administrator training has helped principals to recognize high quality mathematics instruction and to create a supportive building climate.

#### Graduate-level Coursework

The project has offered a mix of internally and externally developed courses, typically 30 contact hours each, offered for two graduate credits. Central to the coursework has been a strong focus on mathematical knowledge for teaching (Ball & Bass, 2003). Courses have been offered to deepen teacher content knowledge, build pedagogical content knowledge, increase understanding of student thinking, explore and discuss implementation of specific instructional materials, and build leadership capacity.

Courses have typically brought teachers together for a week in the summer or for a few hours per week over the course of a semester. In courses designed to deepen content knowledge, teachers typically have engaged in rich mathematical tasks, working in small groups, seeking multiple solution methods, asking questions of one another, and engaging in whole-class discussion. In courses designed to build understanding of student thinking, teachers have examined K-12 student work, viewed videotapes of students being interviewed about mathematics, and conducted their own interviews. Numerous courses

have also featured discussion of mathematics education articles, books, and K-12 instructional materials. Additional details about the project's coursework are provided in Appendix A.

### **Classroom Coaching**

Building-based math teacher leaders were hired soon after the project began. Math teacher leaders serve as resources, helping classroom teachers to reflect on and refine their instruction, organizing and facilitating study sessions at the building level, and encouraging teachers to participate in the district-wide professional development offerings. As the project has matured, these positions are now all funded with district resources outside of the NSF award. The number of positions fluctuates from year to year and from school building to school building, but in recent years there have typically been 20 to 25 elementary math teacher leaders and 5 secondary math coaches across the district. The titles differ between the elementary and secondary levels, but the duties of math teacher leaders (elementary level) and math coaches (secondary level) are similar. The district has also employed a model in which select secondary classroom teachers retain fulltime teaching duties within their buildings, receive special training, and then provide professional development for their colleagues outside of the duty day and during summers.

Over the duration of the project, coaching in the district has evolved to take a student-centered approach. Student-centered coaching involves: 1) setting specific standards and curriculum based targets for students, and 2) working collaboratively with classroom teachers to ensure these targets are met. In student-centered coaching, a teacher and coach work together to use student evidence to adjust instruction. Student-centered coaching strives to add value to a teacher's work with students; the coach's role is



to think alongside a teacher, rather than to serve as an "expert" who comes in to tell a teacher how to teach. Coaches work in partnership with teachers to improve students' achievement of intended instructional outcomes.

Professional development for the math teacher leaders and coaches has been based, in part, on content-focused coaching (West & Staub, 2003) and cognitive coaching (Costa & Garmston, 2002). A version of lesson study (Gorman, Mark, & Nikula, 2010) has also been employed within the district. Additional details about professional development of math teacher leaders and lesson study are provided in Appendix B.

### **Administrator Training**

During the first few years of *PRIME*, project leaders came to see that principals and other district administrators would benefit from their own professional development to strengthen their support of the teachers within their buildings, as well as math teacher leaders and coaches. Project leaders identified a program called *Lenses on Learning*, developed by Education Development Center (Grant et al., 2003a, 2003b, 2006), and attended training. Once trained, these project leaders then offered *Lenses on Learning* training to RCAS administrators in 15-hour increments (one graduate credit each). All building administrators were required to take the first course in the series (*Lenses on Learning I*) and had options to take the second and third courses. Additional details about administrator training are provided in Appendix C.

### **Logic Model**

*PRIME*'s logic model (Figure 1) starts with teacher professional development. Through professional development, teachers deepen their content knowledge, increase their understanding of student thinking, and come to have improved dispositions about

mathematics. Changes in these teacher attributes lead to improved classroom practice. Improved classroom practice, in turn, produces improved student outcomes. Student outcomes of particular importance to *PRIME* include attitudes and dispositions related to mathematics, academic achievement, and reduced achievement gaps.

Although the project emphasizes teacher professional development as the primary intervention, the project also recognizes the importance of numerous other supports, including quality instructional materials, administrative support, parent and community support, assessments aligned with the instructional materials, and a constructive education policy environment.

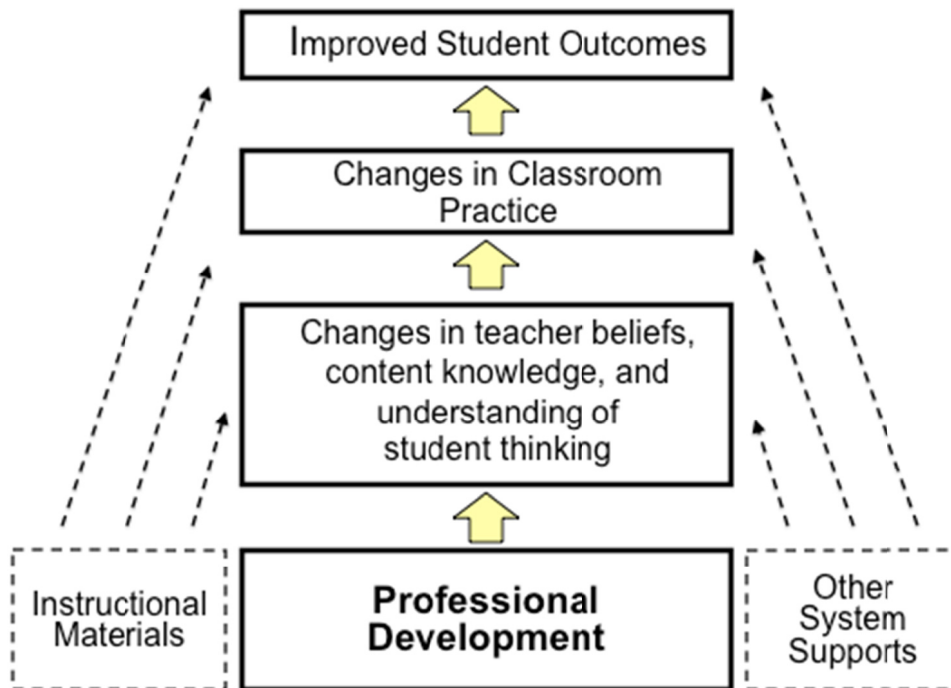


Figure 1. Schematic of *Project PRIME*'s Logic Model.

Each arrow within *PRIME*'s logic model has its own research base. Hill et al. (2008), for example, explored the relationship between teacher knowledge and quality of instruction. Ball & Cohen (1996) considered the influence of instructional materials on

teacher knowledge. Campbell & Malkus (2011) studied the impact of math coaches on student achievement. While there exists a sizeable body of research to build upon, this type of work is complex with plenty still to learn. The authors believe this article contributes to the existing body of research as it examines the implementation of multiple project elements in combination with one another across an entire K-12 district and extending over a ten-year period.

All of *PRIME*'s component elements support one another and have been assembled into a coherent improvement effort. Different pieces of the system must work in concert with others. Teachers must be well supported with staff development opportunities. Instructional materials must be of high quality and well aligned with the staff development. Principal and community expectations must be congruent. *PRIME* has attended to dimensions across the system, and all the while, the partnership has paid careful attention to measurable outcomes.

## **Results**

The most direct evidence about the quality of mathematics instruction within Rapid City classrooms and about changes in teacher practice over the project's ten-year duration come from classroom observations. Indirect sources of evidence include student achievement data and measures of teacher knowledge. Indirect evidence about improvements in teaching is presented first, with the balance of the article devoted to changes in teacher practice.

### **Student Achievement**

Two types of student outcome data are shared here: 1) student achievement on the Dakota Standardized Test of Educational Progress (DSTEP), South Dakota's statewide

accountability measure; and 2) student achievement on a project-administered performance assessment, the Balanced Assessment in Mathematics, developed by the Mathematics Assessment Resource Service (MARS).

*Dakota Standardized Test of Educational Progress (DSTEP)*. From the first year of the project through the most recent data available, 2003 through 2011 (Year 1 through Year 9), the percentage of RCAS students scoring at the proficient level or above on the DSTEP increased from 53% to 72% across all grades tested. While that represents significant growth, it essentially mirrors the growth of the rest of the state, which increased from 60% to 78% scoring at the proficient level or above. RCAS has outperformed the state somewhat at elementary grades and underperformed the state somewhat at secondary grades, but in aggregate, growth within RCAS has paralleled the rest of the state on this measure.

A more powerful DSTEP improvement story exists related to the closing of the achievement gap for American Indian students and for those identified as economically disadvantaged. The gap in achievement between American Indian students and non-American Indian students in RCAS in Year 1 was 37 percentage points. By Year 9, that gap had closed to fewer than 22 percentage points. Similarly, the gap for economically disadvantaged students in RCAS dropped from 35 percentage points in Year 1 to 19 percentage points in Year 9. For the rest of South Dakota over the same period, the gaps have decreased, but much less dramatically. Key to closing the achievement gaps within RCAS has been strong growth in performance among American Indian students and those identified as economically disadvantaged. Additional details about student achievement on the DSTEP are provided in Appendix D.

*Mathematics Assessment Resource Service (MARS) Tests.* To complement DSTEP data, the project introduced Balanced Assessments in Mathematics, developed by Mathematics Assessment Resource Service (MARS). MARS tests are open-response performance assessments that include five in-depth tasks spanning four mathematical strands: number and operations; algebra; geometry and measurement; and data analysis, statistics, and probability. The project considers MARS tests to be well aligned with *PRIME*'s overall vision and approach.<sup>5</sup>

The project administered MARS tests to a sample of 4th and 8th graders in the spring of Year 3 and again in the spring of Year 9. Student achievement on MARS from Year 3 to Year 9 at grade 4 increased from 58% to 77% scoring at the proficient level or above. At grade 8, performance increased from 30% to 42% scoring proficient or above. The growth at grade 4 was statistically significant with Cohen's effect size of 0.4 (medium effect),  $p < 0.1$ . The growth at grade 8 was statistically significant with Cohen's effect size of 0.5 (medium effect),  $p < 0.05$ . Additional details about student achievement on MARS tests are provided in Appendix E.

### **Teacher Knowledge**

The project conducted a small study in Years 2 through 4 to examine the impact of its professional development offerings on teacher knowledge (Sayler, Apaza, Austin, & Roth, 2010). A group of 46 RCAS teachers volunteered to take a test of their content and pedagogical content knowledge during Year 2 of the project and again two years later, using parallel forms of the *Learning Mathematics for Teaching (LMT)* measures (Hill & Ball, 2004). The average amount of professional development completed by each of these

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<sup>5</sup> MARS tasks provide students with a real-world context, and student must communicate the process by which they arrive at an answer.

teachers between test administrations was 80 hours. Each participant had completed an average of 60 hours of professional development within the project at the time of the pre-test and 140 hours at the time of the post-test. The teachers in the sample showed statistically significant growth on the *LMT* instrument over the two-year span with a Cohen's effect size of 0.8 (large effect),  $p < 0.01$ . *LMT* scores are reported as standardized scores with a mean of 0 and standard deviation of 1. The average pre-test score for this sample of teachers was -0.1 ( $\sigma = 1.9$ ), and the average post-test score was 1.7 ( $\sigma = 2.7$ ).

While the teachers in the sample did participate in considerable professional development between the pre and post-test, the study did not examine the relative impact of specific types of professional development (e.g., classes versus coaching). Teacher growth may also be attributable to other project components, outside of professional development, such as the introduction and implementation of new instructional materials.

### **Teacher Instructional Practice**

Direct evidence about the quality of mathematics instruction within Rapid City Area Schools and about changes to instruction over the course of the project comes from classroom observations conducted by the project's external evaluation team, Inverness Research Associates. Inverness collected the first set of classroom observation data in the spring of Year 2, focusing primarily on elementary grades, and including a few observations at middle school. In Year 3, they focused entirely on secondary grades, both middle and high school. In Year 7, they conducted observations across the full span, K-12. In Year 9, for reasons described later, they looked exclusively at middle school. Inverness conducted other evaluation activities in other years, but Years 2, 3, 7 and 9 were times of intensive site visits that included the rating of lessons in randomly selected classrooms.

During each of these intensive site visits, a team of three to seven researchers came to Rapid City for multiple days and observed teaching practice across the district (in addition to conducting other evaluation activities). Researchers visited classrooms in pairs or alone, having made arrangements a few weeks in advance with the teachers to be observed. Prior to observing a lesson, the researcher(s) interviewed the teacher about what was planned. Following the lesson, they asked the teacher to reflect on how it went.

*Classroom observation samples.* Inverness used a random stratified sampling approach to select teachers for observation. Project staff provided Inverness with a list of teachers who taught mathematics on a regular basis in a whole-class setting and, therefore, were observable. The list of teachers indicated teaching assignment, grade level, building, and number of hours of professional development completed within the project. The population of observable teachers within the district each year was approximately 330: 270 elementary teachers, 30 middle school teachers, and 30 high school teachers. In the early years, Inverness sought a representative sample of classrooms across the district in terms of schools, grade levels, those who had participated in 20 or more hours of professional development, and those who had not. Once Inverness drew the samples, teachers were invited to participate and were assured strict confidentiality. With this assurance, teachers were typically quite willing to be observed.

In later years, the sampling procedure remained similar, but Inverness also did some intentional re-sampling of teachers who had been observed in earlier years. In total, Inverness conducted 74 classroom observations reported in this study: 33 lessons in Years 2 and 3 combined, spanning both elementary and secondary, 27 lessons in Year 7, again

spanning both elementary and secondary, and 14 lessons in Year 9 at middle school grades only.

*Classroom observation protocol.* Each lesson was rated using a classroom observation protocol developed by Horizon Research, Inc. (2000a) for evaluation of the NSF-funded Local Systemic Change projects. This protocol was designed to align with the National Council of Teachers of Mathematics (2000) *Principles and Standards for School Mathematics* and is congruent with *PRIME*'s definition of effective instruction.

The protocol asks researchers to rate lessons across several dimensions, including lesson design, implementation, mathematics content, and classroom culture. Then the researcher synthesizes subcomponent ratings into an overall "Capsule" rating. Capsule ratings range from Level 1 (*Ineffective Instruction*) to Level 5 (*Exemplary Instruction*). The middle rating is Level 3 (*Beginning Stages Effective Instruction*). Level 3 (and Level 3 only) is subdivided further into increments of 3-Low (3L), 3-Solid (3S), and 3-High (3H). The project considers lessons rated 1 and 2 to be weak, lessons rated 3L and 3S to be competent, and lessons rated 3H, 4, and 5 to be strong. In the results that follow, lessons rated 3H, 4, and 5 are referred to as "highly-rated."

*Researcher preparation.* Inverness researchers conducting the *PRIME* classroom observations were trained by Horizon Research staff in the use of the classroom observation protocol as part of working on the evaluation of the Local Systemic Change projects. Over the course of a two-day training, researchers viewed and scored videotaped lessons and had to demonstrate sufficient inter-rater reliability on standardized "rating keys" (Horizon Research, Inc., 2000b). Since their initial training, Inverness researchers had observed lessons in pairs on a regular basis and conducted hundreds of classroom



observations across the country using the protocol. Training, pairing, and repeated use of the instrument helped to ensure high inter-rater reliability.

*Data analysis.* Frequency distributions of classroom observation ratings for different years and different grade bands are displayed graphically in Appendix F. To compare means, rating levels have been equated to numerical ratings. Rating level 3L has been equated to a numerical rating of 2.5, and rating level 3H has been equated to a numerical rating of 3.5. Means are compared using Cohen's effect size. The sample sizes involved are too small and the ratings are not normally distributed such that a t-test can be employed and p-values interpreted. Additionally, rating distributions have been consolidated into percentages of highly-rated lessons (3H, 4, and 5) and compared with national samples (Weiss, Pasley, Smith, Banilower, & Heck, 2003). These comparisons are reported in Appendix F as well.

### **Elementary Classroom Observation Findings: Year 2 versus Year 7**

Elementary instruction was quite strong in Year 2 (the earliest observations), but considerably stronger still by Year 7. Average ratings were 3.3 ( $\sigma = 0.8$ ) in Year 2 and 3.8 ( $\sigma = 1.1$ ) in Year 7. Growth from Year 2 to Year 7 is characterized by an effect size of 0.6 (medium effect). By comparison to the national sample, the elementary lesson ratings are remarkably high. Already in Year 2, elementary instruction exceeded the national sample by a wide margin, and by Year 7, the strength was even more pronounced (see Appendix F).

### **Secondary Classroom Observation Findings: Year 3 versus Year 7**

Classroom observation ratings at the secondary level in Year 3 were markedly lower than those at the elementary level in the same timeframe and showed negligible growth as of Year 7. The average rating at the secondary level in Year 3 was 2.4 ( $\sigma = 0.8$ ), and the

average rating in Year 7 was 2.5 ( $\sigma = 1.1$ ). Growth over this period is characterized by an effect size of 0.1 (between zero effect and small effect). Low observation ratings and lack of growth were troubling, but national comparison data (see Appendix F) indicated that Rapid City was not alone. In fact, RCAS exceeded the national sample for highly-rated lessons at the secondary level in both Year 3 and Year 7, but still RCAS and the project as a whole were highly motivated to improve.

### **Comparison of Elementary and Secondary Classroom Observation Findings: Year 7**

After completion of evaluation activities for Year 7, the external evaluation team met with the project leadership team to present classroom observation findings and discuss program strengths and challenges, drawing on the full range of evaluation components (e.g., staff interviews, student focus groups, meetings with teacher leaders and coaches). The status of the efforts at the elementary and secondary levels were in stark contrast to one another. Elementary was doing great; secondary was not. Inverness noted some progress at the secondary level with pockets of strength, but clearly more work was needed to build a coherent K-12 program.

There were several critical components that contributed to the widespread success at the elementary level. These components represent a complex combination of assets the district had in place prior to *Project PRIME*, assets created through *PRIME*, and assets that were leveraged by the *PRIME* funding. They include:

- a clear vision for elementary mathematics teaching and learning consistent with national standards and research;
- a direct and explicit message from top district administrators about the nature and direction of elementary mathematics;

- the adoption and implementation of high-quality, research-based instructional materials;
- professional development for classroom teachers and ongoing classroom support from teacher leaders focusing on mathematics content, pedagogy, and the specific instructional materials;
- ongoing professional development and support for teacher leaders led by the district's elementary mathematics coordinator; and
- principals who were knowledgeable about and supportive of the mathematics improvement efforts.

In contrast to the strengths found at the elementary level, the external evaluation team found the following at the secondary level:

- lack of a clearly articulated district vision;
- lack of a unified effort to improve mathematics;
- a wide range of instructional materials in use;
- confusion about an inquiry-based approach to teaching mathematics;
- variation in principal understanding of and support for improving secondary mathematics teaching and learning.

These findings resonated with experiences across the full project leadership team. The process of bringing internal project leaders together with the external evaluation team to discuss the collection of assets and challenges was pivotal. The outside perspective and clear articulation of critical issues served to unify and inspire the project team. A truly powerful K-12 system appeared to be within the project's grasp, and project leaders committed themselves to achieve it.

### **Intensifying *PRIME* at the Secondary Level: Years 8 and 9**

The next step was to share the external evaluation findings with additional key stakeholders, including building principals, math teacher leaders and coaches, and the school board. What emerged over the next few months was a plan for an intensive effort at the middle school level, in particular. This was a time of students emerging out of a strong elementary program into an uneven and lackluster middle school program, thus making a focus at the middle grades especially timely and promising. District leaders clarified the district vision and then empowered middle school teachers to develop and implement a path forward. Out of this work came the adoption of new instructional materials, creation of new professional development offerings tailored specifically to middle school teachers, and bolstering of the teacher support system. Among the new teacher supports was the establishment of a dedicated professional development team to lead the implementation of the new instructional materials. This team was comprised of practicing middle school teachers who were implementing the new materials in their own classrooms. Team members met regularly as a group, served as leaders within their buildings, provided support to their grade-level peers, and, in turn, were supported by the district's secondary math coaches and secondary math coordinator.

### **Middle School Classroom Observation Findings: Year 9**

To check progress of the intense effort underway, the project asked Inverness to return in Year 9 and conduct classroom observations exclusively at the middle grades. In the findings that follow, all of the middle school ratings from Years 2, 3, and 7 have been aggregated into a single sample ( $N = 17$ ), and that sample is compared to the ratings from Year 9 ( $N = 14$ ). The middle school data were aggregated across Years 2, 3, and 7 in order

to arrive at a sufficient middle school-only sample size. Aggregating in this way makes sense because of the specific interest in detecting changes subsequent to Year 7 and given that the middle school observations were consistently low in Year 7 and prior. The average lesson rating for the earlier observations was 2.1 ( $\sigma = 0.7$ ), and the average rating for Year 9 was 3.3 ( $\sigma = 1.0$ ). Growth from Year 7-and-prior to Year 9 is characterized by an effect size of 1.4 (large effect).

The fact that classroom observation ratings from Year 7-and-prior had a mean rating of 2.1 affirms the project's intensive focus on the middle school level during Years 8 and 9. The classroom observation findings for Year 9 indicate an astonishing jump in the quality of instruction at middle school and suggest a highly effective effort. Furthermore, the percentage of highly-rated lessons increased from below the national comparison sample to well above.

When the external evaluation team and project leaders met to discuss Year 9 evaluation findings, the following key factors contributing to the progress at the middle school level were noted:

- a clear vision and clear message from the district about the intended nature and direction of the math program at the middle school level, resulting in greater alignment between the elementary and middle school level than seen previously;
- greater district-level and building-level leadership and support for instructional improvements in mathematics at the middle school level than seen previously;
- the adoption of new instructional materials, and the expectation that these instructional materials would be the predominant instructional materials used to teach mathematics at the middle school level;

- the ongoing professional development being provided to teachers; and
- improved principal understanding and support inquiry-based mathematics teaching.

### **Path Forward: Year 10 and Beyond**

Ten years into the project, high school teachers are now making a bold move to shift their instructional materials (see Appendix G for more details about instructional materials). High school teachers and leaders are also making plans to ramp up professional development, following the path of the recent middle school efforts and preparing for enactment of the *Common Core State Standards for Mathematics* (Common Core State Standards Initiative, 2010). Additional classroom observations at the high school level are being conducted in advance of their adoption of new instructional materials to serve as baseline data as the new materials are phased in and as the district's math program transitions beyond the end of the NSF award period. The partnership remains active and committed to support the intensified efforts at the high school level and to sustain the efforts at the elementary and middle school levels.

### **Relationships between Classroom Observations and Other Project Data**

Before concluding, it is worthwhile to note connections between the classroom observation ratings and other project data. Classroom observations provide the most direct evidence of changes in teaching within Rapid City, but student outcome data provide valuable indirect evidence that complements the classroom observations, as do measures of changes in teacher attributes and measures of changes to the system as a whole.

Student achievement on the MARS test at grade 4 serves as a good example. Those data show a pattern that closely parallels the elementary classroom observation data - with

solid performance in Year 3 and even stronger performance in Year 9. The eighth grade MARS results are consistent as well. The low student performance in Year 3 on the MARS test at grade 8 corresponds with low classroom observation ratings at middle school over the course of the project up through Year 7. The performance of the eighth graders on the MARS test in Year 9, while still below the performance of the elementary students, shows strong growth, and, again, that growth is consistent with the dramatically improved classroom observation ratings at the middle grades as of Year 9.

Another connection worthy of consideration is the connection between changes in classroom instruction and the closing of achievement gaps on the DSTEP. The project has been focusing heavily on meeting the needs of *all* learners, and achievement gaps have been shrinking on the DSTEP to a degree not evident across the rest of the state, especially gaps between American Indian students and non-American Indian students and between those identified as economically disadvantaged and those not economically disadvantaged. The reduction of these achievement gaps suggests that significant changes to instruction are occurring within RCAS classrooms and that the changes are paying off, especially for those historically underserved audiences.

From an educational research perspective, it is important to be cautious not to draw overly strong conclusions among these loosely affiliated data sets. The data in many instances have inherent limitations (e.g., teacher observation ratings not tied to student achievement scores). But from the perspective of the *PRIME* partnership seeking to change a complex system, the collection of findings is compelling, and the findings are all the more compelling due to plausible, if not completely definitive, connections between them. A hallmark of *Project PRIME* has been the tracking of system measures as described in this

article, sharing indicators of progress and persistent challenges, attending to multiple components of the logic model concurrently, and exploring connections between independent data sources.

### **Limitations of the Study**

One limitation is the small size of the classroom observation samples. Classroom observations are time consuming and require special expertise to conduct. Nonetheless, even with small sample sizes, the project has derived great benefit from having this direct, external measure of the quality of mathematics instruction and its change over time. A second limitation is that baseline classroom observation data were not collected prior to the start of the project. This precludes determination of the project's full impact over its entire span. A third limitation is that multiple project components (e.g., coursework, coaches, instructional materials) have been implemented concurrently. Project leaders perceive that having a mix of project components has been highly valuable, but having delivered a suite of interventions all at once and with a voluntary participation model, it is difficult to discern the relative impact, relationships, and optimal sequencing of individual components.

### **Lessons Learned**

The project is generating a compelling collection of data that affirms the project's vision for effective mathematics instruction. Having classroom observation data to complement student outcome data has been invaluable – to look for overlap and consistency from one data source to another, to reveal different types of findings that are only evident with one tool or another, and ultimately to help steer the project's implementation.



The project has increased its appreciation for well-designed instructional materials that are implemented consistently from classroom to classroom across the district and that build vertically from kindergarten through high school. The alignment of assessments with the instructional materials is also key. The project is pleased that RCAS students at least mirror their peers statewide on the DSTEP despite less than complete congruence between the test and the project. The MARS instruments serve as better indicators of overall project impact at the student level, but they require additional effort and resources and therefore have been administered only on a limited basis. The MARS instruments are better aligned with the direction the state is headed with the new *Common Core State Standards for Mathematics* (Common Core State Standards Initiative, 2010), however, so the need for MARS testing as a supplement to the DSTEP may soon fade.<sup>6</sup>

We have gained insights into the facets of the project that have been most helpful to teachers at different places on the path to becoming stronger teachers of mathematics – when coaching is perceived to be most helpful, when classes are, and when it matters most to have the right instructional materials. These lessons have been learned in part through teachers' self-reporting (Apaza, 2009) and also corroborated and refined through classroom observations and associated teacher interviews.

We have been reminded time and again that K-12 systemic reform requires great patience. Ten years and counting, the project still has much work to do, sustaining the progress and infrastructure at the elementary and middle grades and intensifying the work at the high school level. Additional effort is also required to fully integrate lessons from the

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<sup>6</sup> This claim is based in part on the fact that the MARS instruments have an open-response format as opposed to the multiple-choice format of the DSTEP. MARS items ask students to communicate their thinking, which is consistent with the Common Core State Standards.

project into the university setting, both for teacher preparation and for regular university mathematics classes. The district has built a strong infrastructure for continued teacher development, and the university partners have built their own capacity, learning vast amounts within the K-12 setting that is informing university transformation, but this is a long journey.

With the recent middle school efforts, we have learned the importance of a consistent and coherent message from top administration about the direction the mathematics program is moving. We have observed a wonderful example of empowering teachers to develop an instructional improvement plan and then supporting them to implement it. As the middle school effort continues and as the high school effort ramps up, instructional leadership and professional development infrastructure remain critical. The district has tremendous promise to achieve an exemplary system across all grades, K-12, but such an accomplishment will require continued nourishment of the infrastructure that has been established and continued support from the partnership. Additional reflections and advice to others engaged in similar endeavors is offered in Appendix H.

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## Appendix A: PRIME Coursework

The graduate-level coursework provided to teachers through *Project PRIME* has built on the work of many others. Examples of nationally recognized teacher professional development programs upon which the project has drawn include: Teachers Development Group (*Best Practices and Numerical Reasoning*), Mathematics Education Collaborative (*Patterns, Functions, and Algebraic Thinking* and *Building Support for School Mathematics: Working with Parents & the Public*); Education Development Center (*Developing Mathematical Ideas* and *Fostering Algebraic Thinking*); TERC (*Investigations Workshop for Transforming Mathematics: Professional Development Institute* and *Relearning to Teach Arithmetic*), and the Vermont Mathematics Partnership (*Geometry in the Middle Grades*). Other key resources have included the work of Carpenter, Fennema, Loef Franke, Levi, & Empson (1999), Richardson (1998), and Van de Walle (2003).

Instructors for *PRIME* offerings have been drawn from district, university, and other project staff, often trained by outside program developers. In some instances, entire courses have been taught within RCAS by an outside program developer or agent, typically paired with an internal project member.

There has been a shift over time in which almost all of the professional development for teachers has been developed and facilitated by project staff. The philosophy underpinning this work is consistent with the tenets of effective professional development as outlined in the *Standards for Professional Learning* (National Staff Development Council, 2001, 2011) along with the other resources previously cited.

Courses have been designed to improve teacher effectiveness in the classroom in such a way that student learning is positively impacted. The pedagogy and the mathematics tasks have

been chosen in an effort to model desirable practices within K-12 classrooms. While most of *PRIME*'s coursework was developed prior to publication of the *Common Core Standards for School Mathematics* (2010), there exists good alignment with the *Common Core* and, in particular, with the *Standards for Mathematical Practice*.

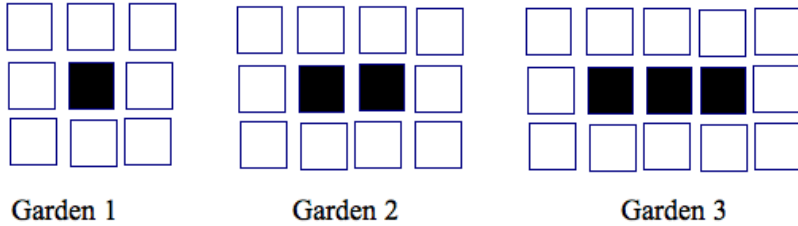
The following mathematics task and facilitator notes provide a taste of *Project PRIME* coursework. This particular task, the Garden Problem, is one of a series of tasks designed to move teachers through the process of understanding patterns used in early elementary grades and how these and similar pattern problems can be used in higher grades to develop a deep understanding of linear functions. This particular pattern was found in a *MathScope* middle school unit published by McGraw-Hill (2005), but any number of pattern problems would work just as well. The facilitator notes, written by the designer of the course, are a description of the questions to be used with a whole series of pattern problems for developing an understanding of linear functions (see facilitator notes that follow the Garden Problem).

After the facilitator notes are titles and descriptions of ten graduate-level courses developed by *PRIME*. Each course is 30 contact hours and is offered for two graduate credits. Taken together, these ten courses qualify a teacher for a K-12 Mathematics Specialist endorsement from the South Dakota Department of Education.



**Sample Mathematics Task for Teachers: THE GARDEN PROBLEM**

**Explain your thinking for all parts of this problem.** Here are three sizes of gardens framed with a single “row” of tiles. Build these three gardens using two colors of color tiles.



1. Using color tiles, build and then draw the next two steps in the pattern. How many border tiles (the white tiles) would you need for *Garden 4* and for *Garden 5*? Explain how you know. Begin a table that shows the number of tiles used for the border of each garden.
2. How many tiles would you need to make a border around gardens of each of these lengths? Explain.
  - (a.) Garden 10
  - (b.) Garden 100
3. What patterns do you notice in the models/drawings? In the table?
4. Explain how you would figure out the number of tiles you would need for a garden of any length?
5. How does your rule relate to the model (show geometrically why your rule makes sense)?
6. Graph the values in your table on a coordinate grid. Use the horizontal axis (*x*-axis) to show the input (garden) number and the vertical axis (*y*-axis) to show the number of tiles in the border for that step (the output).
7. Tell how you would find the length of the garden if you knew only the number of tiles in the border. Use your method to find the length of the garden if the following numbers of tiles are used for the border. Explain your thinking.
  - a. 68 tiles
  - b. 152 tiles
  - c. 512 tiles

**STOP here for whole group discussion.**

There were a number of methods for visualizing the ways in which the pattern was growing:

•  $2n + 6$

•  $2(n + 2) + 2$

•  $2(n + 3)$

•  $3(n + 2) - n$

8. Are these expressions equivalent? How do you know?
9. Theoretically, what would the step before Garden 1 (the “zero” step) look like? (Think about how the garden is “growing” in each step; go backwards to think about the “zero” step.) Add this information to your input/output table. Does it “match” the other patterns in the table? Add this point to your graph.
10. Using the expression that is in simplest form,  $2n + 6$ , compare your table, your graph, and the expression.
  - a. Where does the “2” in the expression “show up” in your table? In your graph? In the model?
  - b. Where does the “6” show up in your table? In your graph? In the model?

**STOP here for whole group discussion.**

## FACILITATOR NOTES

### General Instructions and Questions for Pattern Problems

- All content should emerge via small group work and whole group presentations.
  - Begin with 2-3 minutes of individual think time and then work together in small groups.
  - End with whole group processing.
1. Build or draw the next two steps in the pattern.
  2. Describe what the 10<sup>th</sup> step will look like.
  3. How many \_\_\_\_\_ (tiles, cubes, toothpicks, etc.) in the 10<sup>th</sup> step?
  4. Record your findings in a table (relate the step # to the # of \_\_\_\_\_ in that step).
  5. What patterns do you notice in the models/drawings? In the table?  
**Note: Patterns out of context are open to interpretation. For example 2,4,6,8... could be 2,4,6,8,10,12... or 2,4,6,8,2,4,6,8... or 2,4,6,8,6,4,2,4,6,8... etc.**
  6. Write a rule in words describing how the pattern is growing.
    - Recursive rule (as participants describe this pattern, “label their thinking” by explaining how this is called recursion or the recursive pattern. What is the disadvantage of the recursive rule? You always have to know the step before to use it.
    - General rule for any step number
  7. How many \_\_\_\_\_ in the 100<sup>th</sup> step? How do you know?
  8. How could you figure out the number of \_\_\_\_\_ in any step of the pattern? (the “*n*th” step)?  
This may be the recursive pattern, the general rule in words, and/or the general rule written as an expression or equation (i.e. relating the step number to the number of \_\_\_\_\_). After whole group processing of The Garden Problem, participants should be looking beyond the recursive rule for the general rule. Later, we will be relating the constant rate of change in linear function tables (the recursive rule) to the slope of the line on the graph and to the  $y = mx + b$  form of an equation.
  9. How does your rule relate to the model (show geometrically why your rule makes sense)?
  10. Can you see a different way to visualize the pattern? If so, write a different algebraic expression that matches it and show geometrically why it makes sense. **Different methods will emerge during the whole group discussion.**
  11. Write your rule for the “*n*th” step using an algebraic expression or equation.  
Have participants share different solution methods with the whole group (put on overheads, chart paper, etc: some ways to record the different approaches). Make sure it becomes clear to the whole group how each expression relates to the concrete model or drawing. Some participants may not have an algebraic expression for the first pattern problem they do. This will also emerge as participants share in whole group.

\*\*\*Refrain from simplifying these expressions at this point. We want the expressions to relate to the model. See next step.

12. Are your expressions equivalent? How do you know?  
Check several steps to see if each expression would work. Simplify the expressions. Discuss simplest form.
13. What would the “zero” step look like? Add this information to your table.  
Eventually we will relate this step to the *y-intercept* in the graph and in the  $y = mx + b$  form of an equation.
14. Graph the values in your table on a coordinate grid. Use the horizontal axis (*x-axis*) to show the step number and the vertical axis (*y-axis*) to show the number of \_\_\_\_\_.  
Have a short discussion of independent and dependent variables. Ask participants if anyone can explain; if not, facilitator may explain. They will be using just Quadrant I for the pattern problems, so use centimeter grid paper. They will use pre-printed coordinate grid paper with all four Quadrants when we get to linear functions and slope.
15. Does it make sense to connect the points?  
No, not in the context of this problem. However, you may want to see the “shape” of the graph or the “trend”. Connect the points recognizing that there is no half-step, quarter-step, etc. just to see the shape of the graph. Alternatively, connect the points with a dotted line to show that you recognize that the ordered pairs are discrete points.  
Note: Sometimes students think that you must connect the points in the order given; if the values in the table weren’t “in order” their graphs would be incorrect. Hopefully, this won’t be an issue for our participants, but be aware of the possibility that it may come up.
16. What representations have we used so far?  
Concrete models, pictures, words, tables, graphs, symbols (expressions/equations).
17. What patterns do you notice in the graph? How do these patterns relate to the model? The table? The expression?  
By the end of the series of pattern problems, participants will be looking for the slope and the *y-intercept* in all four of the representations and seeing the connections among the four.

Note: pattern and real-world problems will also be used to develop concepts of quadratic and exponential functions.

## K-12 MATHEMATICS SPECIALIST ENDORSEMENT COURSEWORK

### **ED 601: Foundations and Issues of Mathematics Education (2 credits)**

This course provides an introduction to K-12 mathematics content and process standards, makes the case for using an inquiry-oriented approach in classrooms, and looks at current research. Participants will gain an understanding of the components needed to create a learning environment that encourages and supports *all children* in building understandings, making connections, reasoning, and solving problems as described in *Principles and Standards for School Mathematics*, published by the National Council of Teachers of Mathematics. (Fulfills South Dakota Department of Education Standards 3b 3e 4a 4d [Administrative Rule of SD 24:15:06:39])

### **ED 611: Algebraic Reasoning for K-12 Educators (2 credits)**

This course is designed for K-12 educators to deepen their understanding of algebraic concepts that build from kindergarten through high school. Consistent with the *Principles and Standards for School Mathematics*, published by the National Council of Teachers of Mathematics, the course emphasizes patterns and functions; representation and analysis of mathematical situations; using models and symbols to represent quantitative relationships; and analyzing change. Instruction revolves around rich mathematical tasks and includes explicit attention to questioning, conjectures, and justification. Participants reflect on the benefits and challenges of this kind of learning environment and consider implications for their own teaching. (Fulfills SD Standards 3a 3b 3d 4c)

### **ED 621: Geometry & Measurement for K-12 Educators (2 credits)**

This course is designed for K-12 educators to deepen their understanding of geometry and measurement concepts that build from kindergarten through high school. Consistent with the *Principles and Standards for School Mathematics*, published by the National Council of Teachers of Mathematics, this course emphasizes characteristics of two- and three-dimensional shapes; spatial relationships and reasoning; transformations and symmetry; units, systems, and processes of measurement; and applying techniques, tools and formulas to determine measurement. Instruction revolves around rich mathematical tasks and includes explicit attention to questioning, conjectures, and justification. Participants reflect on the benefits and challenges of this kind of learning environment and consider implications for their own teaching. (Fulfills SD Standards 3a 3b 3d 4c)

### **ED 631: Data Analysis & Probability for K-12 Educators (2 credits)**

This course is designed for K-12 educators to deepen their understanding of data analysis and probability concepts that build from kindergarten through high school. Consistent with the *Principles and Standards for School Mathematics*, published by the National Council of Teachers of Mathematics, this course emphasizes methods of collecting, organizing, and displaying data; using appropriate statistical methods to analyze data; evaluating inferences and predictions that are based on data; and understanding and applying basic concepts of probability. Instruction revolves around rich mathematical tasks and includes explicit attention to questioning, conjectures, and justification. Participants reflect on the benefits and challenges of this kind of learning environment and consider implications for their own teaching. (Fulfills SD Standards 3a 3b 3d 4c)

**ED 641: Understanding Student Thinking in Numbers and Operations (2 credits)**

This course is designed to deepen teachers' awareness of ways that students come to understand whole numbers, rational numbers, and operations. Emphasis is placed on common student difficulties and on how teachers can help to move students from a procedural approach to conceptual understanding.

(Fulfills SD Standards 3a 3b 3d 4a 4b 4c 4d)

**ED 651: Understanding Student Thinking in Algebra (2 credits)**

Based on recent research in mathematics education, this course provides opportunities for educators to deepen their understanding of how K-12 students develop algebraic reasoning. The course focuses on conceptual and procedural understanding of the key algebraic ideas of equality, variables and equations, patterns and functions, proportional reasoning, symbolic representation, and inductive and deductive reasoning.

(Fulfills SD Standards 3a 3b 3d 4a 4b 4c 4d)

**ED 661: Understanding Student Thinking in Geometry & Measurement (2 credits)**

This course is designed to help teachers think through major ideas within the areas of K-12 geometry and measurement and to use recent research to examine how students develop their ideas. The course is also designed to raise awareness of common student misconceptions and to deepen teachers' knowledge of effective instructional practices.

(Fulfills SD Standards 3a 3b 3d 4a 4b 4c 4d)

**ED 671: Assessment for School Mathematics (2 credits)**

This course supports educators in assessing what K-12 students know, what they can do, how they think mathematically, and their attitudes toward mathematics. Current assessment practices, from informal questioning to standardized testing, are explored, and the use of assessment information to guide instruction is emphasized. The course also considers national data and examines connections between staff development, classroom practice, and student outcomes, thereby laying a foundation for discussions about the future direction of local, state, and national mathematics improvement efforts.

(Fulfills SD Standards 3e 4a 4b)

**ED 741: Historical Development of Mathematical Concepts (2 credits)**

This course traces the origins and development of key concepts in the history of mathematics starting with early Egyptians, Babylonians, and Mayans and continuing to current times.

Emphasis is given to the impact of mathematical discoveries on the civilizations that gave rise to them and to the impact of these discoveries on subsequent mathematical thought.

(Fulfills SD Standard 3c)

**ED 751: Leadership in School Mathematics (2 credits)**

This course focuses on how to provide effective professional development for K-12 teachers of mathematics and how to support meaningful change within an educational system. Lessons are drawn from research in mathematics education as well as research about improving schools.

Topics include creation of a demonstration classroom, engaging key stakeholders (e.g., parents, administrators, and community members), forming and facilitating study groups, peer coaching, mentoring, and curriculum review. (Fulfills SD Standard 4e)

## Appendix B: Other PRIME Professional Development

### Professional Development for Math Leaders

The very first professional development experience for Mathematics Teacher Leaders (Math Leaders or MTLs) was a weeklong training in 2003 to build a clear understanding of the philosophy and vision for the instructional change they were going to be supporting in the mathematics program for Rapid City Area Schools. The training focused specifically on the research articulated in *Adding it Up* (Kilpatrick, Swafford, & Findell, 2001) and *Making Sense* (Hiebert et al., 1997). The initial training also provided an opportunity for the group of Math Leaders, along with district administrators and other project partners, to work together to define roles and responsibilities of the MTLs. This training began building a collaborative work group that would continue to meet throughout the life of the project.

Mathematics Teacher Leaders meet one half-day per week to support their own professional growth. These study sessions have focused on three major areas: 1) coaching, 2) mathematics content with pedagogy, and 3) district work. The balance of time spent on these three areas is adjusted based on the needs of the district and of the Math Leaders at a particular time. Below are specific examples of study or work in each of these three areas.

**Study to improve coaching skills.** A majority of study time has focused on current research in the emerging field of mathematics coaching. The following books have served as guides:

- Content-focused coaching (West & Staub, 2003)
- The math coach field guide (Felux & Snow, 2006)
- Cognitive coaching (Costa & Garmston, 2002)
- The PRIME leadership framework: Principles and indicators for mathematics

education leaders (National Council of Supervisors of Mathematics, 2008)

- Cultivating a math coaching practice: A guide for K-8 math educators (Morse, 2009)
- Student-centered coaching: A guide for K-8 coaches and principals (Sweeney, 2011)

On-line resources from these authors have also been accessed for current articles.

In the past few years, MTLs have been asked to provide evidence of practicing the coaching strategies found in these guides. Evidence and documentation of coaching are then shared and discussed to assist all MTLs in growing as coaches. In Year 10, for example, after completing *Cognitive Coaching* training, several MTLs shared videotaped segments of themselves engaged in authentic coaching sessions and reflected on these sessions with their peers.

**Study to improve mathematics content knowledge with pedagogy.** Staff from Black Hills State University have supported district staff in offering some of the mathematics content classes from the K-12 Math Specialist endorsement sequence. Math Leaders have also had opportunities to participate in the specialist classes as they are offered across the district to classroom teachers. Three MTLs and the district's elementary mathematics coordinator have completed the full sequence of the K-12 Math Specialist endorsement.

In a usual year, about one third of MTL sessions involve mathematics content and pedagogy study. Complementing the K-12 Mathematics Specialist coursework, the *Developing Mathematical Ideas* (DMI) series (Schifter, Bastable, & Russell, 2000-2007) has served as a key resource. DMI sessions have typically been facilitated by district and university staff working together. Two MTLs attended national training to become certified DMI facilitators and teach DMI at the district level as well.

With South Dakota's adoption of the *Common core state standards for mathematics*



(2010), much of the recent math content and pedagogy study has focused on understanding the mathematics in each standard and the connection between standards and domains.

**District Work.** Over the years the MTL group has written district curriculum, standards-based report cards, and revisions to both. Pacing guides, assessments, and screeners have been developed, adapted, and implemented as well through this group of building-based MTLs.

### **Lesson Study**

A form of lesson study called the *Learning Lab Initiative* has been initiated by the district Math Coordinators and Math Leaders. Learning labs provide a setting and forum for educators to observe student learning and instruction in a colleague's classroom and reflect on practice in their own classrooms. Learning labs have focused on using formative assessment, supporting student discourse, and the use of a simple learning cycle. The learning cycle involves launching a task, monitoring and supporting student learning, and debriefing the mathematics of the lesson. An additional purpose of the learning labs has been to increase collaboration, dialogue, and reflection among teachers.

Those who designed the learning lab process recognized the importance of coaching and of follow-up over time as professional development components. Learning labs consist of three learning experiences: coaching for the host teacher, the learning lab event, and follow-up study sessions. This total learning lab experience is consistent with the Gorman, Mark, and Nikula (2010) model of lesson study that includes a cycle of planning, teaching, observing, and reflecting on a lesson.

During the coaching experience, a facilitator (a coach) meets with the lab host (a classroom teacher) to discuss a focus for the coaching cycle. Throughout the cycle, the facilitator provides support and resources to refine instructional strategies and to assist the host in

preparing for the learning lab event. The half-day learning lab event utilizes a protocol that includes a pre-brief, classroom observation, and debrief. In addition, monthly study sessions are held afterwards for the purpose of collaborating and further reflecting on the learning lab process.

Learning lab teams have been diverse in grade levels and schools. Each cohort has had multiple grades and brought together teachers from buildings that serve diverse student populations. Each cohort has studied together for a semester with four or five study sessions and three or four classroom lab observations. At the start of each lab cycle, each cohort has considered problems of practice or areas of instruction to improve and, based on the work of Wiggins & McTighe (2005), has formulated an overarching student-based essential question. Study sessions and student-centered debriefing of lessons are viewed through the lens of this essential question. Lastly, all lessons taught and discussed have been "in-sequence lessons" from district-adopted instructional materials. No new lessons have been created for the labs. The goal is to improve teacher practice in using the adopted materials. This is part of staying the course and providing consistency for students.

### **Appendix C: PRIME Administrator Training**

In the second year of the project, *PRIME* was invited by Education Development Center to receive training in the *Lenses on Learning* professional development program. *Lenses on Learning* is designed to help administrators as instructional leaders in their schools and districts, to think through the ideas that underlie standard-based reform mathematics and to relate those ideas to their own work of supporting the reform efforts. Two project staff members attended the two-week training in the three modules that comprised the program at that time.

During the first school year after *PRIME* staff were trained, all three of these modules were offered within RCAS on an invitational bases. More than half of the elementary building principals attended at least two of the three modules, as well as several district-level administrators. In the second year, the district required all building administrators to attend Module One of the training, and the majority of school administrators were able to comply. All three modules were offered each year for the next two years. In the fourth year after *Lenses on Learning* training began in the district, an additional module was released by Education Development Center with a specific focus on supervision and more secondary examples. This new module was offered to all building administrators and was well attended by both elementary and secondary principals.

Sometimes the trainings were held in a location away from the district in order to avoid distractions and allow principals to focus. On the whole, the trainings have been well received.

As one elementary principal recalls,

*In contrast to how I had been taught as a student, these initial sessions allowed us to actually experience a problem-solving approach to mathematics. We were given a problem, and we were encouraged to think and collaborate. I learned that the approaches that I had developed as an adult to solve math problems were strategies that are actually taught to students today. I remember thinking that if I had been taught math*

*in these active, engaging, sense-making ways that I would likely be more confident and competent mathematically as an adult.*

*Lenses on Learning* trainings have continued to be offered as new administrators have been added to the district.

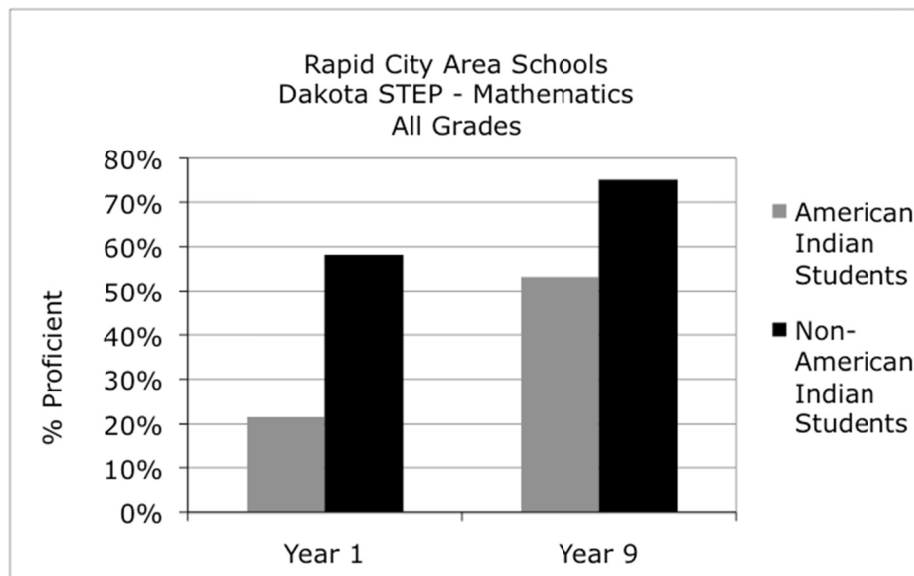
## **Appendix D: Student Achievement—DSTEP Results**

The Dakota Standardized Test of Educational Progress (DSTEP) is a multiple-choice test administered each spring at grades 3 through 8 and grade 11. It is a strong measure of procedural fluency, but less strong in measuring conceptual understanding, communication, representation, and numerous other strands of mathematical proficiency that the project values. Regardless of how well the DSTEP is aligned with *PRIME*'s overall vision and approach, it is the statewide accountability measure and holds high importance for project leaders and other key stakeholders. Student scores are reported in terms of 4 performance levels: below basic, basic, proficient, and advanced.

From the first year of the project through the most recent DSTEP data available, 2003 through 2011 (Year 1 through Year 9), the percentage of RCAS students scoring at the proficient level or above increased from 53% to 72% across all grades tested. While that represents significant growth, it essentially mirrors the growth of the rest of the state, which increased from 60% to 78% scoring at the proficient level or above. RCAS has outperformed the state somewhat at elementary grades and underperformed the state somewhat at secondary grades, but on the whole, the magnitude of growth within RCAS has tracked the rest of the state on this measure. What accounts for the overall growth in student achievement as measured by the DSTEP over the past nine years may well be increased attention statewide to mathematics during these years, with extensive professional development opportunities available both within and outside of RCAS. The growth may also be due to changes in the test instrument, changes in proficiency cutoff scores, and related measurement artifacts.

A more powerful DSTEP story exists related to the closing of the achievement gap for American Indian students and for those identified as economically disadvantaged. The gap in

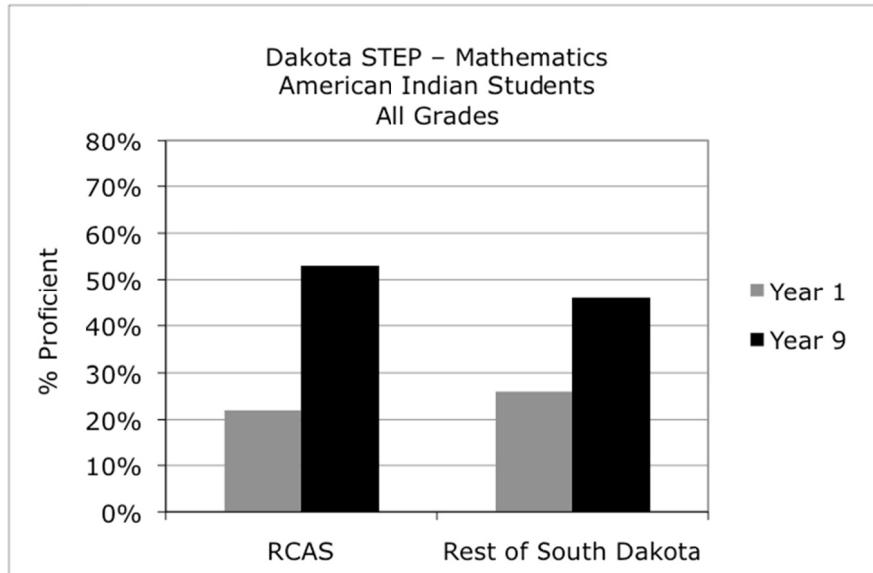
achievement between American Indian students and non-American Indian students in RCAS in Year 1 was 37 percentage points. By Year 9, that gap had closed to fewer than 22 percentage points (Figure 2). Similarly, the gap for economically disadvantaged students in RCAS dropped from 35 percentage points in Year 1 to 19 percentage points in Year 9. For the rest of South Dakota over the same period, the gaps did not close nearly as dramatically: from 37 to 35 percentage points for American Indian students and from 26 to 24 percentage points for economically disadvantaged students.



**Figure 2.** Closing of the achievement gap between American Indian and non-American Indian students in Rapid City, comparing Year 1 to Year 9.

Key to closing the achievement gaps has been strong growth in performance among American Indian students and those identified as economically disadvantaged. Figure 3 shows the growth in achievement of American Indian students within RCAS compared to those across the rest of the state. From Year 1 to Year 9, the percentage of American Indian students within RCAS scoring at or above the proficient level increased by 31 percentage points. Across the rest of the state, the increase was considerably less at 20 percentage points. The growth for

economically disadvantaged students within RCAS showed a similar increase of 29 percentage points, compared to only 19 percentage points outside of RCAS. These data suggest that *Project PRIME* is having relatively greater impact on students historically underserved in mathematics.



**Figure 3.** Growth in achievement among American Indian students in Rapid City Area Schools compared to American Indian students across the rest of South Dakota, comparing Year 1 to Year 9.

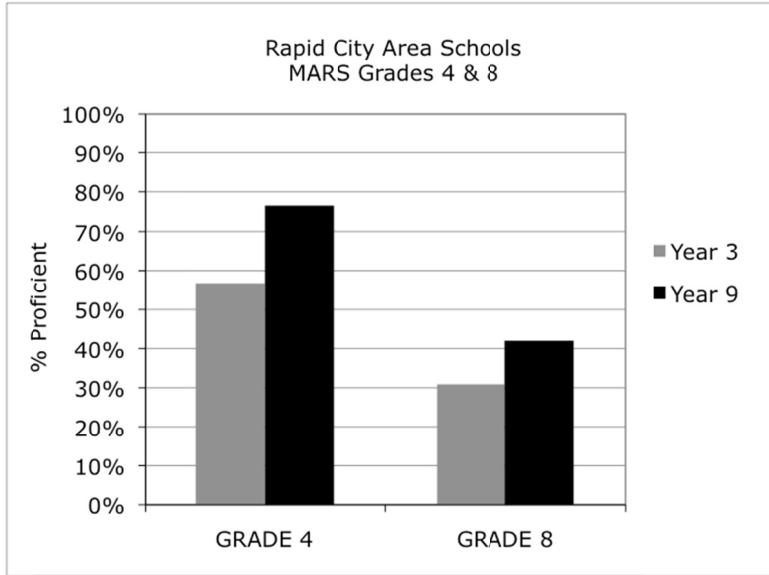
## **Appendix E: Student Achievement—MARS Results**

To complement DSTEP data, the project introduced Balanced Assessments in Mathematics, developed by Mathematics Assessment Resource Service (MARS). MARS tests are open-response performance assessments to be completed within approximately 40 minutes. Each test includes five in-depth tasks spanning four mathematical strands: number and operations; algebra; geometry and measurement; and data analysis, statistics, and probability. The project considers MARS tests to be well aligned with *PRIME*'s overall vision and approach.

The project administered MARS tests to a sample of 4th and 8th graders in the spring of Year 3 and again in the spring of Year 9. At grade 4, one randomly selected class per elementary school building was tested. At grade 8, one randomly selected class per 8th grade mathematics teacher was tested. This protocol yielded sample sizes of approximately 200 to 300 students per grade level per year from the full population of approximately 1,000 students per grade level. Tests were scored using detailed rubrics that accompany the tests. Raw scores were converted to performance levels, Level 1 through Level 4, according to prescribed cutoffs. The project interprets Level 3 to be proficient and Level 4 to be advanced, akin to DSTEP performance levels.

Figure 4 shows increased student achievement on MARS from Year 3 to Year 9 at both grade 4 and grade 8. The growth at grade 4 was statistically significant with Cohen's effect size of 0.4 (medium effect),  $p < 0.1$ . The growth at grade 8 was statistically significant with Cohen's effect size of 0.5 (medium effect),  $p < 0.5$ .





**Figure 4.** Growth in student achievement as measured using MARS tests, comparing Year 3 to Year 9.

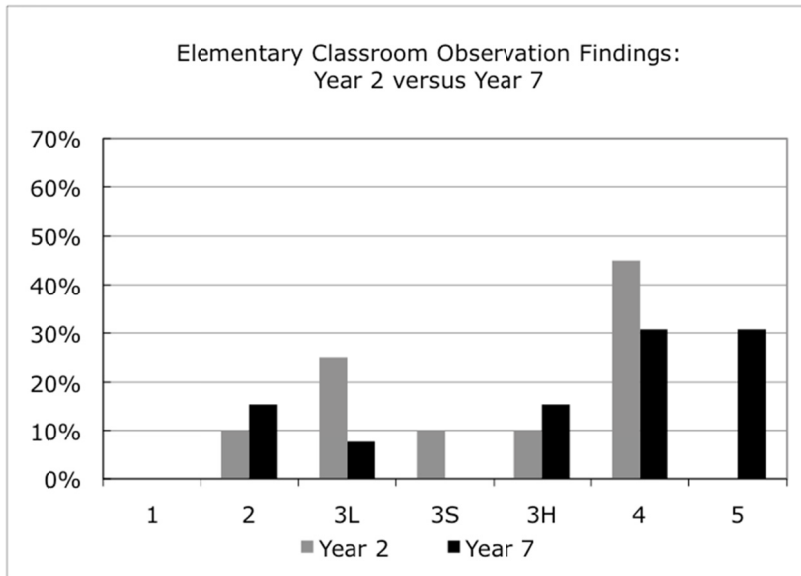
## **Appendix F: PRIME Classroom Observation Results**

Frequency distributions of classroom observation ratings for different years and different grade bands are displayed graphically below. To compare means, rating levels have been equated to numerical ratings. Rating level 3L has been equated to a numerical rating of 2.5, and rating level 3H has been equated to a numerical rating of 3.5. Means are compared using Cohen's effect size. The sample sizes involved are too small and the ratings are not normally distributed such that a t-test can be employed and p-values interpreted.

**Comparison with National Sample.** In 2003, Horizon Research, Inc. completed a study providing a snapshot of K-12 classroom instruction in mathematics across the United States (Weiss et al., 2003). This study serves as a national comparison for *Project PRIME's* classroom observation ratings. The sample sizes for the national study at each grade band are as follows: elementary  $N = 57$ , middle school  $N = 66$ , and high school  $N = 61$ . The percentage of highly-rated lessons nationally at each grade band is shown below in comparison to the percentage of highly-rated lessons observed in Rapid City Area Schools.

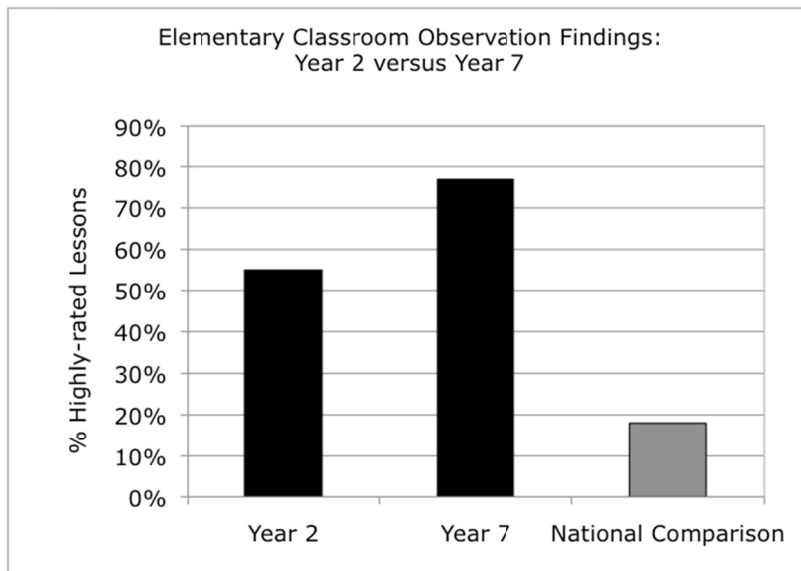
### **Elementary Classroom Observation Findings: Year 2 versus Year 7**

Classroom observation ratings at the elementary level are shown for Year 2 ( $N = 20$ ) and Year 7 ( $N = 14$ ). Average ratings were 3.3 ( $\sigma = 0.8$ ) in Year 2 and 3.8 ( $\sigma = 1.1$ ) in Year 7. Growth from Year 2 to Year 7 is characterized by an effect size of 0.6 (medium effect).



**Figure 5.** Distribution of classroom observation ratings at elementary grades, comparing Year 2 with Year 7.

Figure 6 consolidates the distributions shown in Figure 5 into percentages of highly-rated lessons (3H, 4, and 5). The percentage of highly-rated lessons at the elementary level within the national sample is shown as well.

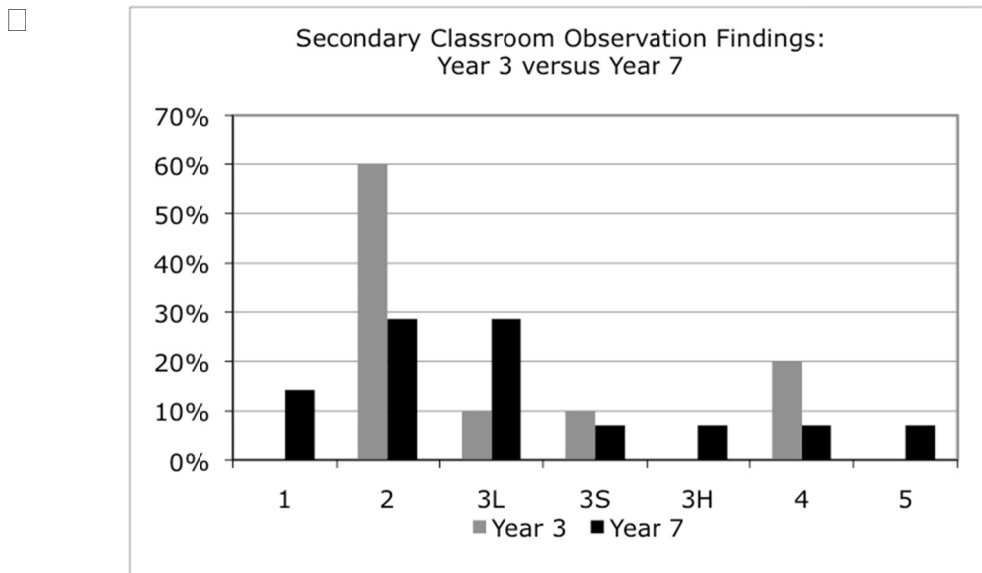


**Figure 6.** Percentage of highly-rated lessons within elementary classrooms, comparing Year 2 with Year 7 and with national sample.

These classroom observations indicate solid teaching at the elementary grades within RCAS as of Year 2 (the earliest observations) and stronger still as of Year 7. By comparison to the national sample, the elementary lesson ratings are remarkably high. Already in Year 2, elementary instruction exceeded the national sample by a wide margin, and by Year 7, the strength was even more pronounced.

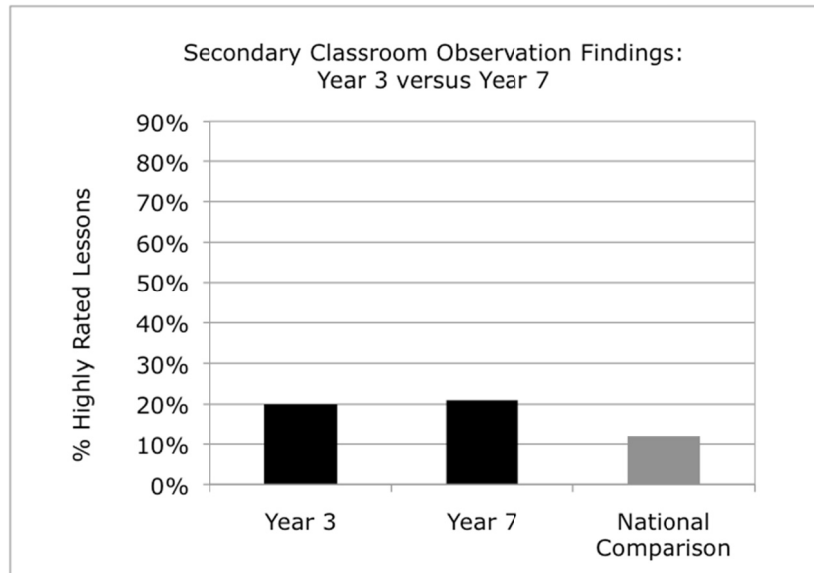
### Secondary Classroom Observation Findings: Year 3 versus Year 7

Figure 7 displays classroom observation distributions at the secondary level for Years 2 and 3 combined (N = 13) and for Year 7 (N = 14). Ten of the 13 secondary observations in Years 2 and 3 occurred in Year 3. For simplicity in reporting from here forward, that sample will be designated as Year 3. The average rating in Year 3 was 2.4 ( $\sigma = 0.8$ ), and the average rating in Year 7 was 2.5 ( $\sigma = 1.1$ ). Growth over this period is characterized by an effect size of 0.1 (between zero effect and small effect). □



**Figure 7.** Distribution of classroom observation ratings at secondary grades, comparing Year 3 with Year 7.

Figure 8 shows the data of Figure 7 consolidated into percentage of highly-rated lessons at the secondary level for Year 3 and Year 7. The corresponding percentage from the national sample is also shown.



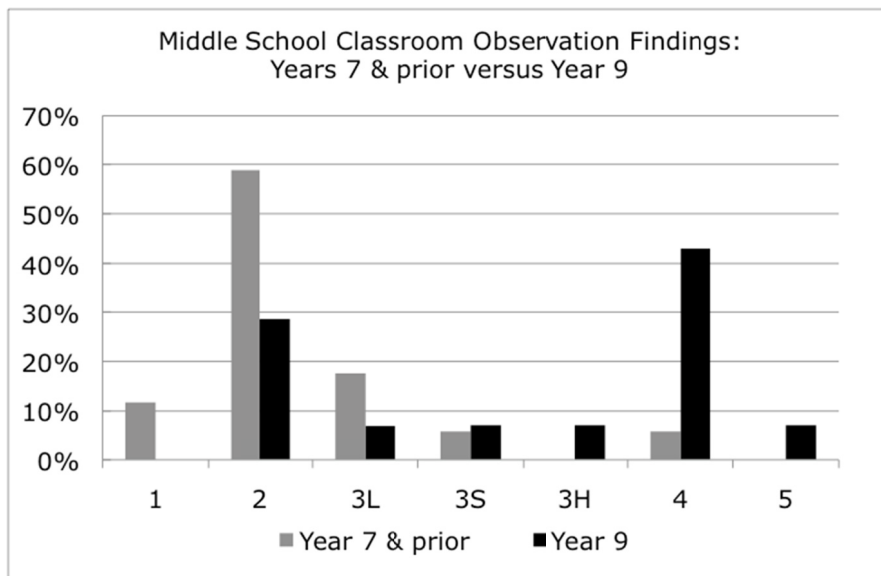
**Figure 8.** Percentage of highly-rated lessons within secondary classrooms, comparing Year 3 with Year 7 and with national sample.

Classroom observation ratings at the secondary level in Year 3 were markedly lower than those at the elementary level in the same timeframe (specifically, Year 2) and showed negligible growth as of Year 7. The percentages of highly-rated lessons shown in Figure 8 also show a lack of growth, but the national comparison data indicate that Rapid City was not alone. In fact RCAS exceeded the national sample for highly-rated lessons at the secondary level in both Year 3 and Year 7.

### **Middle School Classroom Observation Findings: Year 9**

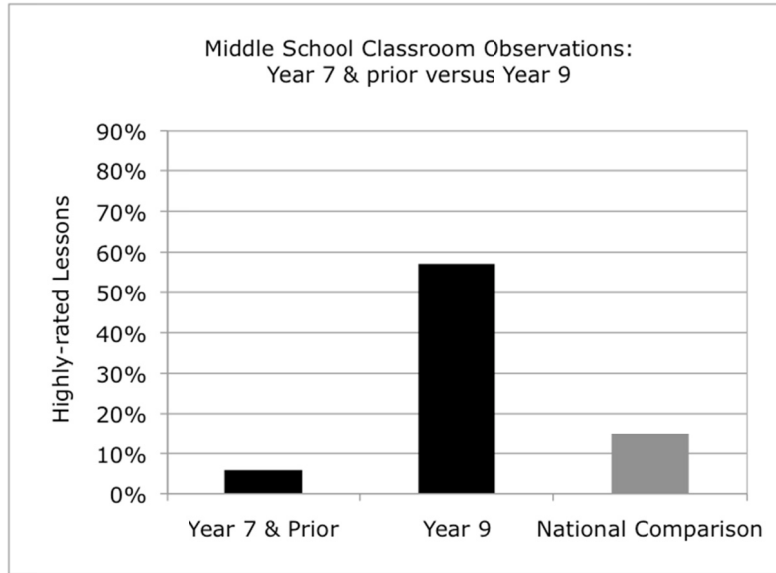
In the findings that follow, all of the middle school ratings from Years 2, 3, and 7 have been aggregated into a single sample (N = 17), and that sample is compared to the ratings from Year 9 (N = 14). The middle school data were aggregated across Years 2, 3, and 7 in order to

arrive at a sufficient middle school-only sample size. Aggregating in this way makes sense because of the specific interest in detecting changes subsequent to Year 7 and given that the middle school observations were consistently low in Year 7 and prior. The frequency distribution associated with the earlier observations (Year 7 and prior) is compared to Year 9 observations in Figure 9. The average lesson rating for the earlier observations was 2.1 ( $\sigma = 0.7$ ), and the average rating for Year 9 was 3.3 ( $\sigma = 1.0$ ). Growth from Year 7 and prior to Year 9 is characterized by an effect size of 1.4 (large effect). □



**Figure 9.** Distribution of classroom observation ratings at middle grades, comparing Year 7 and prior with Year 9.

Finally in Figure 10, the percentage of highly-rated lessons at the middle school level for Year 7 and prior is shown together with the percentage of highly-rated lessons in Year 9 and with national comparison data specific to middle grades.



**Figure 10.** Percentage of highly-rated lessons within middle school classrooms, comparing Years 7 and prior with Year 9 and with national sample.

## Appendix G: PRIME Instructional Materials

Concurrent with *PRIME*'s launch in Year 1, RCAS adopted and began transitioning to the use of new instructional materials: *Investigations in Number, Data, and Space* (developed by TERC) at the elementary grades and *MathScape* (developed by Education Development Center) at the middle grades. Both sets of instructional materials are student-centered, inquiry-oriented, and consistent with the project's vision. At the high school level, the landscape of instructional materials was more complicated and varied in the first few years, including a mix of more traditional, teacher-centered textbooks together with pilot testing of *Discovering Algebra*, *Discovering Geometry*, and *College Preparatory Mathematics*.

Over time, the elementary program transitioned to *Investigations II*, but throughout the project, some version of *Investigations* has been in use consistently across the district. The same level of consistency was lacking at the middle grades throughout the first seven years of the project, with many teachers never transitioning fully to *MathScape*. In the eighth year of the project, the district switched to *Connected Mathematics Project II (CPM II)* as the formally adopted middle school instructional materials. As of the ninth year of the project, *CMP II* was being used much more consistently than *MathScape* materials had been previously (external evaluation findings, 2011).

At the high school level, the district moved steadily toward *College Preparatory Mathematics* as the prevailing instructional materials, particularly for freshman and sophomore-level algebra and geometry. Following the introduction of new instructional materials at middle school in Year 9, however, the district made a decision in Year 10 to seek new materials at the high school level. In particular, they sought materials aligned with the integrated pathway within the *Common Core State Standards for Mathematics* (Common Core State Standards Initiative,



2010), that are student-centered and inquiry-oriented, and that build well on *CMP II. Core-Plus Mathematics* has been selected for introduction in Year 11.

## **Appendix H: Advice to Others**

With the hope that the design and implementation of *Project PRIME* might inform other efforts in other districts, we present here the reflections of co-principal investigator and co-author of this paper Dr. Susie Roth, Director of Staff Development, Rapid City Area Schools.

I have learned so much by being involved with *Project PRIME*, particularly with regard to project design, the importance of vision and direction, and the necessity for strong leadership at multiple levels. My learning is based more on what we did *not* do than what we *did* do, and has been the result of my reflection, ongoing study, and collaboration with others.

First, when launching an initiative such as *PRIME*, time needs to be devoted to designing and communicating numerous elements of the initiative. People want to know why the project is being launched. If care is not taken to thoroughly develop the rationale, research, and explanation, teachers can develop the misperception that they are being criticized for their past approach to teaching mathematics, and this can create defensiveness and impede implementation. Project designers also need to determine and clarify key concepts of the project, the resources and professional development that will support the project, and how the initiative will proceed. Building clarity about participation and commitments supports people in knowing who is involved and what their roles and responsibilities are.

I've also learned more about the vital importance of developing and maintaining a clear, consistent, articulated vision. This involves setting a unified direction and continually moving forward, and sometimes this is an inch-by-inch process. A shared understanding of specific practices brings clarity to developing this vision. Linking the work to a shared purpose brings meaning and significance to the work. When those involved believe in the vision and assume responsibility for the part they play in achieving that vision, the progress a district can make, even in a year or two, is quite remarkable.

Finally, leadership is critical at all levels. *Project PRIME* has been a true partnership, and I have valued the contributions of Black Hills State University, Technology and Innovation in Education, and Inverness. Central office staff, building principals, coordinators, and coaches all are necessary to influence others and take action, and the leadership capacity of all levels to lead an initiative must be developed. When these leaders are passionate about their work and support one another, they are able to persevere when confronted with the inevitable challenges and difficulties of trying to bring about substantive change. And the difficult journey is worth the effort!