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Call for Manuscripts

The purpose of the ***NCSM Journal of Mathematics Education Leadership*** is to advance the mission and vision of the National Council of Supervisors of Mathematics by disseminating knowledge related to research, issues, trends, programs, policy, and practice in mathematics education and relevant to leaders in mathematics education. In addition, the journal aims to foster inquiry into key challenges of mathematics education leadership, raise awareness about key challenges of mathematics education leadership, and engage the attention and support of other education stakeholders in order to broaden as well as strengthen mathematics education leadership.

Manuscripts should fit within one or more of the following categories:

- **Key topics** in leadership and leadership development
- **Case studies** of mathematics education leadership work in schools and districts or at the state level and the lessons learned from this work
- **Reflections** on what it means to be a mathematics education leader and what it means to strengthen one's leadership practice
- **Research reports** with implications for mathematics education leaders
- **Professional development efforts** including how these efforts are situated in the larger context of professional development and implications for leadership practice

Across each of these categories, evidence of the impact of the work is expected along with connections to the existing knowledge base. In addition, manuscripts should be consistent with the NCTM Principles and Standards and should be relevant to NCSM members. In particular, manuscripts should make clear to mathematics leaders the implications of its content for their leadership practice.

The *NCSM JMEL* uses a double-blind review process. Manuscripts are reviewed by at least two volunteer reviewers and a member of the editorial panel. Reviewers are chosen on the basis of their expertise related to the content of the manuscript and are asked to evaluate the merits of the manuscripts according to the guidelines listed above.

Manuscripts should be formatted according to the guidelines of the *Publication Manual of the American Psychological Association* (6th edition).

Manuscripts should be submitted via e-mail to ncsmJMEL@mathedleadership.org. Submissions should include:

- A word file with the body of the manuscript without any author identification;
- A word file with author information; and
- An abstract of no more than 300 words.

Manuscripts may be submitted at any time, although deadlines of January 1st and July 1st are established to support timely review and publication.

NATIONAL COUNCIL OF SUPERVISORS OF MATHEMATICS (NCSM)

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***Note:** Information for manuscript reviewers can be found on the inside back cover of this publication.

Table of Contents

Purpose Statement

The ***NCSM Journal of Mathematics Education Leadership*** is published at least twice yearly, in the spring and fall. Its purpose is to advance the mission and vision of the National Council of Supervisors of Mathematics by:

- Strengthening mathematics education leadership through the dissemination of knowledge related to research, issues, trends, programs, policy, and practice in mathematics education

- Fostering inquiry into key challenges of mathematics education leadership

- Raising awareness about key challenges of mathematics education leadership, in order to influence research, programs, policy, and practice

- Engaging the attention and support of other education stakeholders, and business and government, in order to broaden as well as strengthen mathematics education leadership.

Comments from the Editor

Angela T. Barlow, *Middle Tennessee State University Murfreesboro, Tennessee*

As leaders in mathematics education, we continue to seek activities that have been documented to support mathematics teachers in enhancing their instruction. This issue features two such activities.

In the first activity, Matney describes the Walk-Across Task, an activity used in a professional development setting that requires groups of teachers to examine the development of key mathematical ideas across grade levels, domains, and clusters. As an example, Matney shares the development of a K-5 Walk-Across for Fractions in the Common Core State Standards for Mathematics (CCSSM). Through his analysis of the teachers' tasks and their reflections, Matney reveals the power of this activity in supporting teachers' understanding of the mathematical connections represented within the CCSSM as well as the teachers' emerging confidence in working with the standards.

In the second activity, Barlow and Holbert describe the use of demonstration lessons within a professional development project. In this instance, project leaders taught demonstration lessons in the participating teachers' classrooms as well as in their summer institute. Follow-up interviews with participating teachers provide insight into the impact of the demonstration lessons as well as the key contextual factors that influence the impact of the demonstration lessons.

Activities such as these are but two possibilities for use in professional development projects. In both of these instances, the professional development project was external to the school setting. In contrast, Scott describes the professional development models employed at 10 STEM-focused schools. The characteristics of these models include not only the use of professional development activities embedded within the workday but also the use of teacher leaders to support the models.

As mentioned by Scott, in many cases schools are relying on teachers to assume leadership roles in leading professional development initiatives. Supporting the development of skills in school-based mathematics leaders is critical to the success of these initiatives.

One such initiative involves the use of professional learning communities (PLCs). A key to the success of a PLC is the leadership within the community. With this in mind, Brodie and her colleagues share their work within their PLCs. These PLCs are unique, however, in that they consist of teachers serving as leaders of their own school-based PLCs. Through their examination of the process of supporting PLC leaders, we gain insight into the importance of building a community that focuses on opening and maintaining inquiry while pursuing mathematical knowledge for the teachers and students, three aspects which at times can cause tension with one another.

Developing the leadership skills of mathematics teachers is also the focus of Gurl's work. In this learning community, however, the members are teachers who are learning how to mentor student teachers (i.e., cooperating teachers). As Gurl states, cooperating teachers receive little, if any, training on how to work with student teacher. In this article, Gurl shares the perspectives of cooperating teachers as they formed a community of practice aimed at supporting their effectiveness in working student teachers.

The work of leaders in mathematics education is as diverse as the topics represented in this issue. Yet, we share a common goal: to support improvement in students' mathematical achievement. I hope that the ideas shared within this issue will support you as you work towards achieving this goal!

Learning to Lead Professional Learning Communities in Mathematics

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Professional learning communities are increasingly seen as a generative and sustainable method of in-service teacher development. Professional learning communities are situated in teachers' work and support teachers in using their experience, evidence from their classrooms, their own and their colleagues' insights, and knowledge from research to decide what they need to learn and how they can learn it. Teachers monitor their own and their learners' learning in ongoing ways and engage in inquiry into their own practices and knowledge through deepening cycles of analysis, reflection and action, interrogating current practice and exploring alternatives. For Katz and Earl (2010) professional learning communities are "fundamentally about learning – learning for pupils as well as learning for teachers, learning for leaders, and learning for schools" (p. 28). Curry (2008) argued that an underlying principle of professional learning communities is that "schools cannot be intellectually engaging places for students unless their teachers are likewise actively engaged in learning, thinking, reading and discussing" (p. 735). The collective nature of professional learning communities is important. Teachers collaborate and learn together about how their learners' needs can influence and improve their practice and create collective improvements in their practices.

Professional learning communities can be established both within and across schools and within and across subjects and/or grade levels in a school. In each case, the community explores different issues and links their explorations to school or subject practices in different ways. In mathematics, professional learning communities tend to focus on teachers' content and pedagogical content knowledge. In order to develop their own problem-solving skills and greater flexibility in working with learners, teachers focus in some cases on rich problems in mathematics, how they would solve them, and how learners solve them, (Borko, Jacobs, Eiteljorg, & Pittman, 2008). In other cases, teachers focus on their own instructional practices, through lesson planning and reflection, making sure to notice and attend to learners' mathematical thinking in the lessons (Horn, 2005; Stephan, Akyuz, McManus, & Smith, 2012).

There are strong theoretical arguments for professional learning communities and some evidence that they do produce improved teaching practices and learner achievement (Boaler & Staples, 2008; Katz & Earl, 2010). There is also a growing body of research on how successful communities work (e.g., Curry, 2008; Horn, 2005) and the difficulties in sustaining them, particularly in high schools (McLaughlin & Talbert, 2001). A key element in sustaining professional learning communities is leadership of the communities (Stephan et al., 2012; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). However, very little has been written, however, on how leaders learn to lead professional learning communities. In this article, we focus on how a group of facilitators of professional learning communities worked collectively as a professional learning community in order to learn together to become better facilitators. We draw on data from a professional development project in which we work, the Data Informed

Practice Improvement Project (DIPIP), to describe and analyze some of our learning as leaders[1].

Leadership in Professional Learning Communities

Leadership of professional learning communities is central to their success (Boudett, City, & Murnane, 2008; Katz, Earl, & Ben Jaafar, 2009; Stephan et al., 2012). The functions of leaders can vary, depending on the nature of the community, however two key, interrelated roles have been established as important. The first is creating a culture of inquiry, where teachers work together to understand challenges in their schools more deeply and to support each other in addressing the challenges (Curry, 2008; Katz et al., 2009). By inquiry we mean using data from classrooms to interrogate and challenge current thinking, knowledge, and practice, and to explore alternatives. Inquiry includes critique which involves looking at strengths and weaknesses, posing questions about practice and knowledge, and suggesting ways of building on strengths and improving weaknesses. The second role for facilitators is to support teachers in focusing on their students' knowledge, and subsequently their own knowledge and teaching practices (Boudett et al., 2008; Elliott et al., 2009).

Successful professional learning communities require both critique and care (Hargreaves, 2008; Jaworski, 2006). Successful leaders create the conditions for critique and care by being both critical and caring themselves. Critique is necessary if communities are to shift established practices for the benefit of learners and care is necessary to prevent critique from producing defensiveness. Katz et al. (2009) argued that leaders can "observe what may not be apparent to insiders, facilitate reflection on issues, ask questions, probe for justification and evidence to support perceptions, and help reformulate interpretations" (pp. 90–91). Furthermore, leaders "are not afraid to challenge assumptions, beliefs or simplistic interpretations, and they do so in a non-judgemental and helpful way" (p. 91). However, the extent to which leaders are able to manifest both critique and care varies among leaders and across the situations in which they work. The dynamics of some communities might make critique and care more difficult to establish and sustain, and the same community might present different challenges at different times. Brodie and Shalem (2011) described the co-development of challenge and solidarity in professional learning communities. Solidarity arises in the community through discussion of shared problems and issues in relation to learners and the curriculum and through similar histories as teachers and learners. Solidarity supports challenges to particular teaching practices and creates possibilities for improvement.

While critique and care are necessary, they are not sufficient for successful professional learning communities in mathematics. A crucial element is the focus of the community, in our case the teachers' mathematical and pedagogical content knowledge. Managing the balance between the culture of the community and the substantive learning that needs to take place is complex work for leaders of professional learning communities and needs to be learned by current and potential leaders of professional learning communities. Little has been written about how leaders of professional learning communities learn to do their work, particularly where the goal is improved mathematics learning and practice for teachers and learners. One important principle that has informed our work is that leaders of professional learning communities need the support of their own professional learning community of leaders of professional learning communities (Nelson, Slavit, Perkins, & Hathorn, 2008). In this article, we discuss the work of such a community, of which the three authors are members. We draw on vignettes from two professional learning communities of high school mathematics teachers, for which two of us were facilitators, as an example of how we bring challenging issues to our community, analyze and reflect on them, and then take our learning back to our work as leaders.

Theoretical and Analytic Framework

The theoretical framework that guides our work as leaders and researchers of professional learning communities is Wenger's (1998) theory of situated learning. Wenger argued that people learn through making meaning of activity and practice and through developing identities in relation to meaning, practice, and learning. Wenger (1998) posited three elements that underpin a community of practice:

- mutual engagement – participants engage in actions whose meanings they negotiate with one another;

[1] We acknowledge that there are varying roles for leaders in professional learning communities and that facilitation is one such role. Stoll et al. (2006) distinguished pedagogic and strategic leadership. In this article, we use leader and facilitator interchangeably because we function both as strategic and pedagogic leaders.

- joint enterprise – the enterprise is collectively defined by the participants and constitutes their response to their conditions; and
- shared repertoire – this includes practices or concepts that the community produces or adopts as they make meanings in their situations.

Wenger (1998) asserted that mutual engagement does not require homogeneity; a joint enterprise does not mean participants always agree – in fact, disagreement can be viewed as a productive part of the enterprise; and shared practice does not imply harmony. What is important is that the joint enterprise, and particularly its meaning for the participants, is negotiated collectively through ongoing participation in the community. This applies to both professional learning communities of mathematics teachers and to our professional learning community of leaders.

In the professional learning communities that we lead, teachers choose episodes from their own teaching to bring to their communities for discussion, in order to inquire collaboratively into their practices. As facilitators, we do the same: we choose episodes from these meetings in order to enquire collaboratively into our practices and to improve them. These episodes serve as a mechanism for mutual engagements and developing a shared enterprise. As we talk and write about these episodes, we develop new ways of understanding the facilitation process. A key part of the process has been the development of a set of facilitation moves or practices in which we see ourselves engaged or think we could have engaged. These moves serve as a *shared repertoire* and are organized into four key areas: general management, inquiry, content and building the community.

General management refers to having everything set up for meetings, taking notes of key points to follow up during the meeting, and making sure to attend to project goals. We will not discuss the area of general management in this article. Rather, we will focus on the three other aspects of our role: building inquiry (i.e., interrogating practice and knowledge and exploring alternatives); developing mathematical content in the community; and building the ways in which the community works together, with critique, care, challenge, and solidarity. These areas might complement or be in tension with each other, as will be seen in the vignettes that follow. In looking at these vignettes, we reflect on what actually transpired, what worked well and what did not work so well, what we learned from that episode and what could have been done differently. In our own community, we employ the same principles of inquiry, knowledge, critique, and care that we try to build in the communities with which we work.

Our Context

We work in a mathematics teacher professional development project in Johannesburg, South Africa, called the Data Informed Practice Improvement Project (DIPIP), which establishes and develops professional learning communities of mathematics teachers within and across schools. We currently work with six communities in nine schools, involving 34 mathematics teachers. The schools are located in areas that serve learners of low socio-economic status, most of whom are black. Since the advent of democracy in 1994, promises of improved education for the majority of black learners have not materialised and mathematics achievement and understanding remain low in most communities (Reddy, 2006), severely affecting the life chances of learners from these communities. A myriad of teacher development programs have not succeeded in improving the quality of teaching and learning in schools that serve the poor (Reddy, 2006), and it is hoped that professional learning communities working together in ongoing ways in schools might do so (Department of Basic Education & Department of Higher Education and Training, 2011). The experiences of our project suggest that while professional learning communities can embody the substantive democratic principles of critique, care, and improved knowledge, it takes substantial time, effort, and learning on the part of all members, particularly leaders, to make sure that the communities develop and reflect these values.

The schools in which we work are all functional, however they have minimal material. They have supportive principals and heads of mathematics and a minimum of four mathematics teachers from grade 8 to grade 11. They are also in close proximity to each other. Community meetings take place in the schools and we try to build ways of working that will sustain the communities over the long term. The teachers meet once a week for two hours to work on the project activities. A cycle of activities includes: analysing learner errors on a test; interviewing selected learners to understand particular errors on particular test items in more depth; deciding which key concepts underlie the learners' errors; reading and discussing papers on these concepts; planning lessons to engage with the prevalent errors; teaching and videotaping the lessons; reflecting on the videotaped lessons; and choosing episodes from the lessons to discuss in the community (see Brodie and Shalem (2011) for more detail on the activities). At various points in the cycle, teachers from different communities come together in joint meetings, where they present aspects of their work to each other and give and receive feedback.

In the first year of the project, the facilitators worked closely with the teachers, attending every meeting and taking the entire responsibility for facilitation. After the first year, we gradually withdrew guidance. The communities chose one or two school-based facilitators, who took responsibility for facilitation and we gradually reduced the number of meetings we attended. When we did attend, we observed the facilitator and discussed the meeting with her/him afterwards as a means of support. We also conducted facilitator-training sessions once a month for the school-based facilitators[2]. The vignettes discussed in this article occurred during the first year, when we were still taking responsibility for the facilitation.

The university-based facilitators met weekly for two hours in project team meetings. The project team consisted of the three authors and two other facilitators and formed a professional learning community for the facilitators. During these meetings, we planned the activities, developed the protocols that we used for each activity, discussed the extent to which we and the communities managed to stay focused on program goals, discussed our facilitation strategies, and reflected on what happened in previous meetings, with the aim of improving the activities, the protocols and our roles as leaders of the communities. These meetings established our joint enterprise and mutual engagement in an ongoing manner, and we developed shared repertoires for engaging with each other and the communities. At regular intervals, we presented and analyzed vignettes, such as the two described in this article, in order to promote our own inquiry practices. In order to create sustained leadership in the communities, we recognized that how we learned as leaders needs to become a feature of how subsequent leaders will learn. Therefore, we analyzed our practice as leaders for our own learning and to anticipate the needs of and provide learning opportunities for future leaders in the communities[3].

The systematic nature of our regular meetings allowed for another important feature of professional learning communities: between the official meetings, impromptu and informal meetings occurred, to discuss issues as they arose. The two incidents described in the featured vignettes were first discussed in this impromptu way and allowed one facilitator to learn immediately from the experiences of another. Thereafter, they were brought to a regular meeting for more systematic discussion and analysis, which appears in this paper.

The Vignettes

VIGNETTE ONE

The first incident took place in a community of six teachers: Dimpho, Chamu, Mapula, Khumo, Mandla, and Funeka[4]. Dimpho presented an episode where a learner had written an answer of 10 cm + h cm as an answer to a question about heights, and the teacher simplified it to (10+h) cm. As the community was about to move on to the next episode, the facilitator mentioned, “Remember you’re not taking out centimeters as a common factor there.” Dimpho agreed, but Chamu did not and a long discussion ensued, mainly between the facilitator and Chamu, with some contributions from Dimpho and Mandla. The facilitator’s main argument was that centimeters are a unit of measurement and not a variable, and therefore cannot be operated on in the same way as a variable. Chamu presented a number of arguments, including: the units are multiplied by the number (i.e., h cm is the same as h x cm); km/hour is obtained when dividing distance by time and km by hours; and the unit of measurement for area, cm^2, is obtained by multiplying centimeters by centimeters. The facilitator argued that you multiply the numbers but not the units and that cm^2 is a unit for area, not the result of multiplication. He also argued that kilometers per hour can be interpreted as the number of kilometers travelled in an hour.

During the discussion, Mandla asked, “So if we’re not taking out the common factor, what are we doing?”

[2] The dynamics of this handover process are currently being researched by the third author and will not be discussed here.

[3] Some of these discussions feature as case studies in our training program for school-based facilitators.

[4] All the teachers’ names are pseudonyms.

Dimpho raised two points. First, she wondered whether it was possible to write 2 km/3 hours. Second, she reminded the community that teachers often use language that can be misleading, for example, "centimeters times centimeters equals centimeters squared." Chamu argued that it is correct to write "centimeters times centimeters equals centimeters squared" and that it helps learners to get correct answers. The facilitator argued that even though incorrect reasoning might produce correct answers, the idea is for learners to reason correctly.

During the episode, the discussion at times was heated, with both Chamu and the facilitator showing discomfort in what they said and in their tones of voice. At one point Chamu asked, "What you are saying is that I am wrong to multiply centimeters by centimeters." The facilitator agreed and said that he also used to think that units could be multiplied and divided but has since become convinced that it does not make sense. He gave the example that two rands[5] is written as R2 and it does not mean R multiplied by two. Later, Chamu said, "I think I'm being misunderstood here," and tried to give more examples to convince the others. At that point, the facilitator became frustrated and asked, "Do you understand what the word 'unit' means?" At the end of the discussion, the facilitator acknowledged that the community was not convinced and said that he would bring some readings for further discussion the next week.

The facilitator felt frustrated after the meeting and needed to reflect on it with the community of facilitators. He sent a text message to the other facilitators, asking for a discussion about why it is not possible to multiply units of measurement. Another facilitator consulted two other people and came to the meeting with an understanding of basic and derived units of measurement. The basic units include the SI units of length (meter), mass (gram) and time (seconds); all other units are derived from these. For example, area is measured in square meters and one square meter is defined by the area covered if you have a square of one meter by one meter. One meter per second (m/s) is defined as the velocity it takes to cover a distance of one meter in one second. The facilitators flagged this incident to be written up and discussed at a later point, in order to look at the interactions between Chamu and the facilitator and to think about ways in which the facilitator could have worked more inclusively with the rest of the community in order to defuse the tension and help with the difficult concept.

VIGNETTE TWO

The second incident took place a few days later in a different community, where there were six teachers: Constance, Lindiwe, Zandile, Bongi, Mavis, and Lethu. There was no expectation that a similar issue would arise. However, Lindiwe shared an episode in which she was discussing the formula for area and in response to a question learners gave an area of 24 cm^2. She asked the class whether it could be 24 cm, to which the learners called out "no." She explained to the class that "centimeters times centimeters equals centimeters squared."

The facilitator asked the community what they thought of Lindiwe's statement and as with the previous incident (in Vignette One), there was some agreement and disagreement among the teachers. Lethu argued strongly that if the dimensions of a rectangle are 3 m by 4 m then the area is calculated by multiplying 3 by 4 and meters by meters to get meters squared. The facilitator commented that Lethu was seeing the unit of measurement as a variable and both Lethu and Lindiwe agreed that they were. The facilitator asked, "What does meeters squared mean?" Mavis answered that it is "a block with area of one meter squared" and explained that in primary school, learners use a block with an area of 1 cm^2 to determine the area of a rectangle and count the blocks to get the area. Lindiwe became despondent and asked a number of times, "But why are we squaring it?" and "Why is the unit squared?" The facilitator and different community members then explained different ways of determining area of different shapes, including shapes with curved boundaries, without multiplying dimensions. Lindiwe again insisted, " I understand the blocks but I need to know where the square comes from." At that point, the facilitator suggested that they leave the discussion and come back to it at the following meeting. She was concerned that Lindiwe was upset and wanted to move on to the preparation for the joint meeting with other schools the following week. During the week, the teachers continued the discussion (which we do not have on record) and in joint meeting the following week, Lindiwe acknowledged her original error. She explained that originally she regarded meters squared as the answer to the multiplication "meter times meter." Although she understood the concept of an area with dimensions 1 meter by 1 meter, she did not

[5] "Rand" is the South African currency.

understand the role of the unit for area. Through the discussions with her colleagues, Lindiwe came to understand that the difference between obtaining area through multiplication and the use of the unit. She also realized that a meter (m) cannot be treated like a variable *m*.

Analysis of the Vignettes

We analyzed the vignettes from three perspectives: opening and maintaining inquiry; focusing on teachers' and learners' mathematical knowledge; and building community. Our analysis suggested similarities and differences across the two incidents, and also demonstrated how learning happened among the facilitators, both between the incidents and after reflecting on them.

VIGNETTE ONE ANALYSIS

Opening and maintaining inquiry. In the first incident, a chance mention of a mathematical point by the facilitator led to a sustained discussion and inquiry into mathematical content knowledge. We recognized that inquiry took place because members of the community took different positions in the discussion: they agreed and disagreed with each other; they marshalled different principles and examples to make their arguments; and, significantly, a teacher was not afraid to challenge the facilitator. The fact that a dissenting voice to an incidental remark led to inquiry was significant and suggested that inquiry was an established method of working in the community. On reflection, however, the facilitator was concerned that the discussion had become a dialogue between himself and Chamu and that most of the teachers had left the meeting unsure of the mathematics.

Focusing on teachers' and learners' mathematical knowledge. In relation to content, the facilitator recognized that the teacher was seeing the units as a variable, similar to when teachers argue that $3a + 2b$ is three apples plus two bananas, which "cannot be added."[6] This issue had been discussed many times in our communities (see Brodie (2013) for an example) and the teachers often referred to it. The fact that the facilitator made the initial remark about units in passing, suggested that he was aware that this was a similar case to looking at variables as "things" and that the teachers would know this from the previous discussions. However, the fact that he made the remark at all suggested that he thought it would be useful to say it, possibly to remind teachers of the important conceptual point. He was surprised by the discussion and the major disagreement about the content.

Building community. In relation to building community, the facilitator was concerned about the dynamics in the interaction. There was clearly some evidence of a community where at least one member could challenge the facilitator, was not afraid of arguing for his position, and maintained his position in the face of strong challenges by the facilitator and one other teacher. This teacher clearly felt misunderstood, however, and no other teachers supported him. Therefore, in this case we had challenge without solidarity (Brodie & Shalem, 2011) and critique without care. The facilitator felt challenged in this incident, in three ways. First, he was not able to convey his understanding of the mathematics in ways that supported Chamu and most of the other teachers to come to a deeper understanding of the use of units of measurement. Second, although he was confident in his own mathematical understanding, he felt challenged in that the key principles of the project were being undermined, i.e., that we do not look for procedural short cuts at the expense of conceptual understanding. Third, he was concerned that a focus on one important aspect of our project—content knowledge—might have undermined another—building community. He was so concerned about the mathematical content during the meeting that he gave less attention to how the community was functioning. His appeal to an authority, that of written texts, as a possibility to break the deadlock came from a sense that he needed to develop the content knowledge and had not managed to do so.

VIGNETTE TWO ANALYSIS

Inquiry and focus. In the second incident, although the facilitator was not expecting a similar discussion, when it arose she had thought about the issues and therefore could respond differently. She asked the community what they thought and elicited both agreement and disagreement for the teacher's position. One other community member supported the teacher throughout the discussion. There was inquiry in this community, with agreements and disagreements being justified, other examples given, and references to learners' prior learning. A key facilitator move in this case was to ask what the unit m^2 means. This move had two consequences. First, it allowed another teacher to argue with Lindiwe and Lethu rather than with

[6] A popular metaphor among South African teachers when teaching how to simplify algebraic expressions.

the facilitator. Second, it focused on the key mathematical concept that needed to be discussed. In this case, both solidarity and challenge were present in a balance that made for more productive learning. Mathematically, the focus on the unit of measurement of area as a derived unit allowed Lindiwe to pinpoint what she did not understand: that she could not see the relationship between measuring area with unit square blocks and calculating area by multiplying.

Building community. In relation to community, the teachers were willing to challenge each other and the facilitator. Teachers supported each other, suggesting that both challenge and solidarity were present, as well as critique and care. Lindiwe was despondent, not because members of the community disagreed with her but because she did not understand the mathematics. When asked by the community of facilitators why she did not follow this up, the facilitator reminded us of a previous vignette that we had analyzed. In that instance, leaving an issue unresolved at the end of a meeting allowed the teachers to think about it during the week and come to the following meeting having done the work of convincing themselves and each other (see Brodie, 2013 for more detail). The same happened here.

Learning from the Vignettes

The above analysis suggests a deepening of our knowledge of facilitation, in relation to both focuses of our role, developing a culture of collaborative inquiry and developing mathematical knowledge for teaching. We can articulate the following key aspects of what we have learned and their implications for our facilitation practices.

The different features of communities may be in tension with each other.

In the first vignette, a focus on content knowledge led to defensiveness of one community member while in the second vignette it led to despondence. It has long been acknowledged in the literature that it is difficult for teachers, whose professionalism is linked with their knowledge of mathematics, to admit to gaps in their knowledge and so such feelings are to be expected. The issue for facilitators is how to deal with such feelings when they arise. In the first vignette, the support and care that might have reduced the teacher's defensiveness was not present in the community. The facilitator's choice to focus on the content helped to sustain inquiry in the community but did not help to build cohesion and solidarity among community members. In the second vignette, there was support for the teacher, and while the inquiry during the meeting did not help with her feelings of despondence, the sustained inquiry and support after the meeting did support her to resolve her knowledge and her feelings.

The second vignette shows that all three features of the community (i.e., inquiry, content, and building community) need to work together for successful learning experiences. The first vignette demonstrates that if the features do not support each other, learning may not happen. The facilitator's role is to be aware of these three features: whether or not they are all present, and if not, whether the consequences are negative for the work of the community. If the facilitator believes that one or more of the features is not as prominent as it could be, her/his role would be to work out how to restore the balance. In the first vignette, the facilitator recognized that his focus on the content precluded him from focusing on the community and he could have worked with both together.

We can step back in order to go forward.

Based on her previous learning and the discussion after the first incident, the second facilitator made a crucial decision: to stop pursuing the discussion in the meeting. She did this out of care for the teacher's despondence and because she wanted the community to focus on their preparation for the next meeting. The community continued the discussion during the week, without the facilitator, and resolved the issue. The first facilitator also ended the discussion, hoping instead to appeal to other knowledge authorities. Upon reflection, it was not clear whether he could have done this earlier, because the teacher was insistent on arguing his point. Our reflection on these vignettes, as well as previous ones, suggests that we need to give teachers opportunity and time for their learning to happen. The work in professional learning community meetings can be intense, as the two vignettes demonstrate. Some downtime may be needed to process the ideas and to discuss with colleagues over more extended periods. The fact that the issues from the meetings are continued into school time, suggests that a key element of professional learning communities is being promoted, that teacher learning pervades the school (Stoll et al., 2006), rather than only happening in specified teacher development contexts.

Regarding our facilitation practices, we can learn to end discussions at strategic points, noting that we are doing so and indicating that the community can return to the discussion at a later time. We can suggest that the community continue the discussion between meetings and draw on resources from elsewhere. Someone in the community should take responsibility for remembering to bring up the discussion at the next appropriate time.

Listening to teachers and ourselves is complex and difficult.

A key element of any teaching situation is listening carefully and interpreting what the teachers are saying in relation to their contexts (Davis, 1997). For facilitators, this involves listening, not only to the teachers but also to ourselves as we facilitate, and noticing what we say and the effects of our contributions on the community and the inquiry. In the first vignette, the facilitator made the key mathematical points, but was distracted by the teacher's continued use of examples and therefore did not take time to make sure that all the teachers were on board with the mathematics. A dialogue developed which was not conducive to anyone's learning. The facilitator himself became somewhat emotionally involved, because he was concerned that some of the key principles of the project and previous learning were not being applied. In the second vignette, the facilitator listened carefully and interpreted the emotional states of the teachers. She was able to take a step back and support the teachers to move forward. She was able to listen because of prior reflections on her practice and because she had thought through the mathematical issues with her colleagues prior to the meeting.

The vignettes suggest that facilitators need to be in touch with their own emotions, during and after meetings. The need to create safe spaces for challenge and critique requires facilitators to be in touch with the emotions of the teachers. However, we may not be as well trained or positioned to notice our own emotions and some reflection on this at various points may help to keep the three key features supporting, rather than working against, each other.

Conclusion

Our analysis of these two vignettes illuminates two key features of our learning process: first we learn from reflecting on our own practices, and second we learn from each other's practices. We do this in our professional learning community through mutual engagement around a joint enterprise with a shared repertoire. We learn and grow together in similar ways in which we hope that the teachers with whom we work will learn and grow together. Learning is a complex process, and we engage with it on three levels: what and how learners learn in mathematics classrooms, what and how teachers learn in professional learning communities about supporting learners' mathematical learning, and what and how we learn to support teachers' learning in support of learners' learning.

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Establishing a Community of Practice for Cooperating Teachers

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Student teaching experiences in the field are often considered the most influential aspect of teacher preparation. Due to recent calls for residency programs, these experiences are likely to become more intensive, with a greater portion of teacher training taking place in schools (Duncan, 2009; Shulman, 2005). Often, student teaching placements can be inconsistent in quality and sometimes counterproductive (Field, 1994), with much of the onus of working with student teachers in the field placed on cooperating teachers (also known as mentor teachers), with varying requirements and varying amounts of training, if any. This suggests that cooperating teachers need training and support in order to improve their interactions with and impact on their student teachers. Communities of practice have been seen as a successful approach to the preparation of teachers (Levine, 2010). The premise underpinning this study is that many of the tasks cooperating teachers undertake with their student teachers are indeed the practice of a form of teaching (i.e., teaching future teachers) that needs to be learned, and that cooperating teachers would benefit from reflective inquiry within a community of practice. *Teacher learning* for the purpose of this study is defined as the cooperating teachers learning how to work with and develop student teachers.

The benefits of learning to teach in a community are echoed by many researchers (Frykholm, 1998; Loucks-Horsley, Stiles, & Hewson 1996; Stigler & Hiebert, 1999). Loucks-Horsley and colleagues stated, "Collegiality and collaborative professional exchanges [should be] valued and promoted. Too often, teaching is a lonely and insulated profession. Teachers need to support each other and enrich each other's work" (p. 2). A review of literature revealed only minimal evidence of the formation of communities of practice consisting only of cooperating teachers (Arnold, 2002).

The present study explored the establishment of a community of practice among a group of cooperating teachers in secondary mathematics. In particular, this study examined the interactions among the cooperating teachers with the goals of (1) examining the development of the community among the cooperating teachers; (2) gaining insight into the working relationship between the cooperating teachers and their student teachers, particularly, how cooperating teachers connected what student teachers learned in their on-campus programs and the realities of working with students in the classroom; and (3) determining what the cooperating teachers believed they needed in order to be successful in working with their student teachers. With these goals in mind, the research questions that guided this study were:

1. How does a community of practice develop among a group of cooperating teachers in secondary mathematics?
2. How do the cooperating teachers describe the working relationship with their student teachers?
3. What do cooperating teachers in secondary mathematics believe that they need in order to successfully work with student teachers?

This paper first provides background literature for the study, describes the procedure and participants, and then shares and discusses the findings of the study, including the establishment of the community among the participants, description of the nature of the participants' interactions with student teachers, and what the participants believed they need in order to be successful. Recommendations are made based on the findings.

Background

The typical preservice teacher education program culminates with a student teaching internship (Veal & Rikard, 1998), in which preservice teachers work closely with in-service teachers in the classroom, often taking full responsibility for a class. Teachers have considered the student teaching internship to have been the most helpful phase of their preservice teacher education programs, and it is often viewed as a rite of passage (Koerner, 1992; Graham, 2006). The student teaching site and the cooperating teacher with whom a student teacher works are recognized as critical components of the success of the internship experience. The characteristics of an effective cooperating teacher, however, have been difficult to ascertain. Furthermore, it has been noted the role of the cooperating teacher is not well understood (Graham, 2006).

Research has begun to reveal various practices of effective cooperating teachers. One practice consistently identified is that the most effective cooperating teachers do not require student teachers to emulate their own teaching practices, but rather encourage student teachers to be independent and take varying approaches to instruction (Graham, 2006; Killian & Wilkins, 2009). Graham (2006) made particular note of the "importance of cooperating teachers conceptualizing their role as one of providing a scaffold for teacher candidates during the practice rather than as one of supervising the intern" (p. 1120). Moreover, the approach taken by cooperating teacher may have a sustained effect long after the student teaching internship is completed, since cooperating teachers have the opportunity to encourage a student-centered approach in the classroom (Peterson & Williams, 2008).

There are often problems within the mentoring relationships, including conversations dominated by the cooperating teacher, lack of open discourse, and a failure to acknowledge differences between university and school perspectives (Haggarty, 1995). Some have suggested that student teachers be introduced to a variety of mentoring styles and asked to consider how they might learn from each style so as to allow for a better match (Hawkey, 1998). All of the above conclusions point to the necessity for greater understanding of the relationship and interactions between cooperating teachers and student teachers.

Hammerness and colleagues (2005) discussed that communities of practice are not a new idea, noting that the idea can be traced back to scholars such as John Dewey. They also emphasized the value of a community of practice in "developing and transmitting knowledge from practice to research and back again" (Hammerness et al., 2005, p. 383). This notion can be particularly key when working with student teachers, who, under the influence of their university preparation programs, are often attempting to integrate the theoretical standpoint of their university programs into their teaching.

Frykholm (1998) advocated for communities of learning for preservice teachers in which cooperating teachers and preservice teachers have "the opportunity to grapple together with the deep and perplexing challenges of mathematics teaching" (p. 306). He also noted the importance of community and reflection in the process of learning to teach. The present paper asserts that cooperating teachers as a group would benefit similarly from participation in a community of practice as they develop the practice of working with student teachers. This is particularly salient given the problem that cooperating teachers are asked to carry out the responsibilities of educating preservice teachers while also maintaining the full responsibilities of their teaching jobs, often with the idea that they are simply required to provide a place for student teachers to practice with little or no preparation (Zeichner, 2010).

Methodology

RESEARCH CONTEXT

This qualitative study was conducted during the spring 2009 and spring 2010 semesters at a large urban northeastern public university, which serves a highly diverse student population, more than half of whom are members of minority groups. During these semesters, the cooperating teachers were actively working with student teachers preparing to be secondary mathematics teachers.

PARTICIPANTS

The participants in this study were secondary mathematics teachers serving as cooperating teachers for the aforementioned student teachers. The participants were located at two different schools. Table 1 provides the teachers by school along with the semester(s) in which the participants engaged in the community of practice and the number of previously supervised student teachers.

As described by Levine (2010), a community of practice allows for the learning and development of shared practice over time, as well as the transmission of the practice with newcomers to the community. The participants had varying levels of experience with working with student teachers, and allowed for the least experienced participants to gain insight and suggestions from the more experienced participants. In this way, the participants somewhat fit Levine's (2010) description of "'old timers' [who] support newcomers who are on a trajectory into skilled participation in the practices of teaching" (p. 121), where *teaching* for the purposes of this study is the mentoring and cultivation of student teachers. Although there were no participants in this study who had enough experience to be considered *old timers*, there were participants with varying levels of experience involved in the study.

Table 1. Participants by school

	Adams School	Franklin School
Spring 2009	Lisa (1) Julia (1)	John (0) Caroline (0)
Spring 2010	Julia (2)	John (1) Caroline (1) Gwen (0)

Note: All names are pseudonyms used to protect the identity of the schools and the teachers.

It should also be noted that although the participants all came from the same undergraduate preparation program for secondary mathematics teachers, as did the student teachers with whom they worked, the participants from the two different schools did not know each other. The commonality of undergraduate experience was mentioned as being beneficial to the participants since they were familiar with the programmatic philosophy and student teaching requirements for the student teachers.

PROCEDURES

To develop a community to support the participants and to provide them with a forum for sharing ideas, the researcher initially planned to meet with the participants via online meetings. The participants later expressed that they would prefer face-to-face meetings. The problems with online meetings will be discussed in greater detail in the Results section. During the spring 2009 semester, online discussions, interviews, and one face-to-face meeting at the end of the semester with four participants (i.e., two participants from Adams and two from Franklin) occurred. During the spring 2010 semester, three face-to-face meetings took place with four participants (i.e., one participant from Adams and three from Franklin). A total of four face-to-face meetings were held over the course of two semesters.

MEETING STRUCTURE

All of the meetings took the form of semi-structured group interviews. The questions that guided the interviews and group discussion were as follows:

1. Describe what, in general you felt was successful about working with this student teacher.
2. In what two areas do you feel she made the most growth? How do you feel that you contributed to this growth?
3. In what two areas do you feel she made the least growth, and still needs to work? Do you feel that you attempted to work with her in these areas? Was she receptive?
4. What support would you like to have from the college in order to be a successful cooperating teacher?
5. What support would you like to have from your school in order to be a successful cooperating teacher?
6. What problems do you anticipate will arise as you help teachers fully implement standards-based lessons and teaching? What might you need to learn more about in order to address these problems?
7. How are you working with the student teacher to meet the requirements and philosophy of the program?

These questions were used as a guide, but other issues were brought up by the participants, as was encouraged by the researcher in the interest of building a community. The researcher acted mainly as a facilitator during the meetings, and when a participant raised questions, responses came from other participants in the group, not the researcher. This format allowed the researcher to engage in ethnographic observation of the workings of the group. The researcher took field notes during meetings.

ROLE OF THE RESEARCHER

The researcher served as university supervisor for the student teachers working with the cooperating teachers in the study. As such, the researcher was required to observe each student teacher a total of four times over the course of the semester. In addition, the researcher served as the facilitator of the participants' meetings. These meetings were structured around a set of interview questions provided by the facilitator.

Data Analysis

The qualitative data collected in this study were analyzed using constant comparative methods as described by Charmaz (2006), specifically, initial incident-by-incident coding with subsequent focused coding as various themes emerged from the data. The initial codes that emerged from the data were:

- wanting to know what the student teachers need in order to be successful;
- wanting to help the student teachers;
- an effort to incorporate the programmatic requirements of the program;
- a desire to share ideas among the group; and
- the benefits they felt they received from working with a student teacher.

The following themes emerged from focused coding of the data:

- a variety of ways to give feedback to the student teachers;
- classroom management was more important to a successful student teaching experience than content knowledge;
- conflict with the philosophy of the teacher education program and the realities of day-to-day teaching;
- a reminder of the idealism they themselves had as student/novice teachers;
- grateful to hear ideas from other members of the group;
- agreement that online discussion was not productive;
- wanting a guide for interactions with student teachers;
- wanting student teachers to be receptive to their feedback; and
- indication of what support they feel they need to successfully work with student teachers.

Data analysis concluded with a categorization of the coded text by research question. The results and discussion follow.

Results

The results of this study will proceed by discussion of the results for each research question. Specific text that supports the results will be shared.

THE EMERGENCE OF A COMMUNITY OF PRACTICE

As mentioned previously, in an effort not to burden the participants with face-to-face meetings, the initial plan was to conduct discussions online. An online group was formed and the researcher posted questions that were intended to prompt discussion. There was a mixed level of response to the questions. Some of the participants needed to be sent the questions several times, although all eventually responded meaningfully. The participants, however, did not initiate discussion on their own, and in only one case posted a question to the rest of the group. Later in the semester, the researcher interviewed each of the participants, who mostly indicated that they did not like the online structure. Lisa described the online group as "tough" and John stated, "I am not that good online." Lisa continued, "There is a big benefit to one-on-one, face-to-face conversations. I think they are more real time and interactive than they are online." In a separate interview, Julie expressed a similar sentiment:

> [Face-to-face meetings] are more beneficial because everyone gets to discuss the current topic instead of waiting two weeks for someone to respond to something. You're like 'What was the question? What were we talking about?' I think we would benefit more from meetings than on-line. We would get more out of it.

As a result, the researcher made the decision to have an in-person meeting with all of the participants at the end of the spring 2009 semester. This meeting as well as those that occurred during the spring 2010 semester took the form of semi-structured group interviews. Discussion during these meetings offered evidence of the emergence of a community of practice among the participants.

The researcher utilized the semi-structured group interview questions to facilitate the group meetings. At each meeting, participants shared the techniques and approaches that they used to plan with the student teachers and provide feedback to the student teachers about their teaching. Participants asked each other questions, and provided constructive feedback to each other. In one case, Julia and Caroline shared the different ways in which they provided feedback to their respective student teachers. Julia sat in the back of the classroom and took copious notes that she would share with her student teacher. The notes might have different foci on different days. For example, one day they might focus on board work. The next, they might focus on questioning and discourse. In contrast, Caroline described sitting with a group of students to see how they responded to and interpreted the actions of the student teacher. After hearing Julia's feedback process, Caroline thought that she might be not providing her student teacher with quality feedback. After some discussion, however, the group determined that both participants were both providing valuable feedback using different styles. Julia and Caroline both determined that they would try each other's approach in the future. In addition, Gwen, who was serving as a cooperating teacher for the first time, indicated that she planned on using ideas from both of these participants in order to provide feedback to her student teacher, evidencing Levine's (2010) notion of transmitting knowledge to newcomers in the community.

INTERACTIONS WITH THE STUDENT TEACHERS

Over the course of several meetings, the participants discussed the benefits they felt they reaped as a result of interacting with a student teacher. Caroline mentioned that although she hoped that the experience was beneficial to the student teacher, it was beneficial to her as well due to the advantages of collaboration. John indicated that working with a student teacher reminded him of some the ideas he had as a new teacher.

> It's really beneficial for me because I forgot a lot of things that I came [to teaching with] when I was a first year teacher. I had so many ideas and I had so many things going on, and I forgot them because you know, you get into 'your own thing.' And now, when [my student teacher] came [to my classrooom] with all these ideas, and I remember, I had these ideas, why don't I apply them too? So I am applying things that I always had in mind also, but now that I have more classroom management experience and better things like more strategies at hand now I can apply those ideas that I had before. So it's really beneficial for me, too.

Julia and Lisa reported a similar experience. Julia shared, "I think, like John said, they bring these ideas that we probably had our first year as well, like I DO remember that, and they do bring out that creative side of us too." Other participants agreed, indicating that working with a student teacher is "reenergizing and reinspiring." Julia felt that it "put that little fire back in us to say 'wow, I remember that.'"

The participants agreed that it was advantageous that they all came from the same undergraduate preparation program, noting that they remember "what [the student teachers] are going through." This idealism, however, was tempered by a realism that they tried to impart during interactions with the student teachers. As Julia described in the first meeting during the spring 2010 semester,

> I know that the [undergraduate] program encourages, you know, student-student interaction and all those things. But I don't think we are there yet . . . As far as short term, I think she needs to take more control of the classroom setting, and then think about implementing these great ideas. Because, you know, I told her, it's heartbreaking when you spend this quality time on this awesome lesson, and only you will appreciate it. Because when you come in these kids could not care less about what you are trying to teach them.

In addition to, and perhaps in conflict with the inspiration to remember some of the ideas and ideals with which they entered the profession, the participants indicated an ongoing conflict with what they and their student teachers had learned in their education program and the reality of working in the classroom. Participants also reported a loyalty to the program from which they graduated. Julia voiced her concerns by stating, "It's always in the back of your mind, you don't want to disappoint [the professor]. What would she say if she walked in right now?" This concern was not only in reference to their work with student teachers, but was a reflection on their own teaching practices.

Observations of the student teachers by university supervisors took place four times for each of the student teachers.

When asked during the middle of the semester whether the observed lessons were different from the day-to-day lessons, the participants agreed with Julia's comment: "Yes. Everytime we talk about . . . an observation, it's not what we talk about every day. We do make it what you guys want to hear." The particpants also admitted that, if the lesson that fell on an observation day did not lend itself to innovative teaching, they changed the order of the lessons so that they could help the student teacher incorporate some of the techniques that they felt that the university supervisor "expected" the student teachers to incorporate into their teaching. Gwen shared,

> I think that . . . the message they need here [is] that in a perfect world that you can do all of this every single day, but it is understandable if you don't. I think that is the part that is not really getting to student teachers in general.

Gwen is referring to cooperative learning, real-life applications, and other innovative mathematics teaching strategies.

By the end of the semester, planning for observed lessons seemed to have changed.

> *Julia:* It's like a term paper. You have a rough draft and your final submission. They're going to give you [the observer] their final submission. We talk about the lesson plan, we tweak it, we tweak it and we tweak it [to a greater extent that "regular" days].

> *Gwen:* I think it's pretty much what is going on now, and that is great. She might be a little bit more upbeat, but . . . that's probably the only difference. The prepared work is the same.

> *John:* It's obviously going to change. We [as classroom teachers] do it all the time [when an administrator enters the classroom].

> *Caroline:* It's pretty much the same. We might try to fit a little more into an observation but mostly the same amount of planning goes into each lesson. . . .Its really the same thing that goes on daily.

WHAT COOPERATING TEACHERS WANT AND NEED

Student teacher qualities. Consistently, and within individual and group interviews, all participants expressed that they expected the student teachers to be receptive to their suggestions and constructive criticism. This seemed to be the most consistent comment from all of the cooperating teachers over both semesters of this study. Defensiveness and not being receptive to suggestions were the most undesirable qualities in a student teacher. Further, there was some evidence that the attitude of the student teacher impacted the attitude of the participant, and not vice versa. Lisa described how the positive attitude of her current student teacher "rubbed off" on her, in contrast to the poor attitude of a student teacher with whom she had worked in the past.

> You see that [teaching] is in them, it's what they want to do. And so, because of that, they you want to put more into it too. When you get someone like we had last year, it's so hard to be enthusiastic with that type of person but this year it's very easy to see them and say 'yeah, what are we doing tomorrow, what are we doing today. Let's look at that lesson plan for next week' or whatever. So, just their attitude and approach is very encouraging.

Additionally, the other qualities that were desirable in student teachers were being a hard worker, taking initiative, and being punctual.

Support from the district and university. The participants reported that they wanted more time to meet with their student teachers. The participants from Adams School, where teachers were required to have a duty (e.g., hall or cafeteria duty), suggested that working with a student teacher fulfill the semester requirement for a duty, although they acknowledged that this was unlikely to happen. Lack of time for meeting with student teachers resulted in participants communicating with their student teachers via text messaging, email, and telephone.

The support participants reported wanting from the university involved structure and guidance for their interactions with their student teachers. John described the support needed.

> Maybe the expectations that I should have for her. Not too structured because I believe in giving freedom to the student teacher, if it is a good student teacher. If she is always prepared and has good ideas I believe in giving freedom. . . . But something like . . . what I should look for.

The notion of "what should we look for" was something that was often discussed by each of the participants. They discussed being able to pick apart a lesson and being able to find "everything" wrong with it, but not wanting to overwhelm the student teacher with too many suggestions at once. They suggested a written guide to structure the interactions with their student teachers, with expectations and benchmarks so they could see that their student teacher was making progress.

Discussion

The need to transmit knowledge of practice to newcomers in the community is evidenced by the lack of training and protocol for interactions between student teachers and cooperating teachers. For better or worse, teachers generally come into the profession with an image of what it means to be a teacher, gleaned from the many years logged in classrooms as students of various levels, often known as the "apprenticeship of observation" (Lortie, 1975). Cooperating teachers, having themselves only been student teachers for one semester in most cases, do not seem to have an internalized image to build upon for their practice of working with student teachers. Lisa shared, "I didn't have a very structured student teaching experience. I wasn't sure what I could provide for my student teacher." Gwen agreed.

> I feel like I don't know what it is like to be a cooperating teacher. I was a student teacher *once,* so I can only tell you what happened with my cooperating teacher, but I don't know what it is supposed to be like.

It is evident that the participants involved in this study benefited, both from being cooperating teachers and from being involved in the community of practice. The community gave the participants an opportunity to develop an image of what student teaching should be, and the benefit of working with others with whom they could share ideas, concerns, and different approaches to working with student teachers. This suggests that such communities for cooperating teachers should continue to be examined and developed on a wider scale.

Although the participants all stated that they liked the semi-structured nature of the meetings, it was unclear what the participants might have discussed without the structure of interview questions and without the presence of a facilitator, particularly a facilitator who had additional roles of researcher and university supervisor. Some of the important discussion was sparked by the interview questions, but some was sparked by the related topics that the participants brought up themselves. Without the presence of a facilitator, it might be necessary to have a more experienced member of the group become a leader, so that the conversation stays on topic, and does not simply become only an opportunity for venting about their difficulties. This role might rotate among the members of the community so that responsibilities are shared. Further, the group, not just the facilitator, might generate the questions for discussion either at the beginning of the meeting, or remotely before the meeting, perhaps via email. Part of the responsibilities of the group leader could also include scheduling the meetings, so that meetings do, in fact, take place.

The participants indicated that working with student teachers "reenergized" their teaching, but at the same time, indicated that they were having difficulty reconciling what they perceived to be the idealism of the university program and the reality of the classroom and the students with whom they worked. This issue suggests that cooperating teachers lose some of their idealism as they partake in the teaching environment. Simultaneously, cooperating teachers need help in creating a focus for their student teachers. At times, it seemed that the participants needed permission to focus less on alternative approaches to teaching with their student teachers (e.g., cooperative learning) and work on what they seemed to perceive as the prerequisites to such approaches, such as classroom management and development of discourse.

The participants indicated that they wanted some type of written guide for their work with their student teachers, beyond the general information provided by the college. A guide might include weekly goals, as well as long-term goals upon which the pairs could focus. Further, the participants indicated that they wanted a variety of suggestions for providing feedback for the student teachers, as well as what they referred to as "benchmarks" which would allow them to determine the growth of the student teacher.

Participation in the community also allowed a glimpse of the participants' beliefs about teaching, and the reform approaches recommended by their undergraduate program. Although participants agreed that it was important to try new approaches to teaching, they alluded to the fact that "strategies for teaching" and the establishment of classroom management were necessary before reform strategies are applied in the classroom. According to John, "The first thing I wanted her to do was get control of the classroom. Because after that you can do anything you want."

The participants in this study exemplified many of the characteristics of effective cooperating teachers discussed earlier. In particular, the participants gave the student teachers a good deal of freedom. It was evident, however, that the participants struggled with how much freedom to give their student teachers, as expressed by John:

> I want to give the student teacher a lot of freedom to do what [they want] because when you're going to enter the classroom you're not going to have anyone [to guide you]. So I kind of want to let them go a little bit. I just want to give them the freedom to do whatever they need to do. I don't step up and tell her 'you know you should change this' unless I feel it's like critical for her to do it,you know, unless I feel like a kid is going to fail because of something she's doing. I give her advice . . . and I have conversations with her, but I let her do her own thing. I pretty much give her freedom. But I think . . .sometimes I forget that I am being a mentor and that I should share my experiences with her, like my strategies that I know of and that I don't talk about with anybody, like classroom management strategies or like when you . . . discourse strategies.

Julia agreed, saying:

> I know where you're coming from. We talk about our lesson plans at least three days before the lesson. I have found that I'll sometimes look at the lesson plan and . . . I'll feel like the example is okay, but I feel like something is going to happen here. But it's not bad enough that it is going to throw her completely off, so I leave it alone. I've left it alone, and then when we discuss it I say 'so why do you think that happened?' . . . There have been instances where I think 'this may not be the way to go but I am going to leave it this way.' And then it's a learning experience for both of us. Sometimes it didn't even go the way I thought it would and it went well, and it worked out. And sometimed it has gone the way I thought it would go, and we talk about it.

This struggle regarding how much guidance to give the student teachers was a recurrent theme of the discussion among the participants.

Conclusion

The current inclination to move teacher education into field placements to a greater degree than in the past will put cooperating teachers in the "front lines" of teacher education, a role for which they have often have had no formal preparation. The results of this study suggest that the establishment of communities of practice could facilitate the process of integrating new cooperating teachers into the practice of working with student teachers, while allowing the exchange of ideas among more experienced cooperating teachers.

This study provides evidence that cooperating teachers can benefit from working within a community of practice in order to define and improve their practice of working with student teachers, distinct from their practice of working with their own students. Experienced teachers agree to serve as cooperating teachers without a clearly defined image of what their role should be and need more structure and guidance for their work with student teachers. The structure of the community of practice allowed for less experienced cooperating teachers to gain suggestions and feedback from more experienced cooperating teachers.

Schools of education might consider these findings when setting up field placements for student teachers. Creating small groups of cooperating teachers where informal exchange of ideas and suggestions can take place would likely improve the field placements for student teachers. With the recent calls to move teacher preparation into the classrooms of experienced teachers, the experienced teachers serving as cooperating teachers would benefit from participation in such a community, and experienced teachers who are new to the practice of serving as a cooperating teacher would have a support system to facilitate the process of becoming an experienced cooperating teacher.

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Professional Development Models at Science, Technology, Engineering, and Mathematics (STEM) Focused High Schools

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Over the past 30 years, many states have created opportunities to increase students' exposure to and engagement in science, technology, engineering, and mathematics (STEM) content learning. Some of the many options available to students include: dual enrollment; Advanced Placement (AP) and International Baccalaureate (IB) programs; early college entrance programs; summer programs; residential STEM schools; non brick-and-mortar type educational programs; STEM academies or schools; internships and mentorships; contests and competitions; and service learning programs. One of the advantages that STEM academies or high schools have over traditional schools is an extended time with students to go further into the stages of expertise. They design programs that move students from interest in subject area to competencies to expertise. Specialized STEM high schools come in different forms: state residential schools, schools within schools, self-contained schools, and part-time sites (Jones, 2010). Some schools are on college campuses and are organized under the state's higher education system. Others are administered under a local or regional school system. Despite the increase in the number of STEM-focused schools over the past decade, little is known regarding which of these school models is most effective (Subotnik, Kolar, Olszewski-Kubilius, & Cross, 2010).

Several networks have been formed around the development of STEM-focused schools. Some of these include: The National Consortium of Specialized Secondary Schools of Mathematics, Science, and Technology (NCSSSMST); The Ohio STEM Learning network; T-STEM academies; and the Colorado STEM network. These organizations provide a communication network for sharing ideas and obtaining professional development (PD) for specialized teaching methods and leadership. The purpose of this exploratory study was to begin gathering data from current STEM programs to inform school districts that are considering the development and implementation of a STEM program or school. Specifically, this study examined the PD opportunities offered to teachers who are designing unique academic experiences for students at STEM-focused schools. The following questions were posed:

1. What is the process for planning and implementing teacher professional development at STEM-focused schools?
2. What professional development activities are planned for faculty members in STEM-focused schools?
3. What challenges can be anticipated as we plan to scale up effective STEM teacher professional development for a national audience?

According to the National Research Council (2011), effective professional development should "focus on developing teachers' capabilities and knowledge to teach content and subject matter, address teachers' classroom work and problems they encounter in their school settings, and provide multiple and sustained opportunities for teacher learning over a substantial time interval" (p. 21). As a result, the significance of this research lies in its potential to inform the design of professional development for STEM-focused schools. For this study, STEM-focused schools were defined as schools specifically designed to offer more content, instruction, and experiences applying STEM content than what is typically offered in non-STEM schools within their school districts.

Related Literature

Given the increased attention to STEM, a body of research exists which identifies successful strategies for increasing student's success in STEM. Many of these studies have focused on teachers. Payne (2004) attributed the lack of science skills in the U.S. to poor elementary school teacher preparation. According to Payne, elementary teachers identified science as the curriculum they were least comfortable with teaching. With regard to mathematics, Lloyd (2006) suggested that many teachers have a narrow view of mathematics and its application to the real world. "Research has clearly shown that a good teacher is the single most important factor affecting student learning" (Geringer, 2003, p. 373).

To this end, teachers need training in best practices in STEM pedagogy. According to Wilkins and Brand (2004), teacher training has been successful in changing teacher's attitudes and beliefs about reformed-teaching methodologies. Lloyd (2006) recommended using K-12 standards-based curriculum to train teachers. She suggested selecting activities that are mathematically challenging, illustrate connections among concepts, and emphasize where misconceptions usually occur or real-world contexts.

Recognizing the importance of teacher training, Yoon, Duncan, Lee, Scarloss and Shapley (2007) examined more than 1,300 studies addressing the effect of teacher professional development on student achievement. The authors found that only nine studies directly assessed the effect of in-service teacher professional development on student achievement in Mathematics, Science, and Reading/English Language Arts. All nine studies focused on elementary school teachers and their students. The results of these studies indicated that the "average control group students would have increased their achievement by 21 percentile points if their teacher had received substantial professional development indicating that providing professional development to teachers had a moderate effect on student achievement across the nine studies. The effect size was fairly consistent across the three content areas reviewed" (p. 2). These results support the importance of effective professional development in STEM pedagogies.

In order for professional development to be effective, research has identified key attributes: a focus on teachers' identified needs (Hill, 2009); opportunities for teachers to be active participants in the planning and execution of the professional development (Clark & Florio-Ruane, 2001); and long-term support for implementation of reform efforts identified through the professional development (Ferguson, 2006). In addition, professional development can be most effective if it is collaborative, bringing teachers together in productive learning communities (Grossman, Wineberg & Woolworth, 2001; Lieberman, 1995; Swenson, 2003). "Professional learning communities [are] center to fostering teacher change and student learning" (Borko, 2004, p.6).

One way to avoid the oft-criticized one-size-fits-all quality of professional development is to cater it to teachers' individual needs and to offer specific feedback to teachers about their contextualized practice. Klinger (2004) wrote, "Teachers have different internal characteristics and work in diverse contexts with varying external pressures, and it is important to consider these complex factors when planning for and conducting professional development programs" (p. 252). Similarly, Hill (2009) suggested that professional development be differentiated to teachers just as teaching is differentiated to students. "Content-focused professional development based on classroom practice – including evidence around student learning, the study of curriculum materials, and so forth – is most likely to affect teacher knowledge and performance and student outcomes" (p. 474). Furthermore, professional development is "most effective when it is an ongoing process, which includes appropriate, well-thought-out training and individual follow-up" (Robinson & Carrington, 2002, p. 240). Collegial support networks help teachers implement professional development (Klinger, 2004). One additional critical element of effective professional development is a focus on a particular content area. While much of the professional development offered to teachers emphasizes pedagogical approaches, fewer examples reveal a focus on supporting growth in teachers' content knowledge. Recent research in mathematics in particular has emphasized the need for content-centered professional development. "U.S. teachers need improved mathematics knowledge for teaching" (Hill & Ball, 2004, p. 330).

Table 1: STEM School Overview

Pseudonym	Region	Grade Level	Year Est.	Locale	Charter/ Magnet	Title I	Student Enrollment	Type of school
Archimedes HS	South East	9-12	2004	Large City	N/Y	Y	689	Local/regional
Boyle HS	West	9-12	2000	Large Suburb	Y/N	Y	567	Self contained
Priestly HS	South West	9-12	2002	Large Suburb	N/Y	Y	882	Local/regional
Pythagoras HS	West	9-12	2004	Large City	Y/N	N	874	Local/regional
Einstein HS	Mid-West	9-12	2006	Large City	N/N	N	300	Part-time site
Galileo HS	North East	9-12	1997	Large City	N/N	N	1683	Self contained
Plato HS South	East	9-10	2008	Small City	Y/N	Y	367	Self contained
Marconi HS	Mid-West	9-10	2008	Large City	N/N	Y	224	Self contained
Euclid HS	North East	9-12	2008	Rural Comm.	N/N	N	1654	School within a school
Pascal HS	South East	9-12	2007	Small City	N/Y	N	1649	School within a school

Note: Data collected July 2013 from National Center for Education Statistics, 2012.

Methodology

A comparative case study method was used in this study because it provided the most comprehensive answers to questions about professional development offered at STEM-focused schools. Case studies offer a means of "investigating complex social units consisting of multiple variables" (Merriam, 1998, p. 41). The comparative case study method provided for a holistic description of each STEM-focused school including: teacher professional development opportunities, academic programs, and students served at the selected schools. According to Yin (2003), one advantage of a multiple-case study is that "the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust" (p. 46).

SELECTION OF STEM-FOCUSED SCHOOLS

A criterion-based selection was used to choose the site and participants to be studied. The initial site selection began with a national search of STEM secondary schools that were specifically intended as STEM-focused schools. According to Atkinson, Hugo, Lundgren, Shapiro and Thomas (2007), more than 100 high schools are designed with a STEM focus. The second criterion for selecting a school site was those designed specifically to enhance all students understanding of science, mathematics, engineering, and technology as opposed to programs that were primarily for advanced or gifted students. Schools designed as very selective programs or that have strict entrance requirements are often regarded as elite schools and were not included in this study. STEM schools that had statements indicating that their goal was to provide opportunities for all students, including underrepresented student populations, were selected for further study. The 10 schools that were included in this study were randomly selected from a pool of 57 STEM-focused schools.

DESCRIPTION OF STEM-FOCUSED SCHOOLS

The STEM-focused schools selected for participation in this study were located in various regions across the U.S., with five of them qualifying for Title I status. Table 1 contains a list of the participants using pseudonyms to protect their identity. Six of the schools were designed specifically for the implementation of the STEM program. These schools began with a new building, faculty, and staff members. Four schools were already in existence but were reinvented in order to change their academic emphasis to STEM content. Most of the schools had traditional school facilities while two of the new schools were located in business or commercial settings.

Student demographics. When comparing the demographics of these STEM-focused schools to all public high schools in the United States, there were noticeable differences. Results demonstrated that the STEM-focused schools in this study served a higher percentage of minority students than the national average. Student population was important to this study because it focused on STEM programs for traditionally underserved populations. Table 2 lists the percentage of students in each ethnic group that were enrolled in STEM high schools compared to those enrolled in all U.S. public high schools during the 2009-2010 academic year (School Data Direct, 2010; U.S. Census Bureau, 2011).

The percentage of black students attending these STEM-focused schools was more than three times higher than the national average of 16%. White and Hispanic students were under represented. This over representation of black students in the STEM-focused schools may be accounted for by the location as several of the STEM-focused schools were located in urban areas which have higher black populations. The average percentage of economically disadvantaged students attending STEM schools was 42%, which was the same as the national average (School Data Direct, 2008).

Student achievement. Students who attended the selected STEM-focused schools outperformed their peers on end-of-course assessments in mathematics and reading or English. Participating schools took different statewide assessments so student performance was measured by comparing the STEM-focused school average to the statewide average. When students had more than one mathematics exam (i.e., algebra and geometry), the exit level or graduation required test score was used. The data in Table 3 (see pg. 26) represents the percentage of students who passed the previous year's state standardized tests in English, Reading, and Mathematics. On average, students in STEM-focused schools had a 13% higher pass rate for English and 12.78% higher pass rate for mathematics compared to those who attended other schools. Of the nine schools that participated in state-wide testing, all performed higher than the state average in mathematics and English. Plato High school was a newly opened school and was the only school in this study that did not report end-of-course exam results.

DATA COLLECTION AND ANALYSES

The data collected during this project included documents in print and digital format, telephone interviews, and email communication. These sources were used to provide and confirm information needed in order to answer each research question. Documents were collected from multiple sources including: school websites, State Department of Education archived test score databases, grant applications, and applications for admissions materials. In regard to the use of documentary material, Merriam (1998) identified the greatest advantages as its stability and objectivity. She wrote, "Unlike interviewing and observation the presence of the investigator does not alter what is being studied" (p. 126).

Table 2: Ethnicity of STEM HS students vs. HS students attending U.S. public schools

	% of students enrolled in STEM HS	% of students enrolled in U.S. public high schools	Difference in population
White	32	59	-27
Black	50	16	+34
Hispanic	12	19	-7
Asian	5	4	+1
Other	1	2	-1

Note: Data collected from www.nces.ed.gov (January 2011) and U.S. Census Bureau http://www.census.gov/population/www/socdemo/school.html, (May 2011).

A cross-case synthesis technique was used to analyze the data in this study. Yin (2003) suggested treating each individual case as a separate study then aggregating findings across a series of individual cases. He recommended "creating a word table to display the data from the individual cases according to a uniform framework" (p. 134). Following these suggestions, the contents of the interviews and document data collected were coded and organized in a matrix. Formal analysis of the interview data began by listening to the interviews, then transcribing them, then listening and reading them at the same time. Transcript data were entered into a digital database. Variables were identified and then coded to identify emergent themes, patterns, and questions. Coding and matrices were used for comparison across interviews and interview summaries to retain the context of the data. During the analysis phase, patterns were identified, and explanations as well as rival explanations were highlighted.

Table 3: Comparisons between STEM HS End-of-Course Exams Pass Rate and the Statewide End-of-Course Exams Pass Rate

	Reading/ English	State AVG Reading/English	% Difference English/Reading	Math	State AVG Math	% Difference Math
Archimedes	72	43	+29	76	44	+32
Boyle	98	81	+17	96	81	+15
Priestly	98	92	+6	82	70	+12
Pythagoras	86	66	+20	40	30	+10
Einstein	95	85	+10	97	79	+18
Galileo	99	80	+19	98	84	+14
Plato	Data not available					
Marconi	91	83	+8	88	80	+8
Euclid	87	84	+3	83	80	+3
Pascal	91	86	+5	85	82	+3
AVG			**+13**			**+12.78**

Note: Collected from individual State Department of Education websites (January, 2011).

Results

Results from this study described a variety of ways that STEM-focused schools in the U.S. have implemented professional development for teachers designed to fulfill the goal stated in the Academic Competitiveness Council Report (U.S. Department of Education, 2007): "to prepare all students with STEM skills needed to succeed in the 21st century technological economy" (p.23). Students attending the STEM-focused schools in this study were provided rigorous courses in STEM content. The professional development activities described highlight the type of support that teachers in STEM-focused schools received.

What is the process for planning and implementing teacher professional development?

The role and number of school administrators, master teachers, and university and industry partners varied by school, but all of the schools emphasized a collaborative leadership team that guided decision-making. Master teachers in this study exhibited leadership in multiple, sometimes overlapping, ways and met the Teacher Leader Model Standards (2011). Some leadership roles were formal with designated responsibilities. Other roles were more informal and emerged as teachers interacted with their peers. The variety of roles ensured that teachers could find ways to lead that fit their talents and interests. Regardless of the roles they assumed, teacher leaders shaped the culture of their schools, improved student learning, and influenced practice among their peers. Figure 1 (pg. 27) illustrates the interactions and responsibilities of team members involved in creating professional development for teachers. School administrators, master teachers, and university and industry partners brought different expertise to the group but shared in the responsibilities of educating future scientists and mathematicians. They all had a vested interest in the success of students enrolled in the STEM program and felt a sense of responsibility for their efforts.

This collaborative professional development design model facilitated the mutual support of teachers by having professional conversations addressing the needs of the students and the community, selecting and designing curriculum, and developing an implementation plan that was conducive to all parties involved. This type of professional decision-making design encouraged and supported teacher development as they experimented with a variety of pedagogical approaches using video and hypermedia materials and real-world laboratory experiences.

What professional development activities are planned for faculty members in STEM-focused schools?

Professional development opportunities for teachers at the participating STEM-focused schools focused on developing teachers as leaders, collaborators, and creators of student learning experiences. Key features of professional development included a dedicated time set as a priority for teacher training that was done collaboratively. Teachers were leaders in selecting and leading the activities, and topics were focused on curriculum and instruction that pertained to STEM content and pedagogy. Some schools implemented cross curricular units while others focused on the needs of new faculty members. Teachers were involved in identifying the needs and assisting in the design of PD rather than having it imposed on them from an outside source. In addition, one school had a state approved teacher certification program embedded in its school.

When conducting interviews with STEM school leaders, administrators were asked to describe the professional development opportunities offered to their teaching staff. In addition, some schools provided documents with detailed descriptions of professional development activities offered in their schools. An interesting finding that emerged was the involvement of mentors to train new teachers and develop master teachers in instructional strategies focused on teaching and learning STEM content.

FIGURE 1: *STEM School Professional Development Collaborative Design Model*

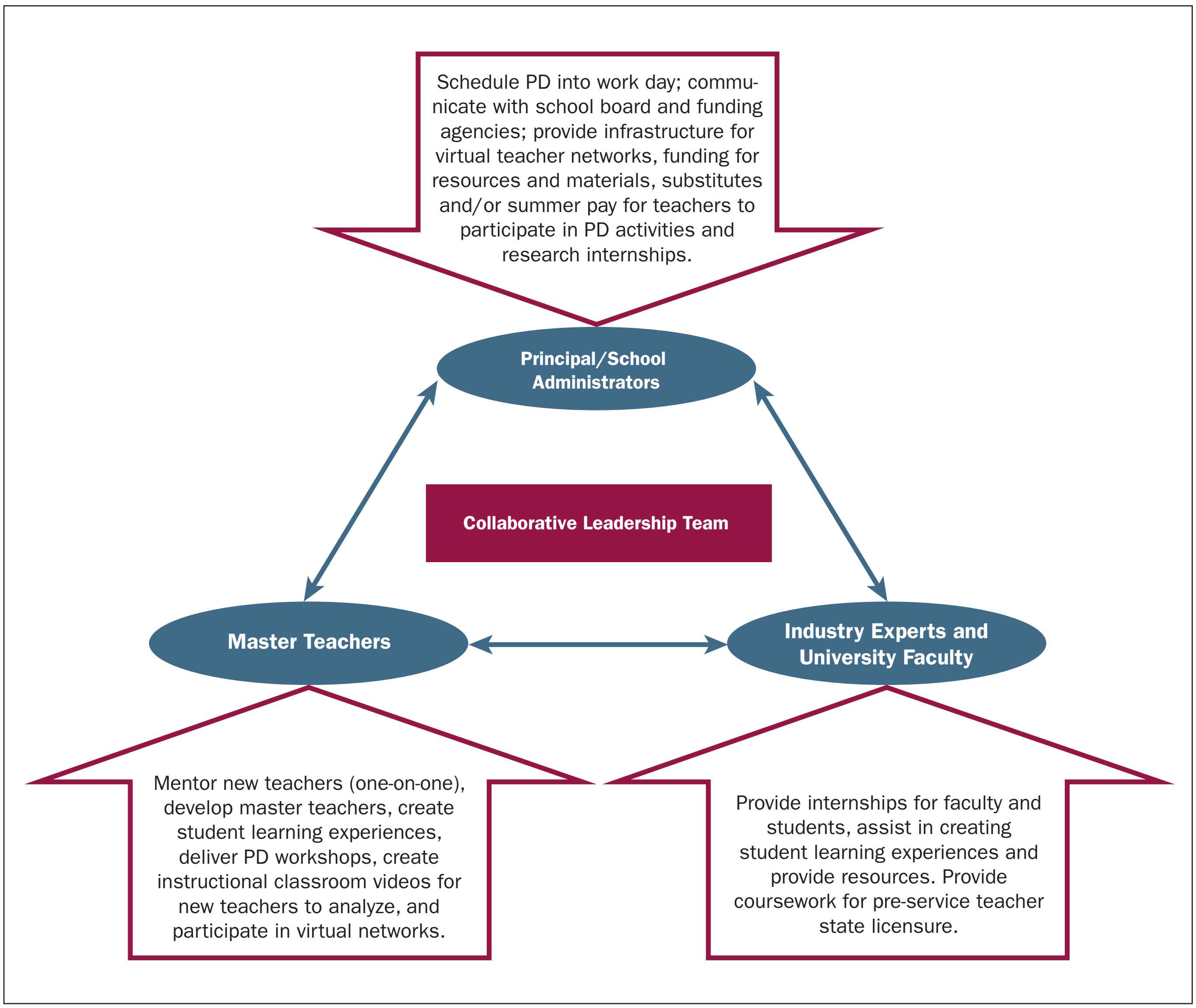

Table 4 contains a summary of some of the topics covered in the professional development activities. There are only seven schools listed in Table 4 because two of the schools were new schools that were hiring staff to teach rising 11th and 12th graders and the third school decided to change the focus of their professional development activities. A brief description for each school follows.

Archimedes High School. Teachers at Archimedes HS had regularly scheduled professional development workshops provided by instructional coaches on a variety of topics. In addition to onsite instructional coaches, educators at Archimedes were provided a virtual mentor network. This resource provided a unique, online video staff development. Teachers watched master teachers demonstrate

Table 4: Summary of Professional Development Activities

School	Topics	Leader	Format
Archimedes HS	Learning labs, Creating and executing master lesson plans, Classroom management that works, Using grading to motivate student engagement, Reading strategies, Assessment and accountability, Rigor in the classroom, Differentiating instruction, Encouraging critical thinking.	Conducted on-site by instructional coaches and online with virtual mentors	Dedicated professional development days at the beginning and throughout the school year.
Boyle HS	Guide to project-based learning, Curriculum integration, Internship program development, Teaching diverse learners, College advising, Technology implementation.	Led by experienced teachers in the school. Some teachers attended professional conferences.	Teachers met one hour before school each day. Various day long PD workshops throughout the year. Two week-long teacher preparation sessions prior to school opening.
Priestly HS	Coursework/workshops offered to fulfill initial teaching license requirements; PLCs focus on using common assessments.	Developed and delivered by the Director of curriculum and assessment	Teachers met in the summer prior to school opening and regularly scheduled weekly meetings during the year.
Einstein HS	Examining student work, Peer reviewed lessons, Developing collaborative integrated course projects.	Instructional coach met with teachers one-on-one, observed classes and designed an improvement plan for each teacher.	Teachers had a common planning period every morning and participated in professional learning communities. Substitutes were provided for teachers while working with coaches.
Marconi HS	Developing trans-disciplinary instructional units; Evaluating and integrating best practices; and Classroom research;	Teachers have participated in an internship with an industry partner. PD was led by master teachers in the school.	Teachers participated in quarterly faculty institutes and have daily common collaborative time. They participate in a 10-week instructional internship at a local business and have a week-long STEM development institute during the summer.
Galileo HS	Creativity and rigor in the classroom	Teachers observed classrooms in and out of content area;	3-day teacher orientation prior to school year and ongoing during the year.
Pascal HS	Curriculum planning; Integrating inquiry-based experiences; developing authentic real-world opportunities for students.	Teachers collaborated with university partners to develop curriculum.	Curriculum was developed during the summer and implemented throughout the school year.

techniques in real classrooms. Archimedes had developed an instructional partnership with a charter school with the purpose of building a professional learning community that observes and analyzes effective instruction.

Boyle High School. Faculty members at Boyle HS participated in ongoing professional development. This included 45 minutes per day without students for collaboration and program development. There were various daylong professional development workshops throughout the year and a two-week long teacher preparation session in August prior to the opening of the school year. The state commission on teacher credentialing had approved Boyle HS to certify teachers through its Teacher Intern Program. Boyle partnered with the state university to provide a 120-hour preservice teacher program and 600 hours of training and practice over two academic years. Interns earned full-time salaries and benefits as provisional teachers while working toward their teaching credentials. To be considered for this program, individuals first applied for a teaching position at Boyle. Once hired, they participated in the intern program. Teachers were positioned for success at Boyle HS by working in teams that dealt with the same cohort of students. They arrived at school an hour before the students each day to plan, discuss student work, and engage in professional development activities. This school offered learning opportunities for practitioners to participate in teacher residencies and institutes.

Priestly High School. Like Boyle HS, teachers could be hired at Priestly HS without a state teaching license. The school provided in-house training. The staff met two to three weeks before school started. They met with the director of curriculum and assessment who gave a very clear set of curriculum guidelines. Although teachers did not have to be certified by the state to teach at this school, Priestly HS had a prescribed training program that was very thorough. Teachers used common assessments across the departments and across the school.

Einstein High School. Einstein HS served as a laboratory for developing the best ways to teach science and mathematics. Teachers rotated in from the surrounding districts, enabling them to take what they learned back to their home classrooms. Einstein HS provided time for teachers to collaborate, support for instructional improvement, and encouragement to develop as professionals. Providing time for teachers to work together was a priority at this school: teachers had common planning time every morning. They also spent time in professional learning communities. During this time, they examined student work, peer reviewed lessons, and worked on collaborative integrated course projects. Coaching was individually tailored to meet teachers' needs. The coach met with teachers one-on-one for an hour, then observed a class, and then worked on improvements with the teacher based upon his/her improvement plan. The school provided substitutes so teachers could work with their coaches. Teachers were encouraged to develop as professionals.

Marconi High School. The professional development plan at Marconi HS included three significant characteristics: quarterly faculty institutes, daily common collaborative time, and embedded industry internship experiences. Regular professional development was focused on cross-training experiences through development of trans-disciplinary instructional units and systemic strategies for knowledge sharing amongst the STEM disciplines. A revised teacher workday allowed for quarterly one-week STEM development institutes in which STEM partners engaged in the study, evaluation, and integration of current best practices and research. Specific time was built into the workday for collaborative faculty work sessions. Marconi faculty had opportunities during the first year of operation and every four years thereafter to acquire, enhance, and refine their own STEM-related skills in four, individualized 10-week faculty internships.

Galileo High School. Galileo HS provided support to new faculty members through a three-day new teacher orientation. New teachers were paired with mentors. Teachers were encouraged to visit each other's classrooms, within their disciplines and outside disciplines. This type of collaboration allowed teachers to see how creativity and rigor worked in another content area, and to see how some of the same students, who they may find challenging, were excelling in other classes.

Pascal High School. Selected educators at Pascal HS were members of a curriculum planning committee, which collaborated with university partners. Integrated inquiry experiences were provided through collaboration between teachers and university engineers who worked with the classroom teachers. These collaborations resulted in authentic real-world opportunities for students to understand and utilize basic and advanced mathematics and science principles.

Cross-case analysis. Although all of the STEM-focused schools provided professional development for their teachers, Marconi, Einstein, and Boyle provided the most extensive training. These schools had regularly scheduled meetings during the workday throughout the school year. They also included mentor support that was instrumental in developing master teachers. Mentor teachers played a different role than master teachers. Mentor teachers were classroom teachers who played a support role for teachers new to the school building. Teachers worked in teams and were responsible for selecting curriculum, developing and delivering integrated lessons, and assessing students. Core learning goals for the state were to be accomplished first, but after that teachers have been granted permission to enhance the program as appropriate.

All schools were involved in professional development that focused on curriculum and implementation of STEM content with diverse students. Einstein High School was the only school that focused on measuring the effectiveness of the instruction by examining student work. The master teachers led professional development that focused on the development and implementation of the curriculum. Two schools included university partners or industry experts in the development of the curriculum.

What challenges can be anticipated as we plan to scale up effective STEM teacher professional development for a national audience?

Hiring and training teachers in STEM content areas was a challenge for many of the participating STEM-focused schools. The principals at Euclid, Galileo, and Pascal identified the teaching staff as key components to program success. They indicated that they tried to select the best teachers for their programs and then train them on the methods being used. To this end, six challenges were identified, each of which will be briefly described.

Teacher leadership training. Teacher leadership has traditionally been restricted to roles such as department heads, textbook adoption committee chairpersons, and teacher mentors. Involving teachers in the decision-making process and encouraging them to be facilitators of change, as typified in the participating STEM-focused schools, was a new role for which the teachers had not been trained.

Time for collaboration. One of the challenges that STEM-focused schools faced was finding time for teachers to meet on a regular basis during the school day. Many of the schools had a small number of faculty members with many tasks that needed to be completed, limiting the hours teachers were available to collaborate.

Changes in instructional methods. Another challenge was encouraging faculty to experiment with various instructional methods to meet the academic needs of the students. Some questioned the effectiveness of new teaching methods like project-based learning rather than teacher directed instruction. Others were concerned about the impact of these changes on students' end-of-course exam scores.

Retention of master teachers. The fourth challenge was finding and retaining master teachers in STEM disciplines that had the pedagogy and content knowledge to mentor his/her colleagues and deliver professional development. Administrators had limited incentives or compensation to offer master teachers for the additional hours they contributed to supporting new faculty and developing coursework.

Identifying specialty teachers. Administrators found it difficult to find teachers who were skilled at teaching specialty courses, such as Integrated Mechanics, 3-D Animation and Biohazards. As a result, some administrators relied on industry experts to teach these courses. One of the challenges to this model was the lack of pedagogical skills that the industry partners possessed. Instructors had to learn to manage 25-30 adolescents with diverse needs and to develop lessons that were developmentally appropriate for this age group. Assessing gains in students' content knowledge was a foreign concept to most of these instructors.

Real-time support for new teachers. Online professional development modules were helpful in allowing new teachers to access videotaped lessons taught by master teachers and to access lesson plans and other teaching materials. The online professional development modules were helpful to experienced teachers who wanted to learn new content or explore new teaching ideas, but they did not provide new teachers with the immediate real-time support they needed to adjust to their role in the classroom. Many novice teachers relied on the teacher next door to answer questions and to provide daily support and encouragement to complete the first year.

Conclusion

Results from this study showed that teachers at the STEM-focused schools were encouraged to improve their own instruction and to look for opportunities to support their colleagues through new and innovative strategies. They participated in regularly scheduled professional development activities that encouraged them to look for ways to improve their own practice, document their findings, and share them with their colleagues.

The principals described faculty as a key component to the success of their schools. One principal attributed his school's success to faculty who "are truly committed to developing the next generation of leaders." Additional faculty members were needed due to the fact that these schools had accelerated STEM courses and a broad range of unique electives. Some schools in this study hired business professionals to teach specialty courses while others relied on certified teachers.

STEM-focused school models in this study required a commitment from principals, industry experts, university faculty, and teachers. Teachers took a leadership role collaborating with school administrators and industry and university partners in the development of student learning experiences and teacher professional development activities.

There was a deliberate plan to develop master teachers by having regularly scheduled professional development activities provided by instructional coaches and virtual mentors. The teaching staff was responsible for selecting curriculum and developing and delivering integrated lessons. Individual teachers were selected to work with university partners to develop real-world integrated inquiry experiences for students. There were various day-long workshops available during the school year and week-long intensive workshops during the summer. These schools also provided mentors or coaches that met with new faculty on a weekly basis. Some schools provided in-house training beginning 2-3 weeks prior to the start of school with continued support throughout the school year. Principals scheduled time for teachers to collaborate and participate in professional development activities. Schools in this study stressed the importance of having a dedicated time set as a priority for teachers to work together. They were led by visionary principals who were confident and committed to making a difference in the lives of students. Results from this study indicated that STEM programs are rigorous with a broad variety of STEM courses and technology enhancements requiring teachers to develop new teaching strategies and content knowledge to deliver this type of instruction.

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Teachers' Perceptions of Observing Reform-oriented Demonstration Lessons

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The primary goal of professional development programs is to support teachers in increasing student achievement. In many cases, this requires a significant change in how mathematics is taught (Sowder, 2007). In turn, this demands not only a change in teachers' beliefs (Pajares, 1992) but also a new vision for what mathematics teaching entails (Ball & Cohen, 1999). Unfortunately, professional development often fails to support teachers in making these changes, as it does not provide opportunities for teachers to view reform-oriented teaching practices with students similar to their own (Santagata, 2011).

Recognizing this deficit, we designed our professional development project for middle grades mathematics teachers to include opportunities for observing reform-oriented demonstration lessons. In some instances, the lessons occurred in project teachers' classrooms. We referred to these classrooms as established classes. At other times, project teachers observed demonstration lessons occurring during the summer months and utilizing a group of students from a local youth organization. These represented non-established classes. Following the demonstration lessons in established and non-established classes during the 2010 – 2011 school year, we sought to document the impact of these demonstration lessons by gaining insights into the project teachers' views. Specifically, the following research questions were posed.

1. How does viewing reform-oriented demonstration lessons impact teacher practice as reported by teachers?
2. What are teachers' perceptions of the benefits of demonstration lessons in established classes?
3. What are advantages of demonstration lessons in established classes versus non-established classes as perceived by teachers?

Researchers have indicated that teachers need opportunities to observe reform-oriented instruction (Borasi & Fonzi, 2002; Santagata, 2011). Including observations of reform-oriented instruction in professional development programs seems to be a logical means for providing these needed opportunities. By examining teachers' perceptions of demonstration lessons in two different settings, the significance of this study lies in its ability to identify characteristics of classrooms that are valued by teachers and therefore necessary to support transference of instructional practices from the professional development setting to teachers' classrooms. In addition, the results point toward specific instructional practices that are enhanced in this setting.

Background Literature

A review of the literature revealed that while a strong case can be made for using demonstration lessons as a part of professional development and there is common agreement on key characteristics of these lessons, there is a lack of research documenting the impact of demonstration lessons on teachers' beliefs and practices. These ideas will be discussed in the paragraphs that follow.

THE NEED FOR DEMONSTRATION LESSONS

When faced with implementing innovative pedagogical skills, teachers need to see classroom instruction modeled.

According to Casey (2011), teachers who are expected to implement these new pedagogical strategies express three common concerns. First, teachers often have difficulty visualizing certain approaches being utilized in their own classrooms. As a result, they question whether or not these new strategies could work in their classrooms. Second, teachers question whether the strategies would be appropriate for their students. In turn, teachers express the desire to see the strategies being used with their students. Finally, teachers expect to see evidence of students showing success with new strategies before they are willing to try the strategies in their classrooms. These concerns described by Casey (2011) suggest that teachers need opportunities to observe reform-oriented instruction and demonstrations lessons may be one means for doing so.

According to Loucks-Horsley et al. (2010), a demonstration lesson has as its purpose to improve teaching and involves a group of teachers observing an effective teacher's lesson either in person or via video. To be successful, the demonstration lesson should be part of a "prelesson discussion, classroom demonstration lesson observation, and postlesson debrief cycle" (p. 197) with the discussions led by a facilitator. Miller (2011) argued that one of the benefits of demonstration lessons is that the lessons provide teachers with the opportunity to view lessons that they might not have otherwise considered to be effective. For example, teachers often desire to have the perfect lesson as opposed to allowing misunderstandings to be revealed in a way that might not have been planned and could be considered a deviation from an ideal plan. Demonstration lessons allow for teachers to view lessons which might not run according to a lesson plan, but allow students to learn beginning from their current understandings and misunderstandings. Unfortunately, teachers seldom have these opportunities to view classroom lessons for the purpose of growing professionally (Santagata, 2011).

SUCCESSFUL DEMONSTRATION LESSONS

Recognizing the need for teachers to observe reform-oriented instruction, professional development programs often include demonstration lessons (Balfanz et al., 2006; Gersten & Kelly, 1992; Gigante & Firestone, 2007; Vesilind & Jones, 1998; Wallace et al., 1999). Many aspects must be in place during the demonstration lessons to ensure teachers have a meaningful and informative experience. Two aspects are particularly germain to this discussion as they served to inform the study. First, demonstration lessons should occur in classrooms that are similar to those of the teachers who are observing the lesson (Casey, 2011; Math Science Partnership Knowledge Management and Dissemination (MSP), n.d.a). Teachers should see lessons in classrooms that they view as similar to their own so that they realize the classroom lesson could happen in their own room (Casey, 2011). Second, a lesson debriefing must follow the demonstration lesson (Loucks-Horsley et al., 2010; MSP, n.d.a; Santagata, 2011). Without the lesson debriefing, the teacher is left with only his or her thoughts about the lesson (MSP, n.d.a). As a result, the teacher might not have identified highlights or features of the lesson that are necessary for ensuring effective implementation. Being able to collaborate, discuss, interpret, analyze, compare, and contrast instances in the lesson and students' understandings with fellow teachers is crucial for teachers to find value in the observation (Santagata, 2011).

RESEARCH ON DEMONSTRATION LESSONS

When demonstration lessons are included with other types of instructional support such as classroom observations or professional development workshops, research has shown a positive impact on teachers' classroom pedagogy (Gersten & Kelly, 1992; Gigante & Firestone, 2007; Vesilind & Jones, 1998). However, there is a lack of documented evidence of the impact of demonstration lessons without the other types of instructional support. MSP (n.d.b) examined fourteen studies from all grade ranges aimed at improving pedagogy or content knowledge. In these studies, the demonstration lessons were part of a comprehensive professional development program that included other types of instructional support. They concluded the following:

> Studies in this set provided evidence of teacher leaders who provided demonstration lessons or modeling as one of their support strategies had positive impact on teachers' classroom instruction and student achievement. However, none of these studies was designed to investigate the unique influence of this teacher leader activity, indicating a fruitful area for future research (MSP, n.d.b, section 3, para. 3)

The aim of the current study was to examine teachers' perceptions of demonstration lessons in two different settings. In doing so, our intent was to offer some clarity to the classroom characteristics that must be considered in delivering demonstration lessons. In addition, we sought to address the gap in the current literature resulting from a failure to examine the benefits of demonstration lessons by examining how teachers utilized the information taken from demonstration lessons in their own classrooms.

Methodology

Phenomenological research has as its goal to identify the perception of participants who have experienced a phenomenon (Gall, Gall, & Borg, 2007). In this study, the phenomenon under consideration was the reform-oriented demonstration lessons in established and non-established classes. As a result, we utilized a qualitative approach to gain insight into teachers' perceptions of these demonstration lessons. In the paragraphs that follow, we will first present the context of the study followed by a description of the selection of participants. Next, our instrumentation and procedures are described. Finally, an overview of the data analysis is provided along with the limitations of the study.

CONTEXT

This research occurred within the context of a professional development project for mathematics teachers in grades four through eight titled Promoting Innovation in Mathematics Education or Project PrIME. The project was an externally funded project affiliated with a small research university located in the southeastern region of the United States. We, the authors, served as two of the project staff involved in implementing the project and were employed at the university: the first author as a tenured faculty member and the second author as a graduate student.

The primary goal of Project PrIME was to improve teachers' mathematical content knowledge. Simultaneously, we aimed to support teachers in improving their own instructional practices. As this was a multi-year project, teachers were invited to return to the project each year for up to four years. Teachers were then referred to by the number of years of participation. For example, a teacher who was participating in the project for the first time was called a "year one teacher" while someone returning to the project for his fourth year was referred to as a "year four teacher."

Project PrIME teachers began each year by participating in a 10-day summer institute. Time within the institute was devoted primarily to content instruction with topics varying according to the year of participation. For example, year one teachers focused on number and operations while year two teachers focused on geometry. Through this content-focused instruction, project teachers were given the opportunity to experience reform-oriented instruction as a learner. We recognized, however, that to strengthen this experience the teachers needed the opportunity to observe reform-oriented instruction in action with middle school students. Therefore, through a partnership with a local youth organization that served at-risk youths, middle grades students visited the summer institute and participated in mathematics demonstration lessons led by project staff. Collectively, these students comprised what we refer to as a non-established class. The class was non-established in the sense that the students did not meet in this classroom setting on a regular basis and classroom norms were not in place.

In addition to a lack of classroom norms, students from the non-established class were different from a "typical" class in that they were students from a variety of grade levels. Although we knew from the literature that demonstration lessons should occur in classrooms similar to that of the teachers observing the lessons, we were hopeful that if teachers saw the reform-oriented instruction methods successfully implemented within what appeared to them to be a challenging teaching situation, they would be likely to believe the methods would work in their more realistic classroom settings. Recognizing this limitation of the non-established classrooms, however, Year 1 teachers observed only a single lesson with the non-established class during the summer institute while other teachers had opportunities to observe multiple lessons with the non-established class.

During the school year, teachers attended a conference and participated in online discussions of assigned readings or student solutions to assigned problems. In addition, teachers attended academic follow-ups. During an academic follow-up, project teachers visited a school site where a fellow project teacher (the host teacher) taught. Here, they participated in the demonstration lesson cycle, including the pre-lesson discussion, the lesson, and a post-lesson discussion. During the demonstration lesson, project teachers sat along the perimeter of the room while a project staff member conducted one or two demonstration lessons with the host teacher's classes. These classes represented what we refer to as established classes. They were established in the sense that the students met in this classroom setting on a regular basis and the classroom norms were in place. During a school year, a total of nine academic follow-ups were conducted. Each group of three follow-ups constituted one round and project teachers were expected to attend one follow-up within each round. As a result, project teachers had the opportunity to observe reform-oriented demonstration lessons in three different established classrooms during an academic year.

PARTICIPANTS

In selecting participants for this study, our goal was to select year one teachers that had attended the same three academic follow-ups. We elected not to consider year two, three, or four teachers as length of time in the project would introduce different, unaccounted for influences on their perspectives. Also, by identifying year one teachers that had participated in the same three academic follow-ups, we aimed to further eliminate unaccounted influences.

To begin the selection process, we compiled a list of the year one teachers who had attended three academic follow-ups. Of the 31 year one teachers, 15 had attended three follow-ups. Next, we eliminated special education and high school teachers from the list because we were interested in the perspectives of middle grades mathematics teachers. This reduced the number of prospective participants to twelve. Using a numbering system, we then noted which of the nine academic follow-ups each of these remaining teachers had attended. We grouped the teachers according to the academic follow-ups they had attended. Three teachers had attended follow-ups two, six, and seven. In addition, two teachers had attended follow-ups two, five, and seven. Given the overlap between these two groups of follow-ups two and seven and the desire to have at least five participants, we decided to invite both groups of teachers to participate in this study, recognizing the difference in one follow-up might impact the two groups' perspectives. All five teachers agreed to participate. Table 1 contains background information on the participants.

INSTRUMENTATION

In order to gain insight into participants' perspectives, we designed a set of open-ended interview questions (see Appendix A) to specifically address the research questions. Within the set of questions, we included follow-up questions in case participant responses were vague.

PROCEDURES

Recognizing the need to provide teachers with the opportunity to observed reform-oriented teaching (Santagata, 2011), we designed our professional development project to include a lesson demonstration component that occurred in two distinct settings. In both settings, project teachers observed reform-oriented demonstration lessons. The lessons were considered reform-oriented as a result of the following.

1. Lesson tasks addressed topics across more than one content strand.
2. Lesson tasks were open-ended and often resulted in multiple solutions and solution strategies.
3. Lessons focused on students constructing their own knowledge through tasks and student discourse.

These lesson descriptors have been identified as "chief characteristics of math education reform" (Ross, McDougall, & Hogaboam-Gray, 2002, p. 125). To insure that demonstration lessons consistently adhered to these descriptors, lessons were led by project staff members, which included both authors and additional mathematics education graduate students from the university. The difference between the two settings, however, was in whether

Table 1: Participant Background Information

Pseudonym	Gender	Race	Grade Taught	Teaching Experience in Years	Highest Degree
Gloria	F	B	4th	20	Bachelors
Kallie	F	W	4th	10	Masters
Tori	F	W	4th	5	Bachelors
Lola	F	W	4th	3	Bachelors
Anna	F	W	4th	18	Masters

the class was an established or non-established class, as previously described.

In June 2010, year one teachers participated in their first summer institute. On the last day of the institute, the teachers participated in a pre-lesson discussion and observation of a single lesson with students from the local youth organization. The students in this non-established class completed the Mystery Op 1 task (Erikson, 1996) and the Counting Cubes problem (Olson, 1999) under the direction of the first author. During the lesson, year one teachers observed with the goal of identifying students engaged in each of the Process Standards (NCTM, 2000). After the lesson, teachers participated in a lesson debriefing led by project staff that provided them with the opportunity to ask questions and share their thoughts regarding the lesson.

During the 2010 – 2011 academic year, project teachers attended up to three academic follow-ups. At each follow-up, teachers observed reform-oriented demonstration lessons conducted by project staff in established classrooms. Lessons in round one follow-ups (follow-ups one, two, and three) occurred during September/October and engaged students in creating and generalizing growing patterns. Lessons in round two follow-ups (follow-ups four, five, and six) occurred in November/December and engaged students in investigations of area and perimeter. Lessons in round three follow-ups (follow-ups seven, eight, and nine) occurred in February and engaged students in explorations of polyhedra that led the students to discover Euler's formula. Just as with the non-established class, teachers observing the established classes participated in lesson briefings and debriefings led by project staff.

Following the last academic follow-up, we identified our participants as previously described. In March, the second author interviewed participants individually using the interview protocol (see Appendix A). Each interview was conducted at the convenience of the participant and occurred at the participant's school. Interviews lasted approximately fifteen minutes, on average. Each interview was audio recorded and later transcribed.

DATA ANALYSIS

In analyzing the interview data, we used an open-coding process (Charmaz, 2002; Strauss & Corbin, 1990). To begin, we individually analyzed the interview transcripts, coding the recurring ideas. Next, we met to discuss the codes, creating an agreed upon list of codes. We then separately analyzed the transcripts again, using the list of agreed upon codes. Afterwards, we met for a second time to review and refine the codes. In some instances, we eliminated codes, as they were not prevalent across the interviews. In other instances, we expanded existing codes as we realized new ideas that were embedded within the codes. As part of this refining process, we were able to develop a descriptor for each code (see Appendix B). Next, we individually coded the transcripts one last time utilizing the revised list of codes with descriptors. Upon meeting together, we compared our codes to check for agreement. The interrater reliability was computed to be 91%. For those instances where there was not agreement, we discussed the data and its coding until an agreement was reached.

To facilitate the identification of trends emerging from the data, we created a chart of the participants and codes. For each participant, we went through the interview transcript and recorded the frequency of statements or collections of statements that corresponded with each code. Appendix C contains this table.

LIMITATIONS

Prior to reading and interpreting the findings, limitations of this study should be taken into consideration. The first limitation is the use of purposeful sampling. We elected to purposefully select our participants to insure that they had experienced the same phenomenon and to reduce the impact of unaccounted for influences. In doing so, however, we introduced the potential for researcher bias, the second limitation of this study. To eliminate the potential for bias, we established clear selection criteria and conducted analyses independently followed by collaborative discussions. Through thick descriptions of our procedures, our intent was to offset the potential for bias. In addition, although the purpose of qualitative research is not to produce generalizable results, through these thick descriptions we have strengthened the transferability of the results. Finally, we were not able to observe participants' classrooms and instead based our conclusions on their views of their own instructional practices. We felt this was appropriate, however, as we were interested in the participants' perceptions.

Results

The results of the data analysis will be organized according to the research questions. Participants' statements taken from the interviews will be shared as a means for supporting the reported results. In these statements, pseudonyms will be used to protect the participants' identities. Also, participants did not utilize the terms established classes or non-established classes in their interviews, instead using project-specific terms. As a result, the project-specific terms have been replaced with the terms established classes or non-established classes as appropriate.

How does viewing reform-oriented demonstration lessons impact teacher practice as reported by teachers?

To answer this research question, participants were questioned regarding how they utilized information gained through observing reform-oriented demonstration lessons in the established classes. Three trends were consistently noted within their responses. Each of these will be described in the following paragraphs.

Utilizing the lessons. All five participants indicated that they utilized the demonstration lessons from the observations with their classes. In some cases, the participant stated that she utilized the lesson as it was implemented in the established class. This was Tori's practice, as evidenced by the following:

> I take tons of notes and when I come, afterwards, after I observe a lesson I usually come back the next day and I . . . teach the lesson or eventually when I get to that subject, I teach the same lesson.

Other participants, like Kallie, indicated that they utilized the lessons but adapted them as needed for their students.

> I bring the lessons back . . . and that's what I do with everything PrIME gives me is just to bring it back and adapt it to the way I need it, so I really like getting the lessons and every lesson that we've seen, I've actually done in the classroom.

Participants clearly saw the lessons as a resource, providing them with tasks and problems that they could use with their own students. This was the view expressed by Anna.

> I'm able to bring a lot of that back and use it 'cause you know, you're just always searching for things and ideas and materials and um, anyway, the follow-ups have been great for giving me problem-solving type things to bring back to my classroom.

Supporting students in thinking about the mathematics. In analyzing the interview data, all five participants spoke to implementing strategies taken from the observations that supported students' engagement in thinking deeply about mathematics. Participants mentioned strategies such as: utilizing a timer as a means of pacing the lesson and providing adequate "think time;" using think-pair-share to support "think time" and increase communication among the students; and providing tasks/questions that focused students' thoughts on the mathematics. While not all participants mentioned all of these strategies, Lola noted all three and tied them to meeting her mathematics objective.

> There, the teacher is just . . . setting the pace sort of about the time how much time the kids have to think about a question and kind of just guiding them and prompting them but letting the kids take hold of the discussions and where the discussion leads. I really started utilizing the think-pair-share. I really like that. Um, I've also as a teacher I thought when I go and prepare my lessons, I think of better questions that I can ask my kids to get them engaged with the lesson instead of just saying here's what we're going to do today, this is how it's done. . . . Am I giving them what they need to really think about it? Am I really getting to the, I guess like really the main idea that I want them to know not just not getting the surface, but getting deep down inside to the concept. . . . I really take the objective, whatever I'm teaching, and I really try to think about what it is I want them to know or about, how I want them to learn it, and just try to get some good tasks like the ones that I've learned from PrIME to really engage their thinking that will kind of, I don't know what the word is, try to get them thinking along those lines instead of me just teaching it to them, saying this is how you do this, kind of letting them, a good task is going to let them problem solve to figure it out.

Improving questioning techniques. Finally, four of the five participants provided evidence of a third trend: improving their questioning techniques. Participants indicated that observations of reform-oriented lessons in the established classrooms reminded them of the need to ask better questions. In some cases, asking better questions involved simply asking students to justify their reasoning. According to Gloria, "I also like how, um, the students, they just don't give the answer, they have to explain why they think they're correct. I like that." In other instances, the participants spoke of creating better questions. Tori said, "Just rewording questions, learning how to ask better questions, I'm getting a lot of that, too, just observing that. . . . I mean just looking at different lessons, too, how we look at different questions." Furthermore, Kallie noted how the lesson observations allowed her to focus on the classroom discourse facilitated through the questions asked.

> So I love getting the lessons and the ideas. Um, I like just seeing the, the interaction between you guys as the teachers and the students and the kind of questions that y'all ask that I might not think of.

What are teachers' perceptions of the benefits of demonstration lessons in established classes?

When questioned about the benefits of the lesson observations in established classes, three themes emerged from the data. Each of these will be described below.

Providing a vision. In their interviews, three participants noted that the demonstration lessons provided a vision of what reform-oriented instruction would look like in their own classrooms. According to Anna,

> The instruction going on [in the established classes], it just really kind of um, gives you an idea of how it's going to work out for you to some extent when you bring, you know, it's just more to me realistic for how it's really gonna go in the classroom.

Like Anna, Lola recognized the support that the demonstration lessons in the established classes provided her in envisioning reform-based instruction in her own classroom. More specifically, student-oriented instruction and questioning caught Lola's attention.

> I got to see how they would do a lesson in [the established classes] and how they conducted it and it was really good because I saw how it was student-oriented and not teacher-oriented and so that was really beneficial, and just kind of questioning that they asked. It kind of gave me a good feel about how I could do that in my own classroom.

As seen here, participants reported that demonstration lessons in the established classes led them to believe that they could carry out similar instruction in their own classrooms.

Rejuvenating the participants. In addition to providing a vision, all five participants stated that the demonstration lessons served to rejuvenate them, reminding them of the reform-oriented practices about which they were learning and "jumpstarting" their implementation of these practices in their classrooms. Tori stated, "Those help a lot, too, cause it reminds, it kind of is a reminder cause I do really good and then I'm glad we [observe in an established classroom] because it kind of gets me back into the routine of things." Similarly, Gloria said, "Of course, I forgot about some of the things that I had been taught this summer so the [established classroom lessons] helped to refresh my mind or my memory about some of the things." Both Tori and Gloria indicated that the reform-oriented demonstration lessons in the established classes served as a reminder of the previously learned instructional ideas. Adding to this, Kallie explained the role of the school environment as it relates to this need for rejuvenation.

> At school we get to where we're in time limitations and so we get in this habit of speedy, speedy, speedy, speedy, you know? And our mind's just thinking about that . . . and so then . . . [the lesson in the established class] just reminds me what I wanna be like. And then I come back here [to my school] and you know, I really do that and they start you know, time time time, get this done and then I'll start going back and then I get to go back to [observe in an established class] and come back, you know. . . . It gets me motivated again. It gets my mind thinking like a PrIME teacher and not like a [state-testing] teacher, you know? It gets my mind back into thinking like a PrIME teacher.

Analyzing instruction. Finally, four of the five participants spoke of the opportunity to analyze instruction via the lesson debriefs. Following demonstration lessons in established classes, project teachers participated in a discussion of the lesson(s) led by project staff members. For Anna, these debriefs provided the opportunity to analyze the lessons and identify instructional strategies to utilize in her classroom.

> The things that we, you know, get to see in the [established classes], we're able to kind of break them down and talk about them when we meet together and then, uh, so many, it gives you so many ideas to bring back to your own classroom and implement immediately while they're fresh on your mind.

Similarly, Lola spoke of how important this opportunity to analyze the lesson was to her.

> I really like the debriefs where we get to go back and talk about it. I really like that. To get everybody's input about what they've learned and what they saw and what they think. You can go back and just ask the questions like what did you see from the lesson, what would you have done, what could you have done differently, you just don't go see the lesson and leave. You actually get to go back and talk about what worked, what didn't work, what would you try different next time.

Based on their responses, participants valued the opportunity to discuss the observed reform-oriented instruction. While this is not necessarily a benefit of demonstration lessons in the established classrooms, participants recognized the opportunity that the demonstration lessons provided for them to engage in this practice.

What are advantages of demonstration lessons in established classes versus non-established classes as perceived by teachers?

In considering the two different classroom environments, participants noted three differences between the established and non-established classes, citing these differences as advantages for the established classes. These advantages are described in the paragraphs that follow.

Engaged students. When reflecting on the two different classroom environments, four of the participants indicated that the students from established classes were more willing to engage in the lesson. Kallie saw the students in the non-established class as the type of students who needed to be held accountable for the work in order for them to engage in the lesson.

> Because [the non-established classroom] was just, you have so many of um, the type of kid that is not on task, the type, and I guess those kids don't care cause it's summer and they're not focused and it's not school and it's not for a grade so they don't care.

Tori also spoke of the students' engagement in the lesson. Unlike Kallie, however, she stated that some of the students in the non-established class engaged in the lesson.

> The [established classes] had more advantages just because the kids . . . know they're supposed to be in school and learning. But, as a new PrIME teacher, I liked seeing [the non-established class] because I had no idea of really what [the project instructors are] wanting. . . . The kids in the summer really, they knew they weren't in school. But some of 'em still did try. I mean, I'm not gonna sit there and say that they weren't engaged because they were. But the, you know the other kids in the [established classes], you could definitely tell they were more excited and . . . they knew they had to do it rather than the other ones didn't, but I still think that they both walked out of there with something.

Established classroom community. In addition to student engagement, all five participants noted that established classes had an advantage in that a classroom community was in place. Anna described this feature in terms of how the classes had "meshed."

> Because, I mean, that was good at the [non-established class], um, even though of course that was summer time and the kids you could tell it, you know. But, . . . you go into an [established class] and you, and you're seeing actual classes that have meshed and have been together.

Similarly, Gloria referred to the relationships of the students.

> Another thing I think that the kids have a better relationship with each other, you know during the school year [in established classes]. They're in the same class whereas these kids [in the non-established classes] are pulled from all different age levels or, well not necessarily age levels but different classes. . . . I think that may have made a difference.

Diverse students. Finally, two of the participants noted that the non-established classes lacked diversity. In reflecting over the two different classroom environments, Lola noted this lack of diversity, yet failed to indicate how she was thinking about diversity. She said, "The makeup was different from I guess when you're in [an established class] environment. You have more diversity. And, in the summer there wasn't a lot of diversity with the [students]." Based on her response, it is not clear whether Lola was considering diversity in terms of race, academics, gender, etc.

Alternatively, Kallie addressed the need for academic diversity within a classroom, something she did not see in the non-established class. In this quote, she is describing the importance of this diversity.

> And then, you have a mixture of kids, you know, like sometimes those good kids keep those other kids focused and on track, and then sometimes those good kids think too, uh, much out there and then those other lower kids bring 'em back in.

Discussion and Implications

Improving student achievement in mathematics requires that teachers re-conceptualize their roles as mathematics teachers (Sowder, 2007). Towards this goal, Santagata (2011) indicated that a deficit of many professional development programs results from a failure to include observation of reform-oriented instruction in classrooms similar to those of the participating teachers. With this in mind, we designed our professional development program to include reform-oriented demonstration lessons in both established and non-established classes.

Results indicated that observing established classes provided participants with a vision of reform-oriented instruction that could be transferred into their own classrooms. As a result of these observations, participants reported that they returned to their classrooms with a goal of improving their questioning techniques and supporting their students in thinking deeply about mathematics. Meeting this goal was supported by their use of the demonstration lessons.

These results support the claim that professional development should include observations of reform-oriented instructions in classrooms similar to those of participating teachers (Santagata, 2011). The results enhance this claim, however, by offering a description of the classroom characteristics valued by teachers in defining similar classrooms. In addition, the results offer insight into features of demonstration lessons that facilitate the transference of instructional practices to individual classrooms. These points along with implications are discussed below.

SIMILAR CLASSROOMS

Through comparisons of the established and non-established classes, we gain insight into the classroom attributes that teachers consider important for establishing the similarity of classrooms. The first of these attributes is the diversity of the students. All of the students in the non-established class were African-American. In addition, teachers in the project perceived the students as being average to below average in terms of academic preparation as a result of their affiliation with the local youth organization. This was compared to the students in the established classes that had a full range of students with regard to race (Caucasian, African American, Hispanic, and Asian) and academics (from well above average to well below average). By noting the lack of diversity in the non-established class, the participants communicated diversity as an important feature of classrooms being observed. It was not always clear, however, whether the participants were referring to academic diversity, racial diversity, or some other student characteristic.

The second attribute of similar classrooms is evidence of an existing classroom community whose norms and practices align with the vision of reform-based instruction. In the established classes, students knew each other and were accustomed to listening to one another, talking about mathematics with each other, and discussing one another's ideas. This was not true in the non-established class. Although students in this class were willing to talk, students were not accustomed to participating in classroom discourse, a key feature of reform-oriented instruction (Chapin, O'Connor, & Anderson, 2003). Students' struggles to engage in classroom discourse made it difficult for participants to benefit from the observation.

Finally, the third aspect of similar classrooms is student accountability. In the non-established class, students had no reason other than self-motivation for participating in the learning activities. While many students in the non-established class possessed this self-motivation, others did not and served as a distraction to the participants. This was in contrast to the established classes where the accountability was in place. While we would argue that over time all students in the non-established classes would develop the self-motivation through the selection of engaging tasks, participants did not have the opportunity to observe this phenomenon evolve with only one lesson to observe. As a result, participants identified accountability as an important aspect for supporting student engagement and as a key attribute of similar classrooms.

In light of these results, we have examined our use of non-established classrooms in our summer institute with an eye on attempting to redesign them so that they appear more similar to teachers' established classes. To this end, our intent is as follows:

1. to identify a more diverse group of students with which to work;

2. to establish classroom norms by working with the students in classroom settings prior to the demonstration lesson; and

3. to work with the organization from which the students are recruited to support student accountability.

FEATURES OF DEMONSTRATION LESSONS

With the key attributes of similar classrooms identified, it makes sense to consider the features of the demonstration lessons that facilitated the transference of instructional practices to individual classrooms. In reviewing our demonstration lessons, we identified four key features. First, the established classes represented classes that were similar to those of the participants, with similar defined in response to the previous question. As a result of the similarity, the participants could imagine the lesson being carried out successfully with their own students. And because the observations of established classes occurred during the school year, the ideas learned could be immediately applied in the classrooms. Thus, the second key feature of this professional development was its occurrence during the school year. Third, each observation of the established classes was followed by lesson debriefings. Santagata (2011) stated that teachers need the opportunity to discuss their observations. When asked about the benefits of lesson observations, participants described the importance of these debriefings, supporting Santagata's claim. Finally, the opportunities to observe multiple established classes over time allowed for the observations to serve as a source of rejuvenation. This aligns with the work of Loucks-Horsley et al. (2010) who reported that professional development needs to be on-going, allowing ideas to be revisited and developed over time.

With these features in place, it was possible for instructional practices observed in the demonstration lessons to be transferred into teachers' classrooms. Our results indicated that these instructional practices included teacher moves that support students' thinking about the mathematics and improved questioning techniques. In light of this finding, in the future we aim to make additional aspects of reform-oriented instruction more explicit through lesson briefings and debriefings with a goal of supporting the transference of these ideas as well.

Conclusion

In reviewing these results, creators of professional development should heed the perceptions of these teachers who speak to the importance of viewing reform-oriented instruction in classrooms similar to their own. While observing instruction within one's own classroom can have profound effects (Barlow, 2012), this is not always a possibility. In the event that observations are to occur in similar classrooms, these classrooms should be similar in terms of student make-up, student accountability, and classroom community. When these conditions are met, the lesson observations support teachers in envisioning reform-oriented instruction in their own classrooms with emphasis given to supporting students in thinking deeply about the mathematics and improving their own questioning techniques. These results are based, however, on a small number of teachers' self reports. Further inquiry is required to verify these results as well as to investigate teachers' ability to notice other dimensions of reform-oriented teaching.

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APPENDIX A
Interview Questions

1. Thinking about the lessons observed during follow-ups… Do you feel the observations are beneficial to you as a practicing teacher? Please explain.

Follow-up Question: After the lesson observations, how do you take information from that day and utilize it in your classroom?

2. So, you know during the summer institute you had the opportunity to watch PrIME instructors teach the [local] kids. Do you feel there are advantages to watching PrIME instructors teach kids during the follow-ups as opposed to during the summer institute? Please explain.

3. What can be done to improve the classroom observations?

*Explain what you mean by…

*Can you give an example of…

*Can you describe in more detail…

*How do you apply that to your classroom?

APPENDIX B

Code	Brief Description	Full Description
Q	Questioning	The teacher mentions questioning in general. Examples include a reference to questioning, types of questions, better questions, probing questions, more than yes or no questions, etc. but with no specific information included.
Q2	Asking for students to justify their ideas	The teacher indicates the expectation that students are to explain how they got their answer and how they know their answer is correct.
Q3	Answering students questions with questions	The intent of these types of questions is to keep the student thinking. They may be in the form of, "I don't know. What do you think?" or "Could there be another solution?"
T	Facilitating students critically thinking about the mathematics	The teacher describes efforts to get students thinking about the mathematics. These may include think-pair-share, slowing down the pace of the lesson, the timer, randomly calling on students, class discussions, etc. Questioning focuses on appropriately supporting students in understanding and/or reflecting problems as well as summarizing their thoughts about the mathematics at hand.
G	Students sitting in groups	The teacher indicates that students are seated in groups. She does not necessarily indicate that the students are working collaboratively in their groups. This is different from "centers."
LI	Implementing the lessons (and sometimes with adaptations)	The teacher indicates that she has implemented the lesson that was observed in the academic follow-up. There may or may not have been adaptations made to the lesson.
LV	Lesson provides a vision of what "this" looks like in their classrooms	The teacher indicates that seeing the lessons enacted during the follow-up helps them to "see" this type of instruction occurring in her own classroom.
D1	Students were more focused.	Teacher indicated that the students in the established class when compared to those in the non-established classes were more focused. They were engaged or in learning mode.
D2	Classroom norms were in place.	Teacher speaks to the classroom norms being set in the established classes as opposed to those in the non-established classes. The students know each other. Behavior expectations are already set. Things of that nature . . .
D3	Students accountable for the work.	Teacher indicated that the students in the established classes are to be held accountable for the work as opposed to the students in the non-established classes who are not held accountable for the material. The material in the lesson is information that the student will need to know. They are willing to learn it. There will be repercussions if they do not learn it. They are taking it seriously.
D4	AF students are more diverse.	The students in the established classes are more diverse. They look like a regular class of students. As opposed to the non-established class of students who all have similar appearances.
D	Lesson debriefs are beneficial.	The teacher indicated that the lesson debriefs were beneficial.
R	Academic follow-ups serve to rejuvenate the teachers	The teacher indicated that going to a follow-up served as a refresher, reminding them of what it looks like to be a project teacher.
E	Students are allowed/encouraged to explore the mathematics.	The teacher aims to have students explore the mathematics on their own. This can be evidenced by statements about stop-and-go, not answering their questions, using manipulatives, selecting good problems, etc. The focus of the teacher is on appropriately supporting students as they are solving tasks or problems.

APPENDIX C

Interview Coding Results

Code	Gloria	Kallie	Tori	Lola	Anna
Q		3	4	2	
Q2	1			1	
Q3		1			
T	3		3	7	2
G	1		1		
LI	2	4	3	1	3
LV		2		1	1
D1	1	2	1	1	
D2	1	1	1	2	1
D3		2	2	2	
D4		1		1	
D	2	1		1	2
R	1	1	1	1	1
E	1	2	2	4	4

Deepening Teachers' Understandings of Mathematical and Pedagogical Connectedness: The Walk-Across Task

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For the 45 states and 3 territories that have adopted the Common Core State Standards for Mathematics (CCSSM), there continues to be a focused effort on professional development that strives to help teachers understand the meaning and intent of the standards (Editorial Projects in Education Research Center, 2013). Developing a vision for how the CCSSM do not represent *business as usual* (CCSSI, 2010) is one of professional development providers' most pressing imperatives. As teachers work to make sense of the new standards, they need to spend time considering the ways in which the standards connect to foster the development of students' mathematical understandings (Association of Mathematics Teacher Educators, Association of State Supervisors of Mathematics, National Council of Supervisors of Mathematics, and National Council of Teachers of Mathematics, 2010).

In my own work with teachers, I have found that providing the time for teachers to consider the connections among standards allows them to see that to teach the CCSSM requires a greater understanding of mathematics and the associated pedagogical content knowledge (Herrelko, 2011). Although for many teachers there remains a disproportionate ratio between the lengths of time spent teaching traditionally and research-based reform practices, I have found that rigorous study of the CCSSM offers both veteran and novice teachers a common place to converse about the nature of teaching and learning. One task I have used to help teachers make sense of the CCSSM is the Walk-Across task (see Appendix A). Simply stated, a Walk-Across is a reorganization of the standards *across* grade level, domain, and clusters with a focus on the connections among a particular subset of mathematical ideas such as fractions or algebra. In this paper, I will describe the findings and perspectives of one group of teachers who recently completed the Walk-Across task and share my views on the implications of these findings for those who lead professional developments focused on the CCSSM.

Mathematical Connectedness

The CCSSM provides key insights into particular mathematical connections within the standards by using clusters and domains of related standards. It is noted that "standards from different clusters may sometimes be closely related, because mathematics is a connected subject" (CCSSI, 2010, pp. 5). This statement that other standards outside of designated clusters may be closely related is a significant one. It can act as a point of entry into deeper exploration of not only the standards themselves, but also of the richness of mathematics. Professional development providers can engage teachers in seeing mathematical connections beyond the indicated structure of the CCSSM as the teachers work to envision a set of sense-making experiences for their students, both within their own classrooms and across their schools and districts.

In examining the mathematics content of the CCSSM, teachers need to comprehend more than what each standard means students should know and do. To cultivate a deeper knowledge of both the mathematical and pedagogical implications of the CCSSM, teachers should be given time to work together to explore the ways in which standards connect across domains and grade levels to develop proficiency in children's mathematical thinking.

Exploring Connections *across* the CCSSM

In a recent four-day professional development workshop, 23 kindergarten through fifth grade teachers from schools in three different counties in a mid-western state were given the task of designing their own Walk-Across (K-5) for fractions. During the designing of the Walk-Across, teachers were asked to show and explain what each standard relating to fractions meant students should know and be able to do, and then explicate the way in which that knowing and doing connected to prior and subsequent standards regardless of domain or grade. Teachers were put into groups of four that spanned grades K-5: two K-2 grades teachers and two 3-5 grades teachers. Teachers worked on the assignment for approximately one hour each day following planned CCSSM professional development that expected them to think through problems involving fractions and related pedagogies that allow for the Standards for Mathematical Practice (CCSSI, 2010) to emerge.

When considering the use of a task like the Walk-Across within a professional development setting, it is important to understand that the task was not offered in isolation of other professional development activities. Its value was intertwined with the other tasks being done throughout the four-day period. These activities ranged from reading and discussing effective mathematics teaching (Herrera, Kanold, Koss, Ryan, & Speer, 2007) and its relation to promoting the expected mathematical practices for students (CSSI, 2010) to the specific content knowledge tasks meant to deepen teachers' understandings of unit fractions, operations on rational numbers, and the denseness of rational numbers. Teachers also considered the teaching of others and analyzed student thinking through the use of locally produced video cases as well as selected sections of *Connecting Mathematics Ideas* by Boaler and Humphreys (2005).

At the end of the professional development, each group of teachers submitted their Walk-Across document and a reflection journal of their own mathematical and pedagogical sense making throughout the professional development. An interpretive analysis (Hatch, 2002) was used on the Walk-Across documents and reflection journals to identify salient interpretations and verify categories of what emerged for teachers during their work on the Walk-Across task. The full version of the directions for the Walk-Across task is included in Appendix A.

Teachers Growing Awareness of Mathematics Connectedness

As teachers considered how the different standards connect to develop students' mathematical knowledge, they found themselves examining a rich network of mathematical relationships. When this realization first happened, it was not uncommon for some teachers to feel overwhelmed. One teacher described it this way:

> I know we hear all the time that mathematics is connected but until we did the Walk-Across for fractions I don't think I really understood just how connected it is. There are so many ways to draw connections and see how learning so many other mathematical ideas helps the learning of later ideas its mind boggling. The most challenging part of doing the Walk-Across was not in finding the ways the standards connected, but in just trying to decide where to stop making connections.

The realization of the connectedness of mathematics can lead to this important perturbation. If mathematics is so deeply connected how does one organize it? This is something with which all teachers of mathematics need to wrestle. I encouraged the teachers to persevere in solving the task by first explicating the connections they felt were the strongest.

Teachers were especially surprised to find a number of standards relating to fractions that were in other domains and grades. In the CCSSM, the domain for fractions starts in grade three. There is not a specified domain for fractions in grades K-2. Once teachers began their focused look for fraction ideas within the K-2 standards they quickly recognized why our professional development on fractions involved elementary teachers of all grade levels. Being able to place one's instruction within the broader perspective of what students learn was another important understanding teachers gained from the Walk-Across task. On the second day of the professional development workshop, one kindergarten teacher wrote the following in his reflection journal.

> I am excited to see how further work on the 'Walk-Across' will help me gain an understanding of how what I am teaching affects what the students will learn in the higher grades. I have enjoyed the fact that since

> yesterday, I have already begun to make more of those connections and see just how much math ideas relate to one another. I think many times, we don't think of math as being related to each other outside of addition, subtraction, multiplication, and division. It is really neat to be able to see the connections that can be made not only across grade level, but also across the domains within the Common Core that helps the students develop into proficient mathematicians.

In this reflection, the teacher described how the Walk-Across aided his emergent understanding that the relations of mathematics expand beyond the four operations and more importantly that it is exciting to see the ways in which his work with kindergarten students prepares them for future learning experiences. The notion that mathematical connectedness expanded beyond the four operations and across domains and grade levels was also made evident in the teachers Walk-Across documents as will be examined in the following section.

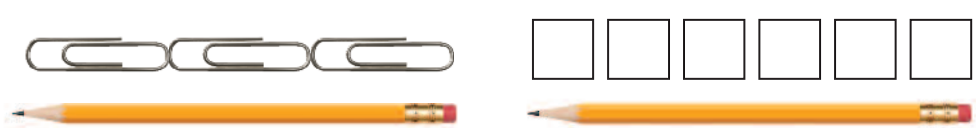
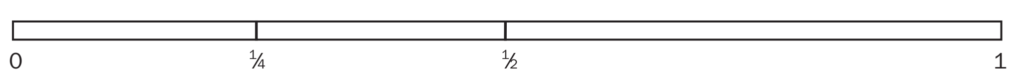
Connecting Mathematics and Learning Experiences across Domain and Grade

Teachers explicated connections to fractions from different standards found in each domain and at each grade level. Sometimes these connections were glaringly obvious, such as 1.G.3, "Partition circles and rectangles into two and four equal shares, describe the shares using the words halves, fourths, and quarters, and use the phrases half of, fourth of, and quarter of" (CCSSI, 2010, p. 16). Other connections were made in subtle yet significant ways, showing that the teacher to develop understanding of

FIGURE 1

Walk-Across Building Fraction Understanding in the CCSS

Special Notes: This standard begins the notion of comparing fractions by realizing it requires a greater number of smaller units to measure a quantity and fewer larger sized units to measure the same quantity.

Common Core Standard	Unpacking What will the child know and be able to do? How does this standard connect with prior and subsequent standards regarding understanding fractions?
2.MD.2 Measure the length of an object twice, using lengths units of different lengths for the two measurements; describe how the two measurements relate to the size of the unit chosen.	The students should be given opportunities to measure objects using various length units and then compare the units used to determine how the size of the units effects final measurement of the whole object.  ***Example:*** Students will compare the measurement of a pencil using both paper clips and color tiles. They will discuss the difference in using the two different units of measure. This skill builds on 1.MD.2 in which students understand that they are measuring with non-standard units and need to be placed end to end for a measurement. This is also developed in kindergarten through K.MD.2 where students develop a sense of comparing measureable attributes and describing the difference. This is a stepping stone to 3.NF.1 and leads directly into 3.NF.2a. Students will be able to understand that a fraction is part of a whole and then represent it on a number line. ***Example:*** Students will make fraction strips by folding 5 equal strips into halves, thirds, fourths, and sixths. Using these 5 strips the students will draw tick marks to represent the fractions on the number line from zero to one.  ***Connect:*** Each paper clip is a larger unit than a color tile unit so it requires more color tiles to equal a whole object. It requires 4 fourths to equal 1 on the number line whereas it only requires 2 halves because ¼ is a smaller fractional unit than ½.

fraction ideas can utilize learning experiences in the other domains. An example of this can be seen in Figure 1 as the teachers drew upon a measurement standard from second grade to explicate its connection to later fraction ideas.

Figure 1 is an excerpt of a group of teachers Walk-Across document showing the connections they found for standard 2.MD.2. The teachers demonstrated how the measurement standards in grades 1 and 2 prepare students for fraction knowledge in grade three. They made explicit the possibility that within the educative experiences provided through the study of measurement there are opportunities for children to see an inverse relationship between the size of the unit and the number of units it will take to span the object being measured. It is in this measurement experience that a connection can be made across grade levels as students of third grade consider the inverse relationship between the size of the unit fraction 1/b and the number of unit fractions it takes to compose one whole unit.

Another set of connections explicated by teachers can be found in Figure 2 (pgs. 54-55). In this Walk-Across excerpt, the teachers focused on the third grade standard of equivalent fractions and fraction size comparison (i.e., 3.NF.3). The teachers described how student mathematical experiences and understandings connect from kindergarten through grade five. The teachers specifically detailed this by referencing the domains of counting and cardinality, measurement and data, geometry, and numbers and operations–fractions. In making these across domain and grade connections, teachers began to reconsider their own practice. Two first grade teachers explained their revelation in this way.

> As we look through the standards I can see that the building blocks for understanding division begin in Kindergarten. I appreciate the time to work through the CCSS. Time is always an issue during the school year. Taking the time to see the progression of math topics through the grades will improve my teaching... I see how important it is to know what is being taught in the other grade levels.
>
> Seeing what they [students] need to know and how they are being asked to show a deeper understanding in the higher grades was good for me to see. I plan to spend more meaningful time on this unit [ideas connected to fractions]. It builds on their later understanding of multiplication, division, and geometric topics to a greater degree than I ever considered.

Seeing the importance for their own understanding of the learning expected to take place across grade levels allowed teachers to describe the ways in which they wanted to change their practice. In their reflections, four categories of pedagogical change emerged. These changes were:

1. providing students time and opportunity to make their own mathematical connections;
2. providing students with worthwhile mathematics tasks to engage their intellect;
3. establishing a safe and respectful learning environment with an expectation of student sense making; and
4. becoming more adept facilitators of mathematical discourse.

As teachers worked through the Walk-Across task, they made decisions on the best way to organize their connections. On the first day of the professional development, there was much discussion on the best way to illustrate the many connections. Some groups felt that it made the most sense to start with the lower grade standards and show how later standards built upon them. In contrast, other groups started with grade three and showed how those standards were built upon by prior standards and supported notions in later standards. Still other groups started with grade five fraction standards and demonstrated how prior standards worked to build student understanding and preparedness for the fifth grade. The different ways of organizing these connections led to important discussion within the professional development about the richness and connectedness of mathematics. This occurrence supported other elements of the professional development as teachers would direct discussion in ways that:

1. went outside their own grade level considerations especially when working on mathematics tasks that were well beyond their particular teaching obligations;
2. promoted open discussion of teaching ideas with those who teach other grades;
3. encouraged mathematics task development that could be used across grade levels;
4. honestly considered the difficulties of changing one's teaching practice; and
5. challenged one another to help colleagues not participating in the professional development to understand their transforming perspective.

FIGURE 2

Walk-Across Building Fraction Understanding in the CCSS

Special Notes: Students need to be able to explain how fractions that "look" different are the same. You have to be able to think about and visualize their size. Manipulatives and numbers lines can be used to demonstrate and understand this concept. Students also have to be able to create fractions that are equal and be able to explain it to their peers using models. Whole numbers can also be expressed as fractions and this can be easily done on a number line by showing different ways to represent 1. Students also need to compare fractions with the same numerator or same denominator.

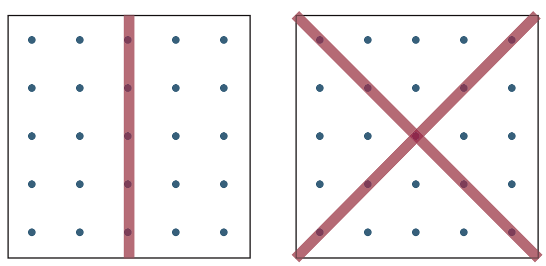
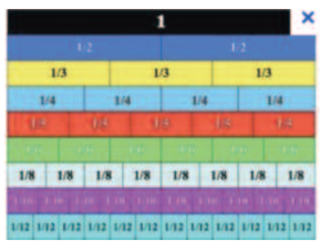
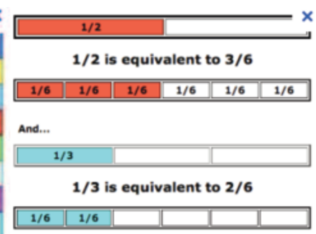
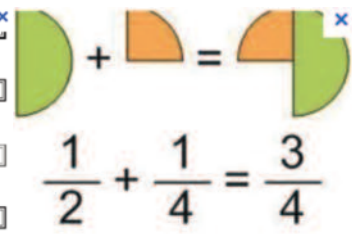
Common Core Standard	**Unpacking** What will the child know and be able to do? How does this standard connect with prior and subsequent standards regarding understanding fractions?
3.NF.3 Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size. a. Understand two fractions as equivalent (equal) if they are the same size, or the same point on a number line. b. Recognize and generate simple equivalent fractions, e.g., 1/2 = 2/4, 4/6 = 2/3). Explain why the fractions are equivalent, e.g., by using a visual fraction model. c. Express whole numbers as fractions, and recognize fractions that are equivalent to whole numbers. Examples: Express 3 in the form 3 = 3/1; recognize that 6/1 = 6; locate 4/4 and 1 at the same point of a number line diagram. d. Compare two fractions with the same numerator or the same denominator by reasoning about their size. Recognize that comparisons are valid only when the two fractions refer to the same whole. Record the results of comparisons with the symbols.	The students should be able to understand and explain equivalent fractions. The will compare fractions of different sizes. They will use a number line to identify equivalency by observing that the fractions are on the same point of the number line. Recognition of equivalent fractions and generating equivalent fractions will be expected of students They will express whole numbers as fractions. Finally, they will look at fractions with the same numerator or same denominator and compare them. They will hopefully see comparisons are only true when they are using the same whole. This standard is an extension 3.NF.1 and 3.NF2. Students need to understand what each number or part of the fraction represents. For example in the fraction 1/5 the denominator represents how many parts the whole is divided into (5) and the numerator (1) represents the number of parts you are considering of the whole. Students will also have experiences seeing the relationship of fractions on a number line. See above example for the connection to a number line. Standard K.MD.2 and K.MD.3. In both of these standards the students are introduced to the academic language of compare. Students have to compare objects with measurable attributes. They also look at a specific number of objects, categorize them and count the number of each within the categories. K.CC.6 also has students grouping objects and depending on how they are grouped they are comparing if the groups are greater than, less than, and equal to each other. Standard 1.G.2 and 1.G.3 focused on students dividing shaped in to halves and fourths and describing them. They are using a variety of language for similar terms. They also see that decomposing into more equal shares makes smaller shares. ***Example:*** A fourth can also be expressed as a quarter. ***Example:*** Geo Board Activity  Standard 2.MD.2 has a great connection. Students spend time measuring objects using unit of two different lengths and they observe and describe the number of units relates to the size of the unit chosen. ***Example:*** If using cubes and large paper clip to measure the height of a bottle the students will see it takes more cubes than paper clip to measure the bottle (4 paper clip to 11 cubes). The cubes were smaller so it took more of them to measure the height verses the paper clip. This will help students to understand later in fractions that as the denominator increase the unit is smaller. It is a great visual for them to see in the earlier grades. Standard 2.G.2 and 2.G.3 have a connection. Students are asked to divide rectangles into rows and columns of same-size squares and count to find the total number. This is a good connection to equivalent fractions. Students are also asked to divide circles and rectangles into two, three,

FIGURE 2 (cont.)

Walk-Across Building Fraction Understanding in the CCSS (cont.)

	and four equal shares and to describe them using words such as halves, thirds, half of, a third of in addition to describing the whole as two halves, etc. which also allow students to "see" equivalent fraction. ***Example:*** Students can complete a paper-folding activity. Fold your paper in half. (How many parts is your paper divided into? How many halves make a whole?) Fold your paper in half again and open it up. (How many parts is you paper divided into now? How many fourths make a whole. How many fourths make a half?) Standard 4.NF.1 and 4.NF.2 have connections. Students are extending their understanding of equivalence. They have to explain why fractions are equivalent. Students must explain how and why they add and subtract fractions and compare fractions with the same denominator. Also, they need to be able to find and tell why they use equivalent fraction for adding and subtracting fractions and how to compare fractions with unlike denominators. ***Example:*** Fraction bars, fraction circles, and a number line are examples of materials that can be used to explain how to add, subtract, and compare fractions with both like and unlike denominators.  The standards 5.NF.1 and 5.NF.2 are extensions of 3.NF.3. At fifth grade students use equivalent fractions as a strategy to add and subtract fractions. Students are expected to develop fluency with adding, subtracting, and comparing fractions and mixed numbers with the same or different-denominators. Mixed numbers is an addition from fourth grade. Students are also solving word problems involving the addition and subtraction of fractions. Students are also using estimation skills to assess if students answers are reasonable. ***Example:*** 2/3 + 5/4 = 8/12 + 15/12 =23/12 or 2/5 + 1/2 = 3/7 (knowing 3/7 less than 1/2)
Resource References:	Geo board activity, taken from Dr. G. Matney, Summer 2012, CORES Elementary ITQ Grant Equivalent fraction image, taken from http://aschouten.wordpress.com Fraction circle image, taken from http.//hr6math.com Sample addition of fraction problem, taken from the Common Core State Standards for Mathematics (2010)

In directing their own discussion in these ways, it became apparent that by creating their own Walk-Across for fractions teachers were generating self-selected questions for discussion. Examples of such questions include: What does the connectedness of mathematics mean for teaching and learning? How do I determine an appropriate entry point into a mathematics topic or does it even matter since it is all connected? When giving a rich task in which students begin to see connections that I have not considered or cannot make sense of, how do I respond as the teacher? These questions demonstrate that the Walk-Across task was supporting teachers' pedagogical considerations as they began to see their own need for greater mathematics understanding and stronger pedagogical content knowledge.

Teachers elected to find and use many resources beyond the documents produced by their own state. As they did this, they began to see patterns in what was being said across states and felt as though seeing the same thing said in different ways and with different examples was helpful; not only in their unpacking of the meaning of each standard, but also in seeing more clearly the mathematical

Table 1: Areas of Emerging Confidence Related to the Walk-Across Task

Area of Confidence	Sample Text from Teacher
Personal Mathematics Knowledge and Ability	In my work with the Walk-Across I have learned a lot of mathematics. I did not think at first looking closely at the standards would teach me anything, but boy was I wrong. Learning about the division problem types and how understanding division connects with fractions are a couple examples. I have grown mathematically in what I know and I can (and HAVE!) solve problems involving fractions that I previously never made sense of.
Personal Pedagogical Knowledge to Help Students Understand Mathematics	As I was struggling to come up with an example for a fifth grade example today, I realized I had done a lesson from NCTM's Navigation Algebra book that fit that standard completely. It would have taken me a long time to make this connection had I not done the Walk-Across. Our completed Fraction Walk-Across turned-out well. It was a lot of work but I feel more confident in planning my teaching since I can see how everything fits together.
Knowledge to Help other Teachers Understand the CCSSM	I really enjoyed seeing some light at the end of the tunnel so to speak when we got into the Walk-across discussion at the end of the day. I feel that it is beneficial to look at the Common Core in this way because you can visually see the connection. I feel that with what we are creating with these Walk-Across documents, we will be able to express to our districts what is to be going on with the Common Core.

connections between standards at different grade levels and domains. One teacher's reflection reveals this.

> After looking at the Ohio Model Curriculum we read what Utah and North Carolina had as well. Then the AH HA moment came and we started seeing how the Standards for Mathematics Practice connected to how students should be interacting with each content standard through representing their own thinking via drawings, patterns, and manipulatives.

Through the development of their Walk-Across, each group of teachers found different resources to rely on and shared their discoveries with others. The finding and sharing of additional resources to complete the Walk-Across task provided the opportunities for teachers to begin to build a learning community and beneficially incorporate the aspects of the learning community throughout the other parts of the professional development.

Emerging Confidence

Through their reflections, teachers expressed a growing sense of confidence, in part due to the Walk-Across task and also from their solving of mathematics tasks above and below their grade levels. They articulated a growing confidence in one of three areas. Table 1 gives the three areas and a representative example from teachers' reflections.

Providing ways to authentically enable teachers to find confidence in their study of mathematics, pedagogical practice, and leading the way for others in their districts is certainly one of the challenges for any professional development. The emergence of these forms of confidence came through the teachers' hard work. Several of them mentioned in their reflections that they spent time outside of the professional development hours working on the Walk-Across and that in the beginning they were "a little overwhelmed." After all, the work of a Walk-Across is not easy. As is exemplified in the final reflections above, by the end of the fourth day the teachers came to value the rigorous thinking they did about how the standards connected.

Implications for Leadership Practice

Beyond the analysis of teachers' reflections, there were several noteworthy elements brought into the other parts of the professional development that may not have occurred without the teachers work in creating the Walk-Across. For example, throughout the professional development, I asked the teachers to describe any relevance they found in the mathematical tasks we were doing in comparison to their Walk-Across explorations and creations. As the teachers realized that I was not going to provide these connections, they began to share their own ideas about the tasks we were doing in the rest of the professional development and the specific standards they were exploring in the Walk-Across. Furthermore, teachers often recognized that the mathematics tasks of which we were making sense dealt with standards that they had not previously considered as being connected to fractions. This reciprocal interplay happened each day of the professional development.

The findings of this study align with Hsu, Kysh, Resek, and Ramage's (2012) work to change teachers' conceptions of mathematics. In their study, Hsu and colleagues demonstrated the importance of the interplay between transforming one's teaching practice and one's conception of mathematics. Furthermore, they described why it is problematic to just tell teachers with "charisma and authority" (p. 38) what to do in their classrooms. When thinking about the experiences we provide for teachers, we need to be careful with what it is we tell them. We should be careful not to substitute our authority for their reason any more than we would ask them to use their authority to cajole a student into the teacher's way of understanding mathematical ideas. The teachers in this study reflected that their prior learning experiences with mathematics led them to develop a conception of the discipline as one of disconnected bits of knowledge. Interestingly, teaching itself, with its daily curriculum maps, bells, and other such delineations holds an impinging logic that teaching is also done in discrete bits and pieces. Professional developments should pursue the difficult task of providing opportunities for teachers to understand mathematics connectivity and its relationship to pedagogies that promote student sense making. The Walk-Across task is appears to hold potential benefit toward meeting this goal.

The nature of mathematical connectedness alone is not enough to ensure students experience the learning of mathematics in connected and meaningful ways. The teacher is a vital interlocutor in the student's discourse with mathematics, whose own understandings and perceptions must work to facilitate meaningful and connected experiences for students' mathematics learning. For this reason, it is important to provide opportunities for teachers to make their own associations among the CCSSM and other parts of professional development devoted to their exploration of things such as worthwhile tasks, classroom norms, discourse, and the nature of mathematics. Through their work in creating their own Walk-Across for fractions, the teachers in this professional development exhibited more connected ways of seeing mathematics and their teaching practice. Through the Walk-Across discussions, the teachers became more open to their development of adaptiveness to students' mathematical ideas and emergent teaching scenarios (Ball & Bass, 2000; Ma, 1999).

Conclusion

When one begins to see mathematics as multiplicity of connections rather than a single linearity of discrete domains, it challenges the notion that good mathematics instruction is done through the learning of minutely focused bits of process and formal representation disseminated from the teacher to the student. Affording teachers of mathematics with the opportunities and support for seeing mathematics as connected ideas across the CCSSM domains and grade levels provides occasions of pedagogical awareness for the teachers to re-organize curricular experiences that allow for student sense making.

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APPENDIX A
Develop a K-5 Walk-Across for CCSSM Fractions

You, along with your across grade level team of 3 or 4, will create a Walk-Across document that contains the K-5 CCSSM related to the learning of fractions and shows your understanding of two important aspects of the CCSSM:

1) What does each standard mean a student should know and be able to do?

2) How does this standard connect with prior and subsequent standards regarding understanding fractions?

You should identify each standard that works to build students' understandings of fractions and concisely show with pictures, graphics, and text what the child should know and be able to do. There should also be a well explicated connection to any related prior standards and related subsequent standards.

To begin, you should give attention to each standard, regardless of domain, and consider whether or not it pertains to one's understanding of fractions. You should only include standards that you feel DO pertain to fractions. Next, consider how each standard that pertains to ideas involving fractions should be accompanied by an explanation of how prior standards prepared students for this standard, and how this standard prepares students for future standards. While explaining the prior and subsequent standards connection, only the name should be listed (for example 3.G.2) and not the full text.

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