Improving Elementary Mathematics and Science Teaching and Learning: Lessons from a School-University Partnership

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ABSTRACT: The challenges of teaching elementary mathematics and science, particularly in urban settings, have been well documented. While evidence exists that sustained professional development in mathematics and science can promote inquiry-oriented instruction and bolster student achievement, little has been written about the particular challenges associated with offering differentiated professional development through school-university partnerships. This paper examines the impact on student achievement and teacher practice when university teacher educators launched a 3-year science and mathematics professional development initiative in grades 3-5 at one of the university's elementary partner school campuses. Our intention was to create a "constructivist" professional learning initiative where the facilitator-researchers were responsive to teachers' ongoing needs and daily teaching challenges. After sharing results, we identify factors that may affect the ultimate success or failure of such initiatives in order to better understand how highly contextualized and differentiated professional development can be structured and sustained.

NAPDS Essentials Addressed: #3/Ongoing and reciprocal professional development for all participants guided by need; #4/A shared commitment to innovative and reflective practice by all participants; #5/Engagement in and public sharing of the results of deliberate investigations of practice by respective participants.

Introduction

Elementary school teachers face challenges when teaching science and mathematics. In both subjects, teachers often feel underprepared to teach effectively. In science, elementary teachers commonly express discomfort with their level of science subject matter knowledge (Kind, 2009; Weiss, Banilower, McMahon, & Smith, 2001), and empirical studies have identified significant gaps in elementary teachers' content knowledge (Burgoon, Heddle, & Duran, 2011; Krall, Lott, & Wymer, 2009; Rice & Kaya, 2012). Likewise, elementary teachers often lack adequate content knowledge for teaching mathematics, and this knowledge is tied to student achievement gains (Campbell et al., 2014; Hill, Ball, & Rowan, 2005).

While elementary educators often feel inadequately prepared to teach both science and mathematics, teachers face an additional challenge in science because the subject often lies at the fringes of the elementary curriculum. A large-scale study by the National Institute of Child Health and Human Development Early Child Care Research Network (2005) found that only six percent of instructional time at the third grade level is devoted to science. While No Child Left Behind (NCLB) has contributed to this imbalance because it stresses subjects other than science in the early grades (Marx & Harris, 2006), science's diminished presence in the elementary classroom existed well before the introduction of NCLB (McCutcheon, 1980) and is due in part to time and limited resources (Spillane, Diamond, Walker, Halverson, & Jito, 2001). In urban districts, challenges associated with delivering high quality science instruction are even greater because they are often under pressure to perform on statewide accountability measures that tend to emphasize subjects other than science (Diamond & Spillane, 2004).

Professional development programs are one way of addressing the challenges associated with urban elementary science and mathematics teaching. Yet, professional development opportunities for teachers often consist of outmoded practices in the form of workshops that may not be appropriate to learning goals, are not sustained over time, and give little or no attention to the broader school community in which teachers are embedded (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2010). In their analysis of over one thousand professional development studies, Guskey and Yoon (2009) found that only nine of the studies provided credible evidence that the professional development initiative had an impact on student learning.

An increasing chorus of scholars has called for differentiated professional development focused on individual teacher needs (Andrews & Anfara, 2003) and embedded within teachers' day-to-day work in schools (Sparks, 1997). Such a view of professional development rests on the belief that teaching is a professional practice that must be learned in and from practice (Ball & Cohen, 1999) because its knowledge is situated in practice. In other words, teachers themselves must continuously assess, adapt and generate knowledge about teaching through the investigation of its central activities.

Most schools, however, lack well-developed structures or systems for providing serious learning opportunities to teachers (Breidenstein, Fahey, Glickman & Hensley, 2012). For decades, the social organization of schools and professional norms of politeness and non-interference have left teachers feeling isolated in their own classrooms (Lortie, 1975; Tamir, 2013). Thus in many school settings, teachers have had few opportunities to observe colleagues or to talk collaboratively about teaching in sustained and rigorous ways (Feiman-Nemser, 2012).

To address the challenges of teaching mathematics and science at the elementary level, we initiated a three-year professional development initiative in math and science at grades 3-5 at a new partner school, Bowen Elementary[1]. Funding received from a local foundation enabled two university faculty members, one specializing in science education and the other in mathematics education, to spend 1-3 days per week working with teachers at the school. Our intention was to create a "constructivist" professional learning initiative where we deeply learned about the context of teachers' work while co-creating the desired forms of professional development with the participating teachers.

We first describe methodological decisions we made then report and analyze results from the 3-year project. We then discuss implications for future school-university partnerships based on our experience at Bowen.

Methods

In this section, we describe the university and elementary school partnership before outlining methods for data collection and data analysis.

University and School Context

Trinity University redesigned its teacher preparation program in 1988 in response to calls for university and school personnel to work together to support children's, preservice teachers' and experienced teachers' learning (Carnegie Forum on Education and the Economy, 1986; Holmes Group, 1990). Specifically, the university created long-term PDS partnerships with a small number of public schools and established a Master of Arts in Teaching degree.

While working with a number of elementary partner campuses over a 20-year period, both teachers and administrators requested the university to provide targeted support to teachers in mathematics and science content and pedagogy. Heeding that request, we secured funding from a local foundation to hire a math educator and create an elementary science and professional development program. After reaching out to a local urban school district, we invited all 40 elementary campuses in the district to apply. Nine campuses submitted an application. Bowen Elementary was selected as the pilot site.

[1] Names of the partner school and teachers are pseudonyms.

The student population at Bowen reflects the student demographics of the larger school district – 90 percent Hispanic, 93 percent economically disadvantaged. Moreover, 68 percent of students are classified as "at-risk" by the Texas Education Agency. The school has a 40% student mobility rate and relatively high teacher turnover. For example, over the course of the three-year partnership, we worked with 19 teachers in three grade levels at Bowen. Only three of these 19 teachers (16%) remained in the same grade level and only five were there all three years. Student and teacher turnover combined with a myriad of changes in district level leadership created significant challenges for the partnership.

Professional Development Initiative

Rather than imposing a pre-determined set of teacher learning activities or curricular program, we imbedded professional learning opportunities within teachers' day-to-day work. That said we intentionally sought out opportunities to promote inquiry-oriented instruction in mathematics and science classrooms. Doing so meant focusing both on teachers' knowledge of science and mathematics content and facility with inquiry-oriented instructional methods.

Previous research has indicated that such an emphasis can be effective. Professional development consisting of a summer institute, ongoing teacher support, and administrative workshops can promote teachers' mathematics and science content knowledge and promote student-centered mathematics and science instruction (Basista & Matthews, 2002). Similarly, Lakshmanan, Heath, Perlmutter and Elder (2011) found that sustained professional development promoted teachers' feelings of efficacy for teaching mathematics and science and their inclusion of inquiry-oriented instructional practices. In a large-scale quantitative study, Supovitz and Turner (2000) found that high levels of participation in professional development (>160 hours) was associated with increased levels of inquiry-oriented science instruction and with an investigative classroom culture. There is also evidence to suggest that sustained professional development leads to higher student achievement in mathematics and science (Johnson, Kahle, & Fargo, 2007).

After consulting with the teachers prior to the start of the partnership, we identified two core components to our professional development: (1) *grade level support for planning* where both the math and science educators met bi-weekly with grade level teams for 90 minutes to unpack the district curriculum guides and plan for instruction; and (2) *individualized support in classrooms* where both the math and science educators taught demonstration lessons, co-taught with participating teachers and observed and debriefed teachers' practice. The science educator devoted one full day a week to his professional development work with the 3rd-5th grade teachers at Bowen, while the mathematics educator spent two full days a week at the school. By planning *with*, co-teaching *with*, and jointly puzzling afterwards *with* the teachers, we engaged in authentic teaching tasks together.

In addition to school-based support provided during the school year, the mathematics and science educators held 3-day summer workshops in the first two years of the project. These workshops focused on establishing relationships and a climate of trust and exploring key components of mathematics and science instruction.

Data Collection and Analysis

We collected a wide range of data to determine impact both on student learning and teacher practice.

Student learning. After securing permission from students' families to participate in the study, we collected student achievement data on statewide mathematics and science exams in grades 3-5. While a valuable measure of student achievement, we recognize that it is just one means of determining student learning and success in school. Other critical factors related to student success and learning include their motivation and attitude toward academic subjects (Vedder-Weiss & Fortus, 2011) and their ability to solve non-routine and real-world problems (Bransford, Brown, & Cocking, 2000). In our partnership work, we focused intensively on fostering students' interest and engagement in mathematics and science and on supporting their ability to approach the kinds of novel math and science problems that they are likely to encounter outside of school.

Thus a second data source included the creation of assessments to measure students' attitude toward mathematics and science: the Attitude Toward Science (ATS) and Attitude Toward Mathematics (ATM) scales (see Appendix A and B). Each scale included 20 statements describing feelings toward mathematics or science and asked students to circle whether they agree, disagree, or were unsure of their feelings relative to that statement. We administered the ATS and ATM scales at the beginning and the end of the academic year for each year of the partnership (with the exception of Fall 2010 for returning students) and assessed student growth on the measure over time.

We focus our analysis on the changes we observed in the group of students who participated in the partnership for all three years, since this gives us the most accurate picture of growth over time and ensures that students in the analysis had a teacher who was participating in the partnership work at the time when they completed the ATS/ATM. Roughly 80 students began 3rd grade at the outset of the study. Of those, 26 remained at Bowman throughout the length of the study and had parental consent to participate. Thus our analysis focuses on these 26 students.

In addition, we designed and administered our own mathematics and science performance-based assessments. Science performance assessments evaluated students' ability to design scientific investigations and to construct scientific explanations from the data they gathered during their investigation. These assessments were developed and pilot tested during the 2009-10 school year and administered as pre/post measures in the 2010-11 and 2011-12 school years. The mathematics performance assessment was designed to measure students' ability to solve non-routine problems, to use mathematical language to communicate about math problems, and to justify their mathematical reasoning. Like the science performance assessment, the alternative mathematics assessment was developed and piloted during the 2009-10 school year and administered as a pre/post assessment during the 2010-11 and 2011-12 school years. Finally, we conducted focus group interviews with participating students in grades 3-5 in December and May of each academic year.

Teacher practice. The second major goal of our partnership work was to improve teacher practice. We hoped to improve teachers' feelings of efficacy for teaching mathematics and science as well as to enhance their instructional practices. To assess growth in teachers' feelings of efficacy, we administered the Science Teacher Efficacy and Beliefs Instrument (STEBI) (Riggs & Enoch, 1990) and the Mathematics Teacher Efficacy and Beliefs Instrument (MTEBI) (Enochs, Smith, & Huinker, 2000). To assess changes in teachers' classroom practices, we kept detailed field notes during classroom visits and bi-weekly planning sessions with grade-level teams; videotaped and transcribed each participating teacher's lessons twice a year in years one and two; and conducted focus group interviews with teachers for all three years of the partnership.

In the third year, two important school-level changes influenced the teacher-based data we collected. First, Bowen's principal departmentalized the 5th grade team so that one individual teacher was responsible for teaching a single content area. Second, given student achievement data concerns, the principal asked that we focus our work exclusively in 5th grade. Thus across year three, both the math and science educator collected detailed field notes during weekly planning sessions with Ms. Delgado, the 5th grade math teacher, and Mr. Timms, the science teacher. Data collection also included videotaping bi-weekly pre- and post-observation conferences as well as videotaping the lessons that the math and science teacher taught.

Analysis occurred throughout the 3-year period as we attempted to understand teachers' practices and develop professional development opportunities responsive to their needs. In the year following the initiative, we transcribed and analyzed Ms. Delgado's and Mr. Timms' videotaped lessons as well as the bi-weekly pre- and post-observation sessions. We developed descriptive codes to help us identify dimensions of teacher practice across all three data sources (Miles, Huberman, & Saldana, 2013). The codes covered aspects of curriculum, planning, instruction, assessment, and classroom management. Doing so enabled us to construct cases of how each teacher's practice evolved.

Results

Our partnership work was framed by two overarching goals: improve student learning and enhance teacher practice. While making progress in both areas, a full vision of success remained elusive.

Impact on Student Attitudes Toward Science and Mathematics

On the Attitude Toward Science scale we observed an initial increase in students' attitude towards science that was reasonably

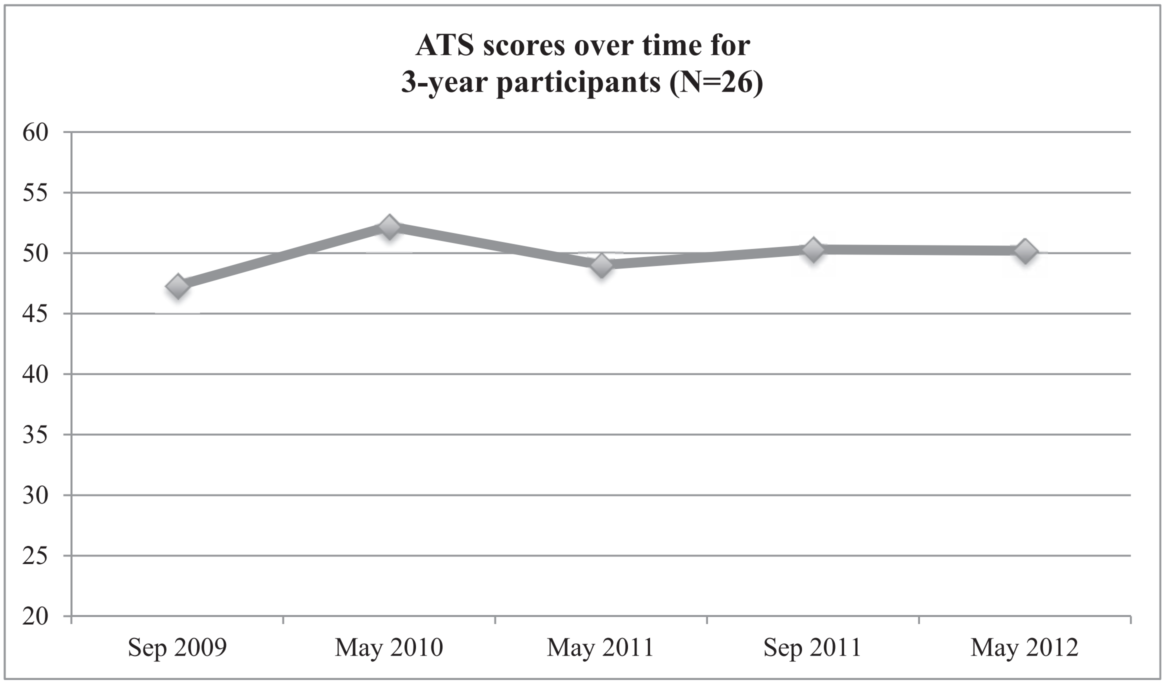

Figure 1. Science Attitude Change over Time for Bowen Elementary Students Who Began 3rd Grade in 2009 and Stayed at Bowen through Their 5th Grade Year

well sustained over the length of the partnership (see Figure 1). We believe the initial increase in students' attitude toward science was due in large part to the fact that for the first time students were engaged in hands-on science lessons. Across the country, many elementary schools dedicate a very small fraction of the instructional day to science (National Institute of Child Health and Human Development Early Child Care Research Network, 2005), and Bowen was no exception. When the partnership commenced, there was a concerted effort and sustained support for teachers to teach science through direct hands-on activities (as opposed to, vicarious experiences through videos or online simulations), and we believe that this emphasis resulted in a measurable change in students' attitude towards science.

On the ATM scale, we observed relatively flat scores over the three years of the partnership (see Figure 2). However, a closer inspection of individual survey items revealed growth in certain key areas, including a tendency for students to disagree more with these statements: I always feel lost in math class; I worry when I study math; Math is boring; I feel bad about myself when I study math. There was also a tendency to agree more with these statements: Learning math is easy for me; The word math doesn't scare me.

Students' Ability to Solve Non-Routine Problems in Science and Mathematics

Our science educator developed three different assessments for each grade level in an attempt to ensure that each assessment was developmentally appropriate. As a result, it is not possible to compare student performance on the 3rd, 4th, and 5th grade performance assessments in order to track their progress over time. It is, however, reasonable to compare scores on the assessments across student cohorts to assess how the performance of Bowen students in each grade changed over time.

In our summative analysis, we compared the scores of students who were in 5th grade during the 2010-11 school year with students who were in 5th grade during the 2011-12 school year. In this analysis, we tracked students' ability to design scientific investigations (see Figure 3) and students' ability to construct scientific explanations from data (see Figure 4). On the performance assessment in science, students in the 2011-12 cohort outperformed students in the 2010-11 cohort, indicating that these students learned more about how to use scientific methods to address a scientific question. The difference in growth between the two cohorts indicates that Bowen teachers improved their ability to support 5th grade students' science learning over time.

Like the science assessment, we focused our summative analysis of mathematics performance-based assessments on the 5th grade cohorts from 2010-11 and 2011-12. Figures 5, 6, and 7 illustrate changes over the year for the 2010-11 and 2011-12 5th grade cohorts. On all dimensions in the mathematics assessment, students in the 2011-12 5th grade cohort grew more than students in the 2010-11 5th grade cohort, indicating an increase in student learning.

Student Achievement

To assess growth on statewide achievement measures, we tracked the school-wide pass rates on the state exams given in mathematics and science in grades 3, 4 and 5. Unfortunately, the state replaced

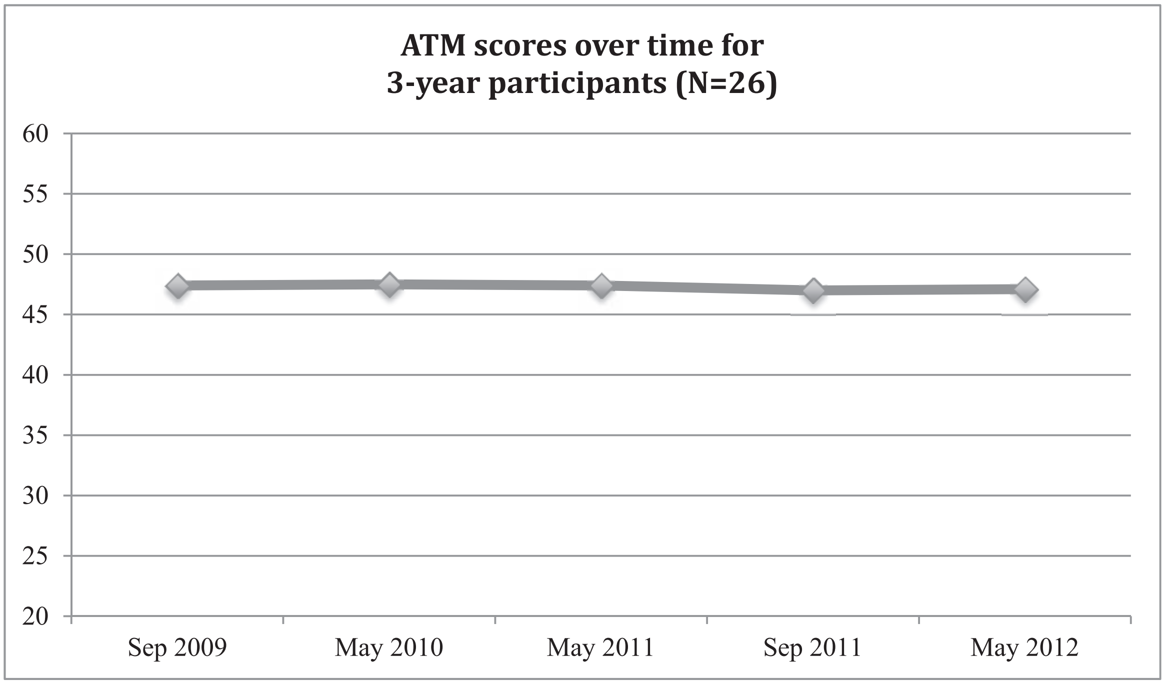

Figure 2. Mathematics Attitude Change over Time for Bowen Elementary Students Who Began 3rd Grade in 2009 and Stayed at Bowen through Their 5th Grade Year

its exams in year three of the partnership and equivalence tables are not currently available, thus we are unable to assess individual student growth on these measures over time. Nonetheless, looking at school-wide pass rates is an indication of the growth in student learning at Bowen over time. Figures 8 and 9 show the school's pass rates for science and mathematics tests during the partnership.

In year one, we saw an increase in the number of students who passed the statewide science exam. Importantly, this

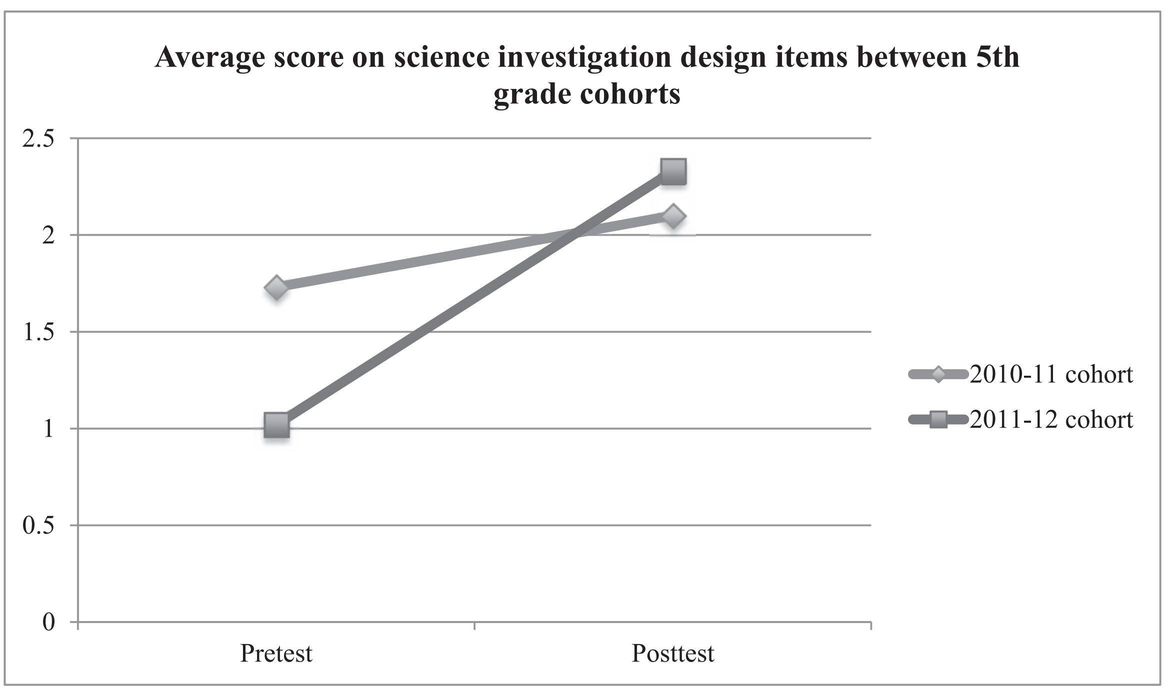

Figure 3. Comparison of Growth during the School Year in Students' Ability to Design Scientific Investigations on the 5th Grade Performance Assessment in Science

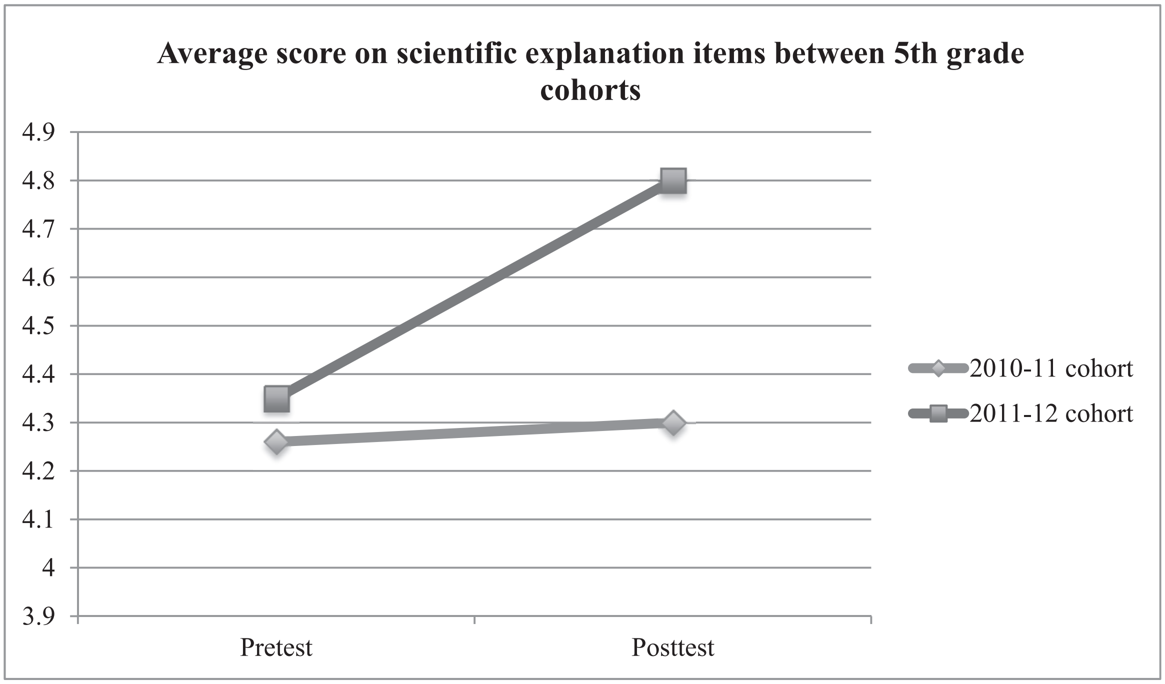

Figure 4. Comparison of Growth during the School Year in Students' Ability to Construct Scientific Explanations from Data on the 5th Grade Performance Assessment in Science

increase crossed the 70 percent threshold, which is the cutoff for schools to reach the state's "Academically Acceptable" rating. After crossing this threshold in the first year of the partnership, Bowen maintained scores in the Academically Acceptable range.

In mathematics, school-wide scores in mathematics steadily increased during the course of the partnership. These scores crossed the 70 percent threshold in the last year of the partnership.

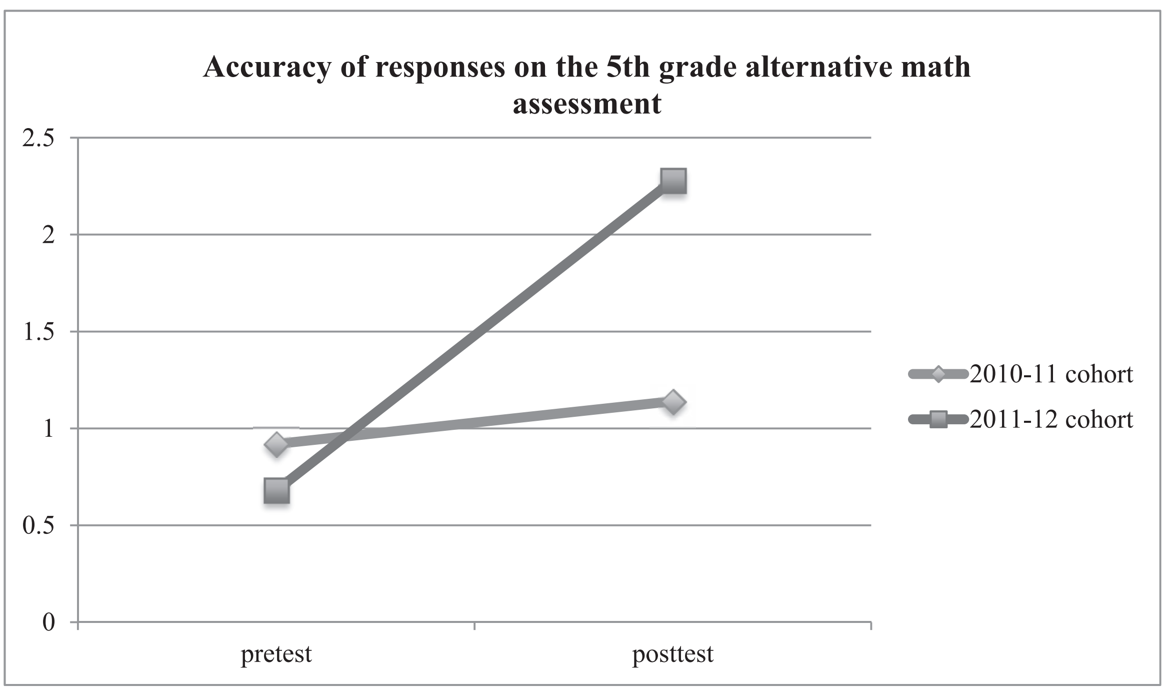

Figure 5. Comparison of Growth during the School Year on Students' Accuracy of Responses on the 5th Grade Alternative Mathematics Assessment

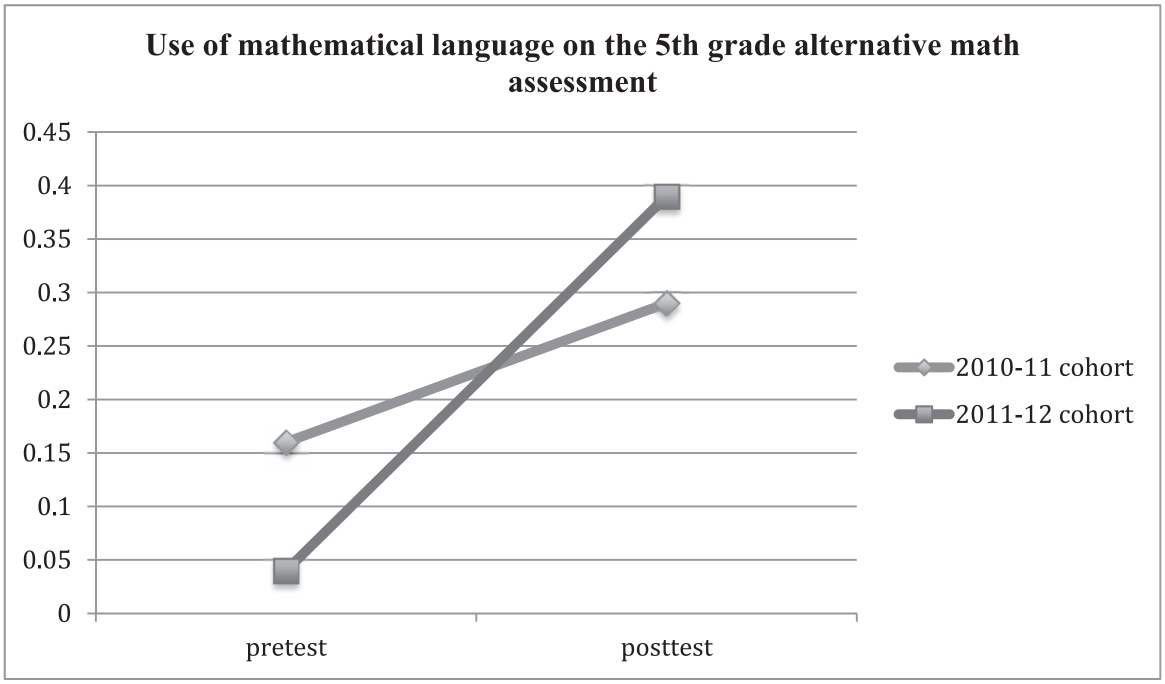

Figure 6. Comparison of Growth during the School Year on Students' Use of Mathematical Language on the 5th Grade Alternative Mathematics Assessment

Impact on Teacher Efficacy

We administered the STEBI and MTEBI instruments in September 2009 to identify a "baseline" efficacy level for participating teachers and administered the measure again each May for the duration of the partnership. Figure 10 shows the change in teachers' STEBI scores for the five teachers who remained at Bowen during all three years of the partnership, and Figure 11 shows the MTEBI results for the same teachers.

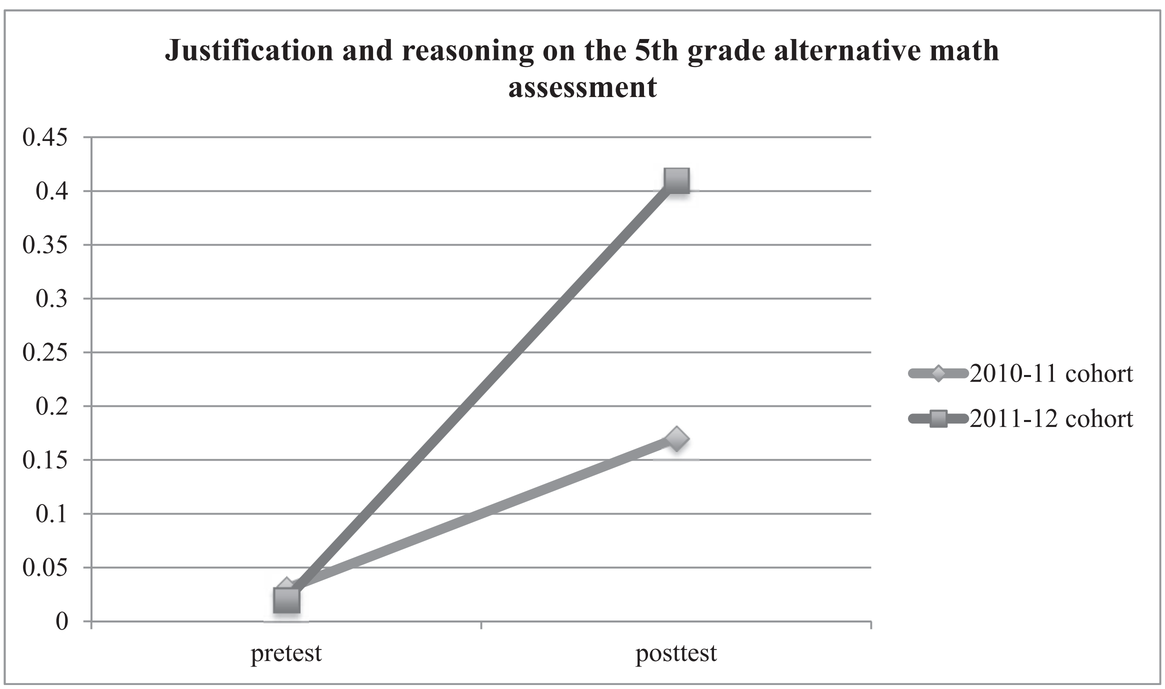

Figure 7. Comparison of Growth during the School Year on Students' Ability to Justify Their Mathematical Reasoning on the 5th Grade Alternative Mathematics Assessment

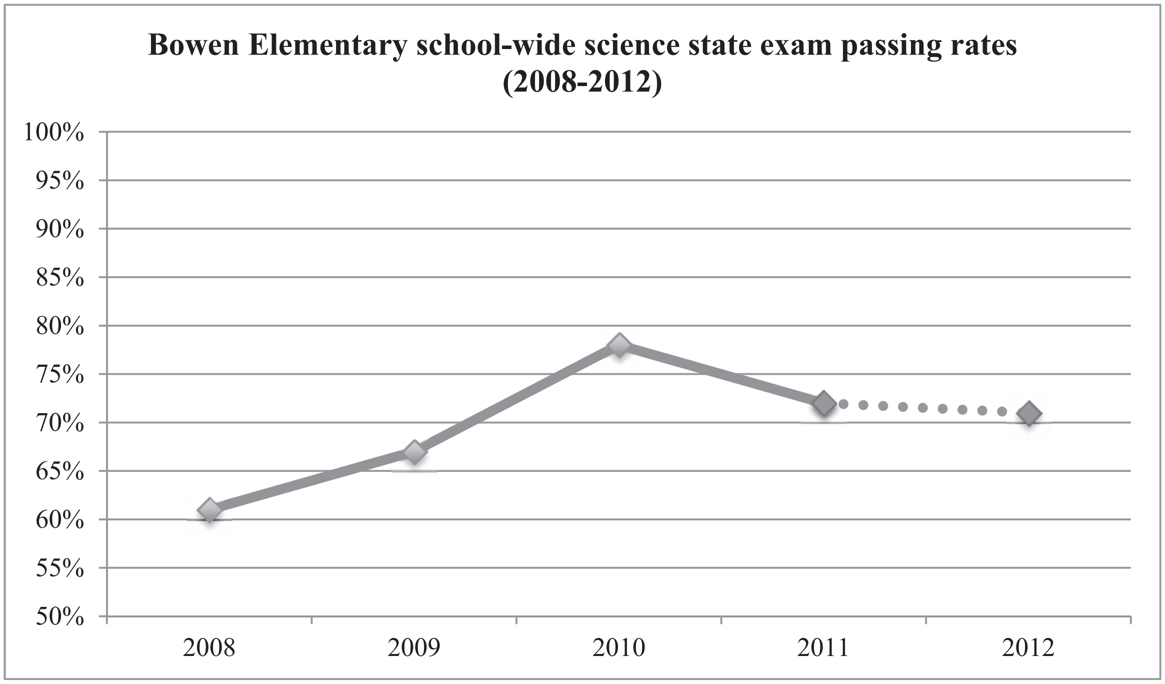

Figure 8. Science Statewide Exam Pass Rates at Bowen Elementary during Years Relevant to the Partnership. Notes: 2008 data is included as baseline before partnership began, and the dotted line between 2011 and 2012 indicate the implementation of a new statewide exam.

On the science efficacy measure, teachers had an initial decline in their feelings of efficacy during the first year. We believe that this initial decline was due to the fact (as reported by Bowen teachers) that they had spent relatively little time teaching science in years preceding the partnership. Teachers reported that when they did teach science pre-partnership, they rarely used inquiry-oriented pedagogy. Thus, the initial decline in teacher efficacy seems to have been a result of teachers being

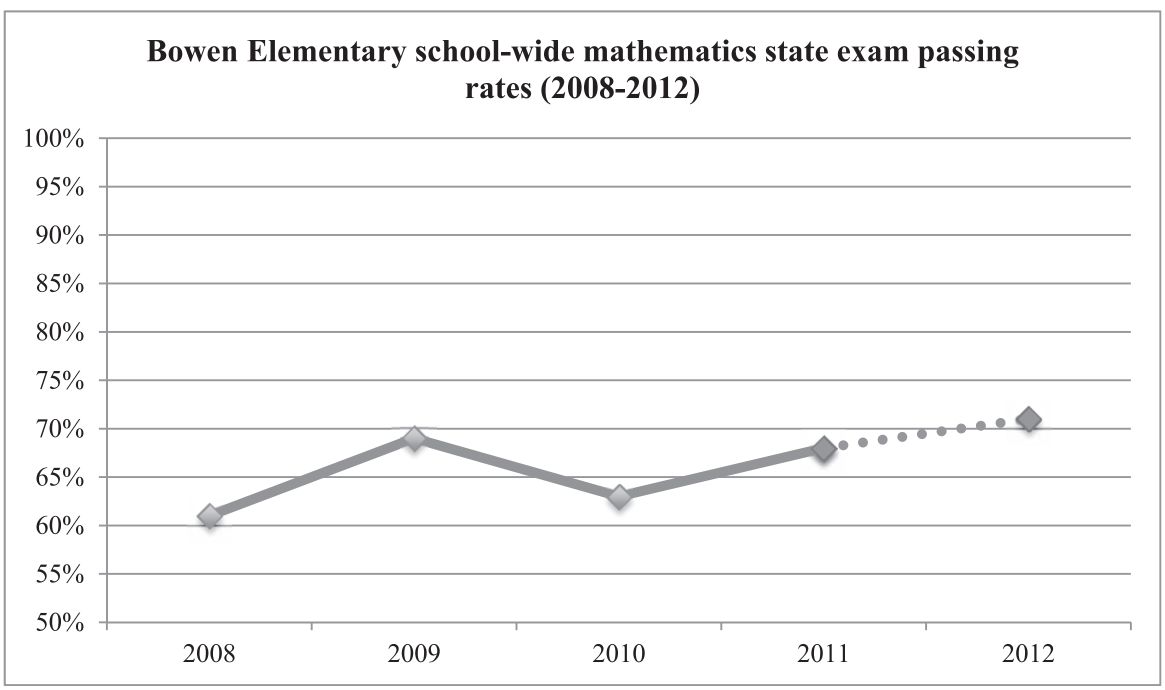

Figure 9. Mathematics Statewide Exam Pass Rates at Bowen Elementary during Years of the Partnership. Notes: 2008 data is included as baseline before partnership began, and the dotted line between 2011 and 2012 indicate the implementation of a new statewide exam.

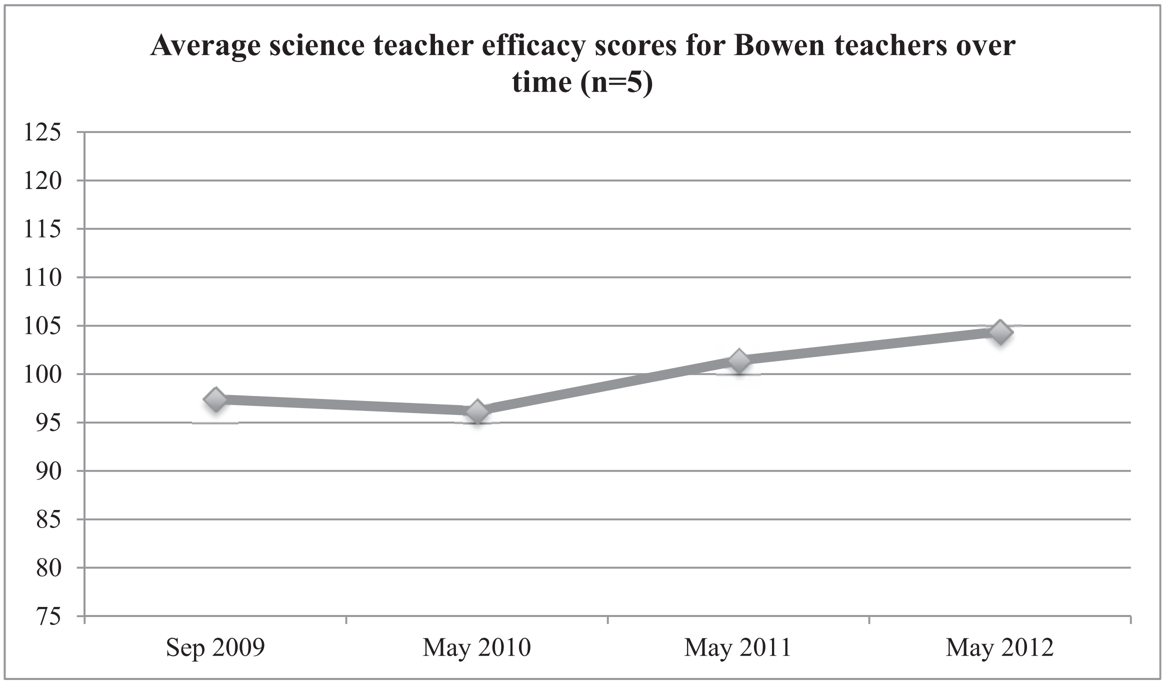

Figure 10. Change in Teachers' Feelings of Efficacy toward Teaching Science during the Three Years of the Partnership among Teachers Who Remained at Bowen for the Length of the Partnership. Maximum score on this measure is 125.

exposed to ideas about teaching science that they had not considered in the past and realizing that they had much to learn. After May 2010, teachers' feelings of efficacy for teaching science steadily increased.

Like teachers' feelings of efficacy for teaching science, their feelings of efficacy for teaching mathematics increased during the course of the partnership. Unlike science, however, teachers experienced a large jump in the first year of the partnership.

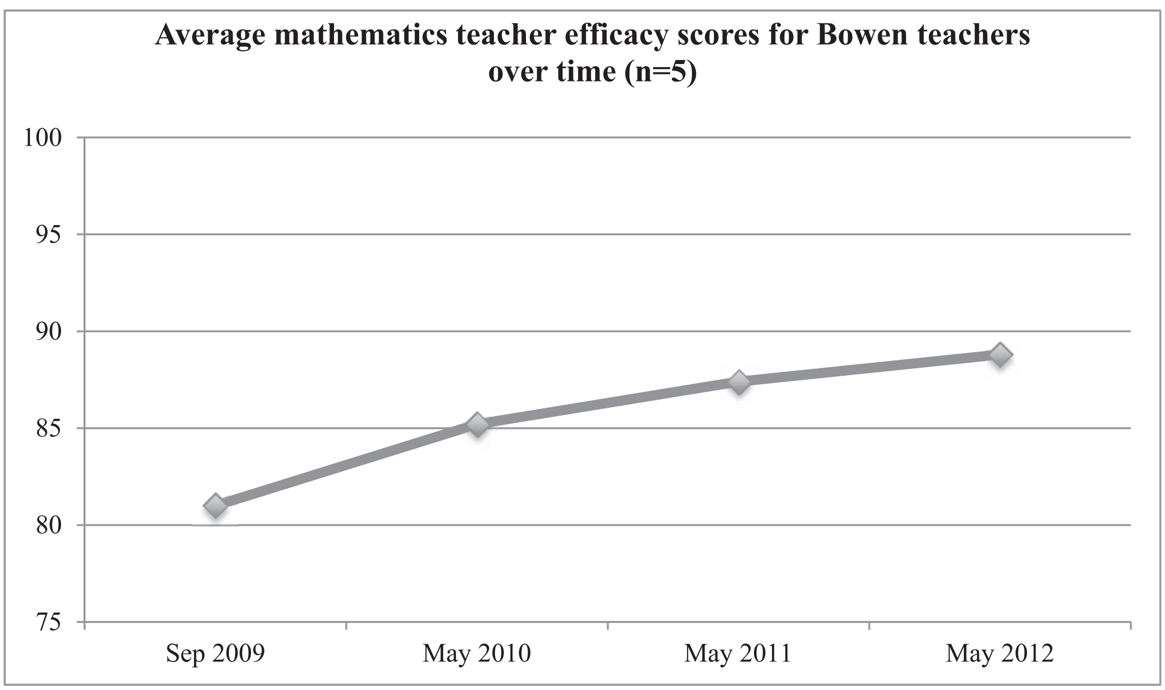

Figure 11. Change in Teachers' Feelings of Efficacy toward Teaching Mathematics during the Three Years of the Partnership for Teachers Who Remained at Bowen for the Length of the Partnership. Maximum score on this measure is 100.

Also unlike science, teachers had been teaching mathematics consistently in the years before the partnership; however, teachers had not been experiencing a high level of success in their math instruction (e.g., passing rates on the state mathematics exams were low in each of the assessed grade levels). When their work in the partnership began, the mathematics educator was able to clarify ideas about mathematics curriculum and pedagogy and provide teachers resources for addressing the challenges in teaching math that they had already identified. The teachers continued to increase their feelings of efficacy for teaching mathematics throughout the course of the partnership.

Science Instructional Practice

Mr. Timms began teaching at Bowen in the partnership's second year though he was not new to the profession. His practice improved in three primary ways: more effective lesson introductions; clarification of structures for student group work; and greater focus on connections between lessons. Initially, Mr. Timms routinely spoke to students for 40-45 minutes prior to a hands-on activity as he introduced science content, discussed activity procedures and corrected student behavior; toward the partnership's end, he shortened this time to roughly 15 minutes. The result was an improvement in students' behavior, as they had to sit silently for less time, and an increase in students' opportunity to explore phenomena through hands-on investigations prior to being introduced to the science content. The practice of introducing content only after young students have had a chance to interact with phenomenon is a critical support for their science learning (Michaels, Shouse, & Schweingruber, 2008).

Mr. Timms more intentionally elicited students' ideas prior to commencing hands-on activities by using strategies that the science teacher educator, Dr. Nordine, emphasized during co-planning sessions. Strategies included KWL charts, "think-pair-share" discussions and "predict-observe-explain" demonstrations. Eliciting students' ideas is a powerful way to increase students' motivation for learning and readiness to understand new ideas (Bransford et al., 2000).

A key component to supporting students during hands-on instruction is providing clear structures for collaboration in groups. At the outset, Mr. Timms struggled to maintain classroom discipline while students worked in groups. One reason for this discipline problem was that students were often unclear about behavioral or procedural expectations. After several model teaching experiences in which Dr. Nordine introduced the lesson and supported students in group work, Mr. Timms began to improve his capacity to keep students on task.

A third major area of improvement in Mr. Timms' instruction was an increased emphasis on clarifying – both for himself and for his students – connections between the lessons in a science unit. To do this, he worked with Dr. Nordine to discuss the overall progression of ideas within a unit and to identify the most central ideas within each. A major support for clarifying connections between lessons was the "driving question board," a visual organizer for inquiry-oriented science units that are designed around asking and addressing scientific questions (Weizman, Shwartz, & Fortus, 2008).

While Mr. Timms made significant strides, progress was slow, and Mr. Timms continued to face significant challenges in his practice at the end of year three. Difficulties included classroom discipline and consistent usage of strategies to promote student thinking and instructional coherence. One barrier to consistently utilizing such strategies is that they require significant preparation. When Dr. Nordine co-planned with Mr. Timms, he frequently used strategies to engage students' thinking in those lessons; however, when Dr. Nordine neither explicitly co-planned nor co-taught with Mr. Timms, the strategies were used far less consistently. This low level of independent implementation may be related to the existing culture of classroom instruction and student expectations at Bowen and across the district, which is explored in greater depth in the discussion section.

Mathematics Instructional Practice

Like Mr. Timms, the 5th grade mathematics teacher, Ms. Delgado, improved her teaching practice in several ways: she shifted her instruction from whole group to small group and one-on-one work with students; she fostered greater independence in students' learning; and she encouraged greater student discourse. At the start of the project, Ms. Delgado described her mathematics practice as whole group driven. She viewed mathematics as a set of rules to learn, thus her instruction focused on giving those rules to students, carefully walking them through her way of solving problems. Ms. Delgado described her pedagogy in the following way: "I talked, you listened, you watch, you write it down."

Ms. Font-Strawhun, the mathematics teacher educator, modeled a different way to engage students in mathematical discourse during demonstration lessons. Ms. Delgado struggled to allow students to think for themselves, acknowledging that she tended to walk students through problems rather than let them work them out on their own. Ms. Font-Strawhun engaged Ms. Delgado in a book study to explore why academically productive talk is essential to mathematics teaching and learning (Chapin, O'Connor, & Anderson, 2013). Ms. Delgado learned about specific talk moves, analyzed video examples of these talk moves, and observed Ms. Font-Strawhun model them in her own instruction. Ms. Delgado also attempted to incorporate talk moves into her own teaching and received feedback from Ms. Font-Strawhun. This professional development enabled Ms. Delgado to begin to foster more student discourse by the end of year three.

Although Ms. Delgado expressed commitment to sustaining student discourse in her classroom once the initiative officially ended, we did not see this occur. Six months later we returned to Ms. Delgado's classroom to see whether/how her practice reflected the strides she had made in year three. Ms. Delgado taught a 40+ minute whole group lesson in which she walked the students through four problems on the overhead, telling them exactly how to solve the problems. She did not implement talk moves during the whole-group lesson nor did she foster student discourse. Thus, like Mr. Timms, without the university teacher educator there to spur him to sustain changes he had made in his practice, Ms. Delgado seemed to revert to instructional practices that she had established before participating in the partnership.

Discussion

We faced several significant challenges during the three-year project. First, there was a high degree of turnover at Bowen Elementary. Over the course of the three-year partnership, we worked with 19 teachers in three grade levels at Bowen. Only three of these 19 teachers (16%) remained in the same grade level at Bowen all three years, and only five participated in the project all three years. This level of mobility presents significant challenges when supporting and sustaining changes in the culture of teaching and learning in a grade level. Student mobility created yet another challenge. Despite this challenge, it is remarkable that teachers' feelings of efficacy in teaching both mathematics and science rose at a time of high mobility and turnover. We believe that this increase can be attributed to giving them tools for reflection and real-time decision-making as they started to think more deeply about what it means to teach science and math effectively. For example, the science teacher, Mr. Timms, increased his ability to keep students engaged and elicit students' ideas. Strengthening his ability to manage students' behavior during his instruction would most likely leave him feeling more efficacious in his teaching. In addition to this increase in teacher efficacy, we observed that student attitudes were sustained relatively well over time. This observation is non-trivial because past studies have documented evidence that students across a range of settings experience a decline in attitude toward science and mathematics in the late elementary years (Murphy & Beggs, 2003; Pell & Jarvis, 2001; Wood et al., 2012). Despite these successes, student and teacher mobility remained a challenge throughout the partnership and likely mitigated its overall impact.

Compounding the challenges posed by student and teacher mobility at Bowen was the significant turnover in district leadership during the course of the partnership. The superintendent, who had approved the formal school-university partnership, resigned at the end of the first year to accept a position at another school district. At the same time, the assistant superintendent who had played a significant supportive role in establishing the professional development partnership at Bowen retired and was replaced with a new administrator who expressed concern about the partnership when entering his new role during the 2010-11 school year. Moreover, Dr. Nordine began collaborating with the district science coordinator and district science teacher specialists from the beginning of the partnership, yet the science coordinator retired six months into the first year and was not replaced, and the science teacher specialist position was eliminated at the end of the 2010-11 school year. In mathematics, there was no district mathematics coordinator in the first year of the partnership. In both science and mathematics, district content leadership positions were eventually filled with administrators who lacked specialization in these content areas.

Losing key district-level partners at the end of the first and second years made it exceedingly difficult to sustain lines of district-level communication and collaboration that had been initially established. We knew firsthand from prior school-university partnerships that "collaboration, reflection, and regular communication among participants" must be in place (National Association for Professional Development Schools, 2008, p. 6). Researchers know that "communication systems underlie almost every aspect of partnership operations and functions" (Hora & Millar, 2011, p. 142). We addressed this challenge by repeatedly connecting with new district administrators as they were appointed. In addition to reaching out to them by phone, email, and in person, we continually invited multiple district administrators to our quarterly advisory committee meetings. However, no district-level administrator attended those quarterly sessions after the first year.

Most aspects of collaboration between district, school, and university partners rests on individual relationships (Rice, 2002). Without access to the district administrators with whom we needed to collaborate, the success of our professional development partnership was significantly limited. Lacking regular ongoing communication between the university and school district, there was no way to work through the misalignment between our vision of teaching and learning and the district's vision. From the outset, we centered the partnership on our fundamental belief that teachers are professionals who with support and guidance are able to make lasting changes in their teaching through the careful examination of teacher practice and students' learning. We also fundamentally believe that students deserve high-interest, content-rich, developmentally appropriate learning opportunities. In contrast, neither deep teacher learning nor deep student engagement was a priority at the district and by extension at Bowen.

In retrospect, without being clear from the outset what our fundamental beliefs about teaching and learning were, our initial written agreement lacked sufficient "teeth" to support the transition following changes in district leadership. We learned the hard way both how essential and challenging it is to craft an articulation agreement that clearly specifies not only the roles and responsibilities of all central players but also the structures required to foster collaboration and communication, which are two of the nine required essentials for a Professional Development School (National Association for Professional Development Schools, 2008).

That said, "[c]ross-institutional partnership work is complex and messy, and must create an emergent 'road map' that cannot be specified entirely in advance" (Glass & Wong, 2009, p.173).

Even though we could not have anticipated the specific challenges we encountered, we should have been more proactive and assertive when new district leaders expressed concerns and/or appeared uncommunicative. Having devoted so much time to relationship-building the first year, we failed to anticipate how much the changes in leadership at the district level would alter the messaging they provided to school administrators and teachers. We did not anticipate the turf war that ensued.

An increased emphasis at Bowen on performance on state exams and district benchmark tests (exams created in the district to mimic the state test) was partly a result of district restructuring. Such an emphasis is not uncommon in urban school districts, and it often is associated with lower quality instruction (Settlage & Meadows, 2002). Faced with the prospect of being reassigned without enhancing school performance on state testing measures, administrators at Bowen increasingly emphasized compliance with district directives, curriculum guides, and adherence to scripted instructional interventions. At the same time, our partnership work was focused on enhancing teachers' capacity for making instructional decisions and productively adapting curricula for their students in context. Unfortunately, teachers received mixed messages from district/school administrators and their university partners.

While we worked to help teachers reconcile the discrepancies in this messaging by introducing strategies for adaptation while adhering strictly to state standards and assessments, this type of teacher-generated adaptation was undervalued and even expressly prohibited by district administrators. It was a continual uphill battle to engage teachers in developing their pedagogy when such teaching skills were not valued within the district. The district focused nearly exclusively on state accountability measures. District mandates centered on improving test scores in ways that ignored quality instruction and deep student learning. Our own project goals seemed fundamentally misaligned with the goals of the district.

A heavy emphasis on teacher compliance from district and school administrators had a negative effect on the perceived value of teacher participation in partnership work and was concomitant with decreases in the amount of time allocated for teacher participation in partnership activities. Whereas in year one teachers had 90 minutes of dedicated planning and collaboration time with the science and math educators each week, only 45 minutes were set aside in year two, and no protected planning and collaboration time was reserved in year three. This reduction in reserved professional collaboration time and increased emphasis on teacher compliance sent a de-professionalizing message to teachers that instructional decisions would be made by district leaders rather than them.

We attempted to address this ongoing concern by encouraging the Bowen administrators and teachers to experience firsthand what research has borne out, namely that schools become better places for kids when teachers become better teachers, when they improve their practice, when they are serious learners. What researchers have found, and what we directly experienced in our work with teachers at Bowen, is that when professional developers and school leaders work with teachers to help them become serious learners, not all teachers readily do so (Breidenstein et al., 2012).

In studying adults as learners, Kegan (1998) identified three different types of teachers as professional learners: instrumental, socializing and self-authoring. Instrumental knowers want concrete answers, processes and procedures. They want concrete steps and specific advice about how to follow rules. They are often convinced that there is a "right way" to do something and so want to be told that way. On the other end of the developmental continuum of adult learners, self-authoring knowers are clear about who they are and what they stand for. At the same time, they expose and explore their fundamental assumptions publicly. They understand that there are tensions in implementing any professional practice, and they both expect and accept the ambiguity associated with those tensions. They understand that there are no easy answers.

Instructional leaders, including Dr. Nordine and Ms. Font-Strawhun, who support adult learning in schools need to understand not only different ways of knowing, but also how the different approaches they use will be experienced by the different adult learners with whom they work. Bowen's 5th grade science and math teachers, for example, were in many ways instrumental learners. Mr. Timms needed help knowing when/how to distribute materials, how to structure science experiments, how to gain and maintain students' attention, basic skills in teaching. Ms. Delgado, too, showed signs for the first two and a half years of the partnership as being an instrumental learner. In her teaching, she valued concrete strategies that Ms. Font-Strawhun provided her. It was only toward the end of Ms. Font-Strawhun's intensive three-year intervention with this teacher that she showed signs of moving in the direction of becoming a self-authoring knower. Unfortunately, after visiting the math teacher's classroom once the project had ended, there was no evidence that the teacher had sustained the small changes that she had made.

Implications

The university-district partnership was designed as a "constructivist" professional learning initiative where the facilitators/researchers would deeply learn about the context of the work while co-creating professional development activities with the teachers. One of the primary lessons learned from this project is the overwhelming role that context plays in the successes or challenges encountered. The specific context of Bowen and the district came into play in a number of facets of the initiative. First, district and university alignment is essential in the design of a partnership, and full support, collaboration and trust by all partners is paramount. If the district does not view the professional learning initiative as a "value add," it will be unwilling to engage in risk-taking by supporting teachers in developing new instructional strategies. The designation of a consistent point of contact at the school as well as the Central Office that serves as a liaison and "sense-maker" for the central administration is essential to the initiative's ongoing support and success as well. Without this alignment and deep understanding, competing initiatives will be prescribed and the school will be caught between district mandates/initiatives and the goals and activities of the university partnership.

Second, the selection of the campus is essential. Without the autonomy to shape professional learning or to re-conceptualize it in substantive ways, an initiative such as this cannot be implemented on a campus with fidelity and becomes subject to the fears and pressures of district mandates and state accountability. In the case of Bowen Elementary, concerns regarding student performance early on triggered greater campus oversight and more prescriptive interventions by the central administration. This, in turn, constrained the ability of the initiative to truly work with each teacher to improve teaching and learning and reduced the project's support to solely address test preparation and reactive interventions mandated to raise student performance. The short term gains achieved by remedial interventions actually undermined the capacity of campus educators to take a longer view of substantive development of teaching and learning in mathematics and science and constrained the overall professional learning initiative.

Finally, baseline proficiency with, and the desire to develop, a professional learning community on campus would be an asset in a "constructivist" professional learning initiative. A foundation of teacher professional learning based on their own sense of efficacy and expertise as well as their desire for continuous growth, learning and improvement creates a rich context in which work of this nature can flourish. Related to this is the need for the professional developers to be keenly aware of the continuum of teachers' abilities/proficiencies as adult learners and the scope of the differences that may exist along that continuum. The campus' experience with professional learning became a defining and limiting variable with the partnership's initiative.

We acknowledge that external funding enabled the math and science teacher educators to restructure their roles to invest significant time and effort as school-based professional developers and researchers. While the university took sole responsibility for securing funding for the initiative, school-university ties can be strengthened when district, university and school jointly apply for a grant (Wasielewski & Gahlsdorf, 2014). While the labor-intensive nature of school-based professional development often requires external funding, their study suggests that collaboratively securing a grant builds trust and enables partners to galvanize important human resources for the initiative.

In retrospect, greater transparency regarding the specific teacher outcomes related to research-based excellence in mathematics and science instruction would have provided greater structure for our initiative and served as a counterbalance for the constructivist methodology that was utilized. This would have also provided a "target" or focus for the teacher-learners as they self-assessed and helped to shape their professional learning pathways. We still believe that strong and impactful professional learning should address the individual needs of each teacher, meeting them where they are and helping them grow from there. However, we are keenly aware of the contextual variables that either promote or hinder professional learning and, thus, professional partnership initiatives among a university, school and district. SUP

Appendix A: Attitude Toward Science Scale (ATS)

Directions: This survey asks how you feel about science. There are no right or wrong answers. With the help of your teacher, please read each of the sentences below carefully and respond by circling the face for "agree," "unsure," or "disagree".

Agree Unsure Disagree

1. I am drawn to science.
2. I look forward to my science class.
3. Science helps me to be thankful for nature.
4. I am happy when I am doing science problems.
5. Studying science is a waste of time.
6. Studying science does not scare me at all.
7. Science is helpful.
8. Science is boring.
9. I feel calm when I answer science questions.
10. Learning science terms is hard for me.
11. I can think of many ways to use science concepts outside of class.
12. I don't use science concepts much in my life outside of school.
13. I feel good about myself when I get science concepts.
14. I feel tense when asked to think about a science problem.
15. Learning science is easy for me.
16. I worry when I study science.
17. I look forward when it's time for science class.
18. I feel bad about myself when I study science.
19. I like to study science more than other subjects.
20. I am good at using science ideas outside of class.

Appendix 2: Attitude Toward Mathematics Scale (ATM)

Directions: This survey asks how you feel about mathematics. There are no right or wrong answers. With the help of your teacher, please read each of the sentences below carefully and respond by circling the face for "agree," "unsure," or "disagree."

Agree Unsure Disagree

1. Math teaches me to be more exact.
2. It is easy for me to solve math problems.
3. I want to build my math skills.
4. I am happy when I am doing math problems.

5. I like math much less than other subjects.
6. The word math does not scare me at all.
7. I connect with math.
8. Math is boring.
9. I feel calm when I answer math questions.
10. I always feel lost in math class.
11. I can think of many ways to use math outside of class.
12. I value using math in my life outside of school.
13. I feel good about myself when I solve math problems.
14. I feel nervous when I try to solve a math problem.
15. Learning math is easy for me.
16. I worry when I study math.
17. I look forward for when it's time for math class.
18. I feel bad about myself when I study math.
19. I like to study math more than other subjects.
20. I believe that I am good at solving math problems.

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