RITE Grant Research Report
The Effects of Virtual Classroom Learning Environments on Middle Grades Mathematics Teachers' Instructional Practices

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THE EFFECTS OF VIRTUAL CLASSROOM LEARNING ENVIRONMENTS ON MIDDLE GRADES MATHEMATICS TEACHERS' INSTRUCTIONAL PRACTICES

This research investigated the effects of the *Saba Centra*™ interactive virtual classroom learning environment and the *BlackBoard*™ virtual classroom on middle grades mathematics teachers' instructional practices. These teachers were students in four blended format (synchronous, asynchronous, and face-to-face) graduate courses designed to increase middle grades mathematics teachers' content and pedagogical content knowledge. The purpose of the research was to address the following: (1) What aspects of *Centra*™ and *BlackBoard*™ contributed to the teachers'/participants' learning (2) What aspects of the blended format for the courses encouraged the development of professional teaching communities? and, (3) In what ways has participation in courses using *Centra*™ and *BlackBoard*™ enhanced the instructional practices (e.g. use of reform teaching materials, alternative assessment, etc.) of the teachers/participants?

Background

In 2005, two university researchers secured a sub-grant from the Appalachian Mathematics and Science Partnership (AMSP) to design and deliver four blended format (synchronous online, asynchronous online, and face to face) courses which focused on increase participating middle school mathematics teachers' content and pedagogical content knowledge. The four courses were Rational Numbers, Algebra, Geometry, and Probability and Statistics. Since significant efforts to transform instructional practices in mathematics classrooms to align with the vision in reform documents have yet to take place (Braswell et al., 2001; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Research Council, 2001; Stigler & Hiebert, 1999), instructors were hoping to design courses that would impact instructional practices. Research on changing instructional practices suggests that the process is dynamic and subject to the contexts of teachers' work (Apple & Jungck, 1992; Senger, 1999). Thus, the difficulties in transforming mathematics teachers' instructional practices suggest that efforts to improve instruction must not only focus on individuals' practices, but also the contexts in which these practices take place.

However, professional development learning opportunities vary widely. Ball and Cohen (1999) noted that many professional development opportunities impose a one size fits all mentality and consist of one time sessions and workshops that intellectually limit teachers' opportunities to learn about curriculum, students, and teaching. More recent recommendations (e.g., Ball & Cohen, 1999; Borasi & Fonzi, 2002; Sykes, 1999) yield a new set of goals for professional development activities, goals that show promise for creating lasting change in teachers as well as improved student achievement. These goals were summarized by Sowder (2007) and include:

1. Developing a shared vision (e.g. the *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000) outlines a vision of what students should know and do)
2. Developing mathematical content knowledge and pedagogical content knowledge
3. Developing an understanding of how students think about and learn mathematics
4. Developing an understanding of the role of equity in school mathematics
5. Developing a sense of self as a mathematics teacher

To meet these ambitious goals, teachers need sustained opportunities to develop new knowledge and skills as well as new ways of thinking about what it means to learn, teach, and do

mathematics (Borko & Putnam, 1995). Thus the courses were designed to familiarize teachers with the vision of reform documents, increase pedagogical content knowledge and content knowledge, and encompassed two academic years.

In addition to the literature surrounding professional development for mathematics teachers, the literature regarding online professional development for rural teachers was considered when designing the courses. Rural residents tend to select low paying jobs close to family and friends over high paying jobs some distance away (DeYoung & Lawrence, 1995; Seal & Harmon, 1995). Rural areas also value place, community, and family over other more distant national priorities (Seal & Harmon, 1995). Thus, the emphasis on local jobs and priorities often contradicts the broader emphasis placed on improving mathematics teaching and learning. In additional to cultural barriers, rural research identifies several obstacles to quality mathematics education including:(a) inadequate facilities to attract talented mathematics teachers, (b) insufficient staff development, (c) distance to training sites, and (d) in-service development that lacks quality and content (Royster, 1994). In addition, linear and objectivist approaches to learning dominated online approaches to education (Vrasidas & McIsaac, 2001). In contrast, over the last two decades, education experts have embraced constructivist tenets in classrooms where individuals construct their own knowledge through interactions with their environment and with others. Our ultimate goal for the online courses was to provide mathematics content and pedagogy oriented professional development for rural teachers that offered participants the opportunity to learn through rich social interactions with one another, countering the feeling of isolation that rural teachers face, without having to travel long distances.

Course Design. The courses were designed to include synchronous, asynchronous, and face-to-face instruction. Centra™ software provided the synchronous component. This software allowed users to speak "live" with other members of the class, indicate agreement with a statement using a check or an "x", ask questions, share a whiteboard space for collaboration with other class members, text chat, and share applications from their local computers. Each participant was provided headphones, a web camera, and a Notetaker™. The Notetaker™ permitted students to share their handwritten work online through the application share feature. Additionally, an members could share ideas using Geometer's Sketchpad, the library of virtual manipulatives website (nlvm.usu.edu) and several other interactive websites, such as NCTM's Illuminations (illuminations.nctm.org) by either using the application share feature in Centra™ or by asking teachers to complete an activity on the website and return to the class and report their findings via the Centra™ software.

Blackboard™ served as the asynchronous software for the course. With *Blackboard*™, instructors posted course documents, assignment directions, and external links on a *Blackboard*™ course website for students to access remotely. This software also contained a digital drop-box for submission of assignments and the capability of sending individual or group e-mails. The discussion threads available on the *Blackboard*™ site provided the online environment for teachers' reflections on class assignments. Face-to-face class meetings took place the first and last class sessions of each course. Occasionally, the instructors would visit specific schools, signing on to teach class from that school. Additionally, the participating teachers asked to meet face-to-face with the course instructors for special class meetings.

In an effort to create communities of learners, course instructors required teachers to "sign on" for class at the same location as another teacher. While teachers "signed on" to class with their own individual computer, they were in a location with at least one other teacher. This model created site-based cohorts consisting of 2-3 teachers. In addition, *Centra*™ permitted us to

assign "breakout groups" across cohorts so that teachers at one location could enter into discussions with teachers at another site. Instructors alternated between using the *Centra*™ breakout discussion tool across sites and using discussion groups that were site-based. Course activities were designed to encourage collaboration and communication among teachers.

Situating Teaching Learning within the Classroom. Given the importance of the context of teachers' work, course instructors purposefully planned, adapted, and created course assignments that were situated within the teachers' classroom practice, or could easily translate to the teachers' classrooms (Cady, 2007). Thus course assignments were based on the following research paradigms:

1. Using Standards-based curricula to enhance teachers' mathematics content and pedagogical content knowledge (Ball, 1996; Beckmann et al., 2004; Reys, Reys, Beem, & Papick, 1998)
2. Using cases of middle grades mathematics instruction to expand teachers' conceptual understanding of mathematics and to reflect on pedagogical decisions mathematics teachers make (Merseth, 1996; Stein, Smith, Henningsen, & Silver, 2000)
3. Examining student work in order to increase teachers' flexibility in mathematical thinking and the ways in which they use student work to guide instruction (Franke & Kazemi, 2001; Wilcox & Jones, 2004)

Each of these paradigms is effective in improving student achievement when used in face-to-face instruction. However, no one has reported using these methods in an online environment. Therefore, little is known about how this online coursework impacts the instructional practices of in-service mathematics teachers. This study attempts to fill that gap by visiting seven middle school mathematics teachers one year after the courses had ended. The changes in teachers' instructional practices, the development of communities of learners in geographically isolated areas, and factors that course developers should consider when designing online courses for preservice and inservice teachers are documented.

Context

This research project included seven teachers from four schools in a rural southeastern United States county. (One teacher left the district midway through the fourth course, completed the course, and participated in this study.) The system serves isolated and economically disadvantaged communities within the county. Aside from the teacher who moved to a nearby district and changed grade levels, all teachers were teaching in the same school and grade level for all the courses and when participating in this study one year after completing the courses.

Over the last several years, the district has actively pursued grant funding to improve mathematics and science education. Specifically, they have sought ways to not only deepen the mathematics and science knowledge of middle grades teachers, but to encourage the integration of mathematics and science in the curriculum. This integration of the subject areas was encouraged through partnership enhancement program (PEP) grants that linked university faculty and district personnel with math and science teachers. In addition, some principals created instructional time for integrated mathematics and science laboratory investigations. District leaders have also tapped local business and community leaders to provide resources and expertise for math and science teachers that would enhance the curriculum.

Theoretical Perspective

The sociocultural perspective used in this study suggests that learning is primarily social in nature and occurs as people interact. This framework allows us to study teacher change (Stein & Brown, 1997) by investigating teachers' participation in communities of practice (Lave & Wenger, 1991; Wenger, 1998). Within this framework; learning is synonymous with shifts in participation within established communities of practice. This view sees communities as "repositories" of meaning that convey the rules, norms, and expectations for members of the community. To understand the community, one must be knowledgeable about the interactions of the members and the historical contexts of the community. Growth within the community is marked by more central participation of the individuals in the actions of the group. Therefore, changes in instructional practices should be accompanied by changes in the teachers' roles as mathematics teachers within the context of the classroom, school, district, or professional mathematics teacher communities. Borko et al. (2005) developed a framework that aligns classroom instruction with the tenets for effective mathematics instruction described in the Principals and Standards for School Mathematics (NCTM, 2000). This framework was used to analyze the instructional practices of the teachers in this study. It includes the following aspects:

- *Collaborative grouping*. The extent to which the series of lessons uses student groups to promote the learning of mathematics. The extent to which work in groups is collaborative, addresses nontrivial tasks, and focuses on conceptual aspects of the tasks.

- *Structure of instruction*. The extent to which instruction is organized to be conceptually coherent such that activities build on one another in a logical manner leading toward deeper conceptual understanding and are enacted in ways that scaffold students' current understanding.

- *Multiple representations*. The extent to which the series of lessons promotes the use of multiple representations (pictures, graphs, symbols, words) to illustrate ideas and concepts, as well as students' selection, application, and translation among mathematical representations to solve problems.

- *Hands-on*. The extent to which students participate in activities that are "hands-on." The extent to which the series of lessons affords students the opportunity to use appropriate instructional materials (including tools such as calculators, compasses, protractors, Algebra Tiles, etc.) and that these tools enable them to represent abstract mathematical ideas.

- *Cognitive depth*. The extent to which the series of lessons promotes command of the central concepts or "big ideas" of the discipline and generalizes from specific instances to larger concepts or relationships.

- *Mathematical communication*. The extent to which the teacher and students "talk mathematics." The extent to which students are expected to communicate their mathematical thinking clearly to their peers and

teacher and to use the language of mathematics to express their ideas. The extent to which the classroom social norms foster a sense of community so that students feel free to express their ideas honestly and openly.

- *Explanation and justification*. The extent to which students are expected to explain and justify their reasoning and how they arrived at solutions to problems. The extent to which students' mathematical explanations and justifications incorporate conceptual as well as computational and procedural arguments.

- *Problem solving*. The extent to which instructional activities enable students to identify, apply, and adapt a variety of strategies to solve problems. The extent to which problems that students solve are complex and allow for multiple solutions.

- *Assessment*. The extent to which the series of lessons includes a variety of formal and informal assessment strategies to support the learning of important mathematical ideas and furnish useful information to both teachers and students.

- *Connections–applications*. The extent to which the series of lessons helps students connect mathematics to their own experience, to the world around them, and to other disciplines. (p. 82)

Data Collection

Semi-structured interviews and classroom observations of each teacher provided information regarding shifts in teachers' roles as mathematics educators and the evolution of communities of practice. The interview questions sought to gather information on teachers' participation in the online courses, their current instructional practices, changes in their practice as a result of participating in the online courses, and the development of communities of practice. Classroom observations provided information about participants' roles as mathematics teachers within their schools and information regarding their instructional practices. To triangulate our findings regarding their instructional practices, we asked participating teachers to create what Borko et al., (2005) described as a Scoop Notebook. The Scoop Notebook consists of artifacts related to key features of classroom practice, such as instructional materials and strategies, classroom learning activities, and the classroom teacher's students' work. These notebooks have shown significant promise for representing what teachers and students do in the classroom (Borko et al., 2005). In this study, the documents collected for the Scoop Notebook included: (a) instructional materials, (b) assignments, (c) quizzes and tests, (d) student work, (e) feedback or comments on student work, (f) teacher descriptions of the lessons, and (g) teacher reflections on the lessons. These documents primarily took the form of photocopies and written reflections. Participating teachers collected data for the Scoop Notebook over an uninterrupted five to seven day period of instruction. Data collection (interviews, observations, and notebooks) took place over a two month period, roughly one year after the online courses ended.

Findings and Discussion

The findings are organized around the three main purposes of the study (a) documenting the impact of participation in courses using *Centra*™ and *BlackBoard*™ on the instructional practices (e.g. use of reform teaching materials, alternative assessment, etc.) of the teachers/participants? (b) documenting the aspects of *Centra*™ and *BlackBoard*™ that contributed the development of communities of learners; and (c) identifying the aspects of *Centra*™ and *BlackBoard*™ that contributed to the teachers'/participants' learning that course developers should consider when designing online courses for preservice and inservice teachers. While a detailed analysis of teachers' individual practices in relation to the contexts of their work is forthcoming, this report describes the aggregated data from all participating teachers rather than individuals.

Changing Instructional Practices

Teachers' instructional practices were identified from the data collected in the Scoop Notebook and classroom observations and collaborated with interviews. The following sections describe participating teachers' instructional practices according to each of the dimensions in Borko et al.'s (2005) framework.

Collaborative grouping. Classroom observations indicated that students spent the majority of instructional time working individually as only one teacher was observed using collaborative grouping. Several of the participating teachers used collaborative grouping in the five to seven lessons included in the Scoop Notebook. These collaborative groups were used to introduce a unit of study or to reinforce previously learned material through a culminating activity. Room arrangement did not encourage collaborative groups either. Only two teachers had room arrangements that supported the use of collaborative grouping. In their classrooms, students sat at round tables with two to four students per table. While students worked individually at times, it was evident from their behaviors that students were familiar with the idea of working in groups. However, for the most part, observations and the scoop notebook data showed classroom instruction for the participating teachers consisted of students situated in rows watching the classroom teacher demonstrate solving several sample problems. Students were then expected to solve similar problems.

Structure of instruction. In the online courses, participating teachers used the Connected Mathematics Project (CMP) curriculum to build content and pedagogical content knowledge. An ancillary goal in the courses was to encourage teachers to use more open-ended, investigatory activities (similar to those found in CMP) in their own classroom. As a result of the courses, one teacher adopted CMP for all classroom instruction and several others reported regularly using CMP as a resource to supplement their district adopted text. Teachers use these activities to introduce or conclude a unit, often attempting to support students' understanding of the broader ideas presented in a unit of study. However, despite using the activities, teachers continued to rely heavily on their district adopted textbook. Consequently, teachers presented mathematics as a set of isolated skills and concepts.

Multiple representations. Students' use of multiple representations was not evident during many classroom observations and students primarily used symbols to represent mathematical ideas. However, when teachers did use multiple representations, they were also using resources other than their district adopted textbook. The fact that students' use of multiple representations was evident primarily when teachers used CMP is not surprising; the tasks students complete in CMP often require students to represent concepts in more than one way. Conversely, when teachers used their district adopted text, they typically centered instruction on procedurally oriented tasks that did not provide opportunities for students to create or use

multiple representations. Students' opportunity to share their representations with other students and the teacher was also dependent upon the extent to which students had opportunities to work collaboratively with one another and the extent to which the classroom teacher fostered whole class discourse around sharing students' thinking.

Hands-on. Of the fourteen total classroom observations made, four lessons involved the use of concrete materials for learning. These materials included snap cubes to discuss independent and dependent probabilistic events, pipe cleaners to construct a polyhedron, and dice or coins to simulate probability experiments. While the use of manipulatives was limited during classroom observations, five of the seven teachers reported using hands-on materials in the lessons included in their Scoop Notebook.

Cognitive depth. It was not possible to determine the cognitive depth of a series of lessons from the observations or the Scoop Notebooks.

Mathematical communication. Communication in the classroom primarily consisted of teachers presenting information to students. Students did ask questions, but it did not appear in the classroom observations that teachers encouraged questions or discussion. In their lesson reflections, teachers often noted the benefits of the few discussions they had with students in terms of information gained regarding students' mathematical thinking. Since the extent to which opportunities for students to communicate their mathematical thinking is contingent upon teachers' use of both collaborative grouping, in classrooms where teachers used collaborative grouping there was more student-to-student interaction, and thus more opportunities for students to "talk mathematics." During the collaborative group work, opportunities existed for students to discuss mathematics – both in terms of explaining their thinking and using mathematical language. However, not all teachers used collaborative grouping regularly, thus students' opportunities to talk about mathematics in these classrooms was limit to whole class discussion. During these whole class discussions, classroom observations indicated that most participating teachers expected students to provide a numerical solution when called upon and supply a procedural explanation as to how they arrived at that solution.

Explanation and justification. When participating teachers called on students to justify their solution, computational and procedural arguments sufficed in each classroom. It was not expected in any classroom that students' justification center on conceptual understanding or why the procedures used made sense in the context of the problem. For example, when one teacher asked students to explain how they arrived at a solution for the linear equation $y = 100 – 6x$, a student provided this justification, "*We multiplied the number times six then we subtracted from 100."* Although the problem was set in a context that provided opportunities to explain why those procedures made sense, the teacher saw this justification as sufficient for explaining how students arrived at the solution.

Problem solving. Problem-solving in the participating teachers' classrooms typically consisted of following procedures to arrive at a single numerical solution, since all participating teachers selected tasks that typically had one solution. While multiple solution paths were possible for many of the problems presented in class, teachers focused on one solution path and did not elicit ideas from students regarding other solutions. Only a few problems that teachers included in their Scoop Notebooks were open-ended. No evidence of alternative explanations or discussions of problem-solving strategies was found.

Assessment. Other than verifying that students had the correct procedures for solving a particular problem, ongoing assessment during instruction was not evident during observations. The majority of problems included in the Scoop Notebooks as formal assessments required

single numerical solutions that provided limited knowledge of students' understanding of mathematics. Some teachers did include problems that called on students to create their own problem situation or describe why certain procedures were appropriate for a particular problem.

Connections. Many of the teachers presented problems that connected mathematics to students' lives either through opportunities to collect data or through a problem context. For example, in one classroom, the lessons described in the Scoop Notebook gave students several opportunities to collect data. Lessons taught during classroom observations also provided similar opportunities. When teachers drew on outside resources such as CMP, students also had opportunities to make connections to other areas of mathematics. Yet, rarely did teachers make those connections explicit. Limited opportunities existed for students to make connections to other subject areas.

For the most part, the teachers' self-reported descriptions of current instructional practices were consistent with data collected during observations and in the Scoop Notebook. Thus, we are confident that their self-reported practices are fairly accurate portrayals of what takes place in their classrooms. Observation and interview data regarding teachers' instructional practices were not collected prior to teachers' participation in the online courses. However, teachers' discussed their practices during the courses. Additionally, during the interviews, teachers described changes in the practices since their participation in the courses. Since teachers self reported descriptions of their current practices aligned with the observations and data from the Scoop Notebook, we are confident that the self-reported descriptions of their instructional practices during the courses and their descriptions of changes are also aligned.

Changes in Practice. Although the broad changes in instructional practices we had hoped would take place has yet to happen, we do notice several dimensions in which participating teachers' instructional practices have begun to align with the pedagogical approaches suggested in the online courses. First, the tasks selected by the teachers involve more problem solving and investigation. By incorporating a standards-based curriculum and other reform-oriented materials appropriate for their grade level into the online courses, the teachers were exposed to these tasks and required to experiment with them in their classrooms. While many had at first exclaimed, "my students will never be able to do this," they tried the problems in their classrooms and met with some success. Most of the teachers now use similar tasks on a regular basis in their mathematics classroom. However, the tasks were not implemented in the intended manner. For example, while the norms of communication in most teachers' classrooms did not regularly include discussions of mathematical ideas, the majority of teachers were reflective in the Scoop Notebooks about the information they gained when they did include discussions as a part of a mathematics lesson. Teachers were also now asking for justifications and/or explanations from students. Even though these justifications and explanations emphasized computations and procedures, this is an important step in developing the norms of communication that require students to provide justifications. Thus, while wholesale adoption of the instructional practices advocated for in the online courses was not present in the data collected, teachers made important strides in developing instructional practices that align with recent reform documents in mathematics education.

Developing Communities of Learners. An important goal in the courses was to develop communities of practice (Wenger, 1998) that might act as a local resource for teachers once the courses ended. Contrary to the notion that online courses foster isolation, our data suggest that

they can actually enhance collegiality, and thus reduce isolation for teachers. Two aspects of the course promoted the collegiality of the teachers -- the three-site design allowed for some face-to-face interactions and *Centra*™ provided across site interactions. Participants valuing working face-to-face with one or two other colleagues from their school or neighboring school and being able to share ideas with teachers at other schools is evident from the following quotes from participants:

> *I like the idea of working with other teachers in problem solving activities as well as designing lessons. You learn a lot about teaching styles and innovative strategies from other teachers.*
>
> *It was nice to be able to meet close to the school and[online classes] helped develop a higher level of teamwork among the other participants at my school… It was also beneficial to observe each other teaching a lesson and then discussing what was going on in the classroom during the lesson.*
>
> *Being able to talk with other teachers who are in the class to gain ideas and new ways of presenting topics is a big asset to our school system.*

By requiring teachers to sign on with their own computers but in the same local (usually their school) and across the district by connecting middle grades mathematics teachers online, communication was fostered among participants. A community of practice, however, is characterized by a shared set of goals for improving instructional practices, an environment for critical reflection on mathematics education, and support for teachers, novice and experienced, in their efforts to adopt instructional practices that align with recent reform documents. The development of an environment for critical reflection is evident in the following online interchange:

> *Carson: …Can any of you tell me which points are going to change and which points aren't going to change?[Carson is leading a discussion regarding a problem that involves reflecting a figure across the x and then the y axis]*
>
> *Hillary: The y values will be the same, x values the inverses.*
>
> *Carson: What do you mean by inverses?*
>
> *Hillary: The opposite sign.*
>
> *Andy: [marks no]*
>
> *Andy: I was just disagreeing with the inverses, I agree with the opposite sign.*
>
> *Carson: We can talk about inverses and opposites. Why do you disagree?*
>
> *Andy: My brain is telling me when I hear the word inverses, I think fractions.*

Hillary: And when I hear flip a fraction, my brain tells me reciprocal

Misty: Reciprocal is the inverse, the opposite is the negative of the whole or the positive of the negative.

Carson: I think this is where we need to make sure we use the whole vocabulary terms because the multiplicative inverse is the reciprocal and the additive inverse we are talking about the opposite.

The goal of establishing a community of practice across the district was not realized. Interview data suggested that participating teachers did not have a shared set of goals for improving instruction across the district. Although teachers saw a common problem of students lacking basic skills in mathematics, teachers in each of the schools had very different ideas about how to address this problem. When teachers talked about improving mathematics instruction, it typically centered on instruction within their classroom and/or school, not the district as a whole. Additionally, teachers noted that they did not have opportunities to talk with other mathematics teachers around the district about mathematics teaching and learning once the courses ended.

Despite the fact that a community of practice was not developed across the district, we did see changes in the way teachers worked with one another within individual schools. The teachers at one school enjoyed a level of collaboration that constitutes a community of practice. One of these mathematics teachers attributed much of the teacher collaboration within the school to the professional development courses.

I feel like it's helped me develop closer relationships than I would have otherwise … It's more of a friendship than just a professional colleague relationship.

The conversations between mathematics and science teachers regularly focused on the teaching and learning of mathematics. When describing a recent conversation between the two, one recalled a conversation they had regarding being open to the various approaches students take when solving a problem.

I think it is important to be open to the fact that there's different ways to work a problem, and I know [colleague's name]} and I have had discussions about this, that as long the kids can explain why they did something, if it's not exactly the same as what we've done, then that's okay … as long as they can explain why and it works every time.

In addition to conversations regarding teaching and learning mathematics, she felt a sense of comfort and openness to critiquing mathematics teaching between herself and another mathematics colleague. She cited one example where she and her colleague discussed their pedagogical choices for division of fractions. One teacher taught students to multiply by the reciprocal, rather than focusing on what constituted the whole, which the other saw as central to students' conceptual understanding.

At the same school, the teachers felt a sense of responsibility to improve mathematics instruction at the school. Their efforts predominantly focused on improving scores on the state achievement test, which they felt were important to other teachers, parents, and administrators in

determining educational effectiveness. While their individual practices were different in very important ways, their shared sense of purpose and open dialogue for critical reflection on instructional practices fostered an environment for continued progression towards the pedagogical approaches suggested in the online courses.

Though these teachers enjoyed a high level of collaboration, these teachers did not sense that same relationship between the teachers at another middle school. One teacher described the other school in the following way.

> *It seems [the other middle school] is more one for themselves. They don't seem to have the cohesiveness. We really work well in teams here and it seems more [at the other middle school] it's more – instead of a team, it's a teacher. They didn't seem very familiar with working [together] as we do… It was a lot of different, you know, sometimes we all have ideas, but kind of meld in the middle…*

However, the teachers at the second school saw themselves as having a positive working relationship with one another. In fact, the mathematics teachers shared a common planning time to afford them the opportunity to regularly discuss mathematics. Yet, when asked about the nature of their conversations in their meetings, one mathematics teacher stated the following.

> *I try to meet twice a month if we can, it all depends on if we have to meet for a particular reason, if our principal will need something that we need to talk about - if we had a faculty meeting. But recently, it's been really busy, so, we haven't had that many. It varies on the topics. We're coming up with a formative assessment test this Friday. We'll talk about that, what we need to do.*

Beyond these meetings, teachers use this time for individual tasks and planning. This same mathematics teacher also commented on other informal opportunities for mathematics teachers to come together. He described conversations teachers had in the hallways regarding difficulties they had with particular students or prerequisite knowledge students were lacking. Based on data collected during interviews and observations, the conversations mathematics teachers had did not involve critical reflection of instructional practices, developing a share vision for instruction, or agreeing on a shared set of goals for mathematics instruction.

The remaining two participating teachers from the third school seemed to be at the beginning stages of developing the sort of critical dialogue encouraged by the online classes. However, one of the teachers left to teach in a neighboring district. As such, their opportunities for collaboration diminished. Both, however, continued to take university coursework towards an advanced degree and enrolled in the same courses. Additionally, they maintain regular email contact, sharing lessons and ideas regarding mathematics teaching and learning. Although they lack the level of collaboration to constitute a community of practice, we take their level of collegiality to be an indicator of the positive influences the professional development courses had on their work as mathematics teachers.

In attempting to determine why a community of practice was fostered at one site and not another, we looked to other local contextual influences on teachers' work. At the first school, where a community had been formed, there were three changes in principals in three years. As a

result, the teachers reported relying on one another for support. The other schools, with stronger school-based leaders, seem to have teachers that followed the principal's lead and teachers did not seek out leadership roles for themselves. We see this as evidence of the types of identities related to mathematics teaching that these individuals possess. For instance, the teachers at the other schools derive a mathematics teaching identity from what the school defines as appropriate ways of teaching mathematics. On the other hand, the teachers engaged in the professional teaching community look to one another to define appropriate ways of teaching, and thus hold an identity that is not linked to school norms and expectations, but to goals, values, and beliefs of that particular teaching community. We see this distinction as integral to understanding the ways in which teachers incorporate the pedagogical suggestions made in graduate coursework into their own classrooms.

Additionally, teachers at the first school had a number of opportunities to collaborate with one another beyond the online courses. Thus, the extent to which we can attribute the evolution of the professional teaching community to the courses is unknown. However, these teachers reported that the professional development courses acted as an initial catalyst for their future collaborations. Some of those collaborations beyond the professional development courses included teachers from other schools, further signifying the contextual differences (i.e. norms, values, and beliefs) of the two schools.

Views of Online Professional Development

Two main themes emerged from the data collected on participating teachers' experiences in the professional development courses: (1) garnering resources for classroom instruction and (2) discussing mathematics teaching and learning with other teachers. Using a standards-based curriculum appropriate for the grade level they teach situated teachers' learning opportunities in the context of their work (Borko, 2004). Thus, teachers were able to use that material directly in their classroom. Although the curriculum itself was in paper form and delivered to each of the sites, teachers were able to share their work with teachers at their site and with teachers at other sites using Centra™ software. Thus, Centra™ and the cohorts provide teachers with not only answers to problems, but also multiple representations of mathematical ideas. Yet, given that teachers worked in remote locations and constructing these representations was more challenging than face to face coursework, oral descriptions of participating teachers' problem solving strategies was vital. Thus, perhaps one of the most important aspects of the class was teachers' emerging fluency with mathematical language and oral representations of mathematics.

Along with these oral descriptions of mathematics, teachers also valued discussing issues regarding teaching and learning in individual classrooms. One teacher provided the following comment.

> *There was tons of math knowledge just floating around so it was great to get together and be able to talk to other people who have a passion for something as much as you do. That was the neatest thing about the courses is you had math teachers from everywhere, all in our district, all getting to sit and share ideas and realize that there's one problem, but we're seeing it eight different ways and that really helps. Because when you are able to say, "Well some of my students are probably seeing it this way or this way …" You had ideas on how to approach the same thing.*

The value teachers found in garnering resources and discussion mathematics content and pedagogy aligned with the growth we found in teachers instructional practices. Teachers' increased use of standards-based materials and increased value of communication in the mathematics classroom were clearly aspects of the design of the courses that contributed most to teacher change.

While many of the aspects of the professional development courses are found in face to face courses as well, attempting to create a coordinated set of classes in an online environment that aligned with the research based on effective professional development proved challenging. Many of the teachers reported that they would have preferred face to face meeting over the online format, yet some of the same teachers noted that they would not have been able to participate had the course not been available locally and online.

Conclusions

While the importance of professional development for improving instructional practices of teachers may be clear, providing access to that professional development to the large number of teachers who work in geographically isolated areas continues to present challenges. Perhaps the most feasible way of providing ongoing professional development to these regions is through online professional development. By brining teachers together using synchronous forms of communication, professional development providers can mimic some of the aspects found effective in face to face instruction. However, online professional developers cannot assume that face-to-face methods can transfer to the online environment. Rather they should continue to seek new forms of technology and alternate instructional strategies to enhance teacher learning. Equally important to providing content is making it relevant to teachers' specific teaching contexts. Thus, engaging teachers in exploring mathematics content appropriate for their level, using materials that represent what research notes to be effective for that grade level, and providing teachers opportunities to share ideas from their specific teaching contexts remains critical in online environments. Although our teachers have yet to adopt the pedagogical approaches suggested in professional development as a whole, we have seen improvements in specific dimensions of mathematics teaching and significant changes in certain individual teachers.

Recognizing that making changes in instructional practices is a lengthy and difficult process, the full impact of each course may not be seen immediately. Perhaps, teachers need to try some of the activities, reflect upon their influence on students' understanding and then use this assessment of their students' understanding to inform their practice. A reiterative cycle of experimentation and reflection over an extended period of time may have more influence on their instructional practices. Since professional teaching communities is at the forefront of many recent professional development initiatives (e.g. Cobb, McClain, Lamberg, & Dean, 2003; Stein & Brown, 1998), perhaps the development of these communities can provide the impetus teachers need to continue this reflection and experimentation. However, the ability to develop these communities of practice may be less dependent upon the professional development design and implementation and more dependent on the local contexts. The local school situation may play an important role in supporting and inhibiting the evolution of these communities. It remains to be seen if online forms of professional development can foster the type of collaboration that is sustainable and ongoing.

Further studies are needed to determine if courses that are strictly delivered online have similar findings. Furthermore, additional sites, both rural and non-rural, are needed to determine if online forms of professional development can have similar outcomes as site-based professional

development. Whether or not online forms can match their face to face counterparts, online forms of professional development remain a viable and necessary option for reaching some of our most underserved communities.

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