Groth, R. E. (2007). Case studies of mathematics teachers' learning in an online study group. *Contemporary Issues in Technology and Teacher Education*, *7*(1), 490-520.

Case Studies of Mathematics Teachers' Learning in an Online Study Group

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Abstract

Two teachers participating in an online study group provided the foci for in-depth case studies. Transcripts of conversations they had with colleagues about issues related to reform-oriented pedagogy were analyzed from both acquisition and participation perspectives on learning. Both teachers exhibited mainly marginal changes to their pedagogical reasoning structures and were generally resistant to adopting ideas posed during online debates. At the same time, the text-based environment provided a setting for both participants to structure their emerging thoughts about changes to their existing pedagogical reasoning structures. It also served as a forum for them to identify gaps in their personal knowledge and to obtain further professional development to address them. The methodology and theoretical perspective employed in the report provide a foundation for further research on teachers' learning in online environments.

The National Council of Teachers of Mathematics (NCTM 1989, 2000) outlined a vision for mathematics instruction differing sharply from traditional teaching practice with each of its standards documents. Although the standards documents have had some impact on mathematics content taught in schools (Lott & Nishimura, 2005) and some impact on pedagogical practices (Ferrini-Mundy & Johnson, 1997), the traditional paradigm for mathematics instruction still holds great sway, especially in the U.S. Despite reform recommendations, the predominant U.S. classroom culture still reflects more traditional mathematics pedagogy (Jacobs et al., 2006).

Reform-oriented pedagogical practices have well-documented positive impacts. Boaler (1998) illustrated how students in traditional mathematics classrooms developed mainly limited procedural knowledge, while those in open, project-based settings developed flexible conceptual understanding. Riordan and Noyce (2001) found that students in Massachusetts using NCTM Standards-based middle school curricula exhibited higher levels of achievement than students in more traditional programs. Reys, Lapan, Holliday, and Wasman (2003) reported resonant findings in Missouri. These studies, as well as several others conducted over the past decade, indicate that students of teachers employing standards-based instructional practices perform as well as their counterparts from traditional classrooms on traditional tests of content, while generally outperforming them in new content and processes emphasized by the standards (Kilpatrick, 2003).

In light of the evidence illustrating the positive impacts of reform-based pedagogical practices, it is important to help teachers develop the knowledge base necessary for their implementation. Shulman (1987) noted, "Teachers must learn to use their knowledge base to provide the grounds for choices and actions" (p. 13). A key challenge for teacher educators is to help teachers examine standards and pedagogical recommendations thoughtfully rather than to accept or reject them uncritically (Sparks-Langer,Simmons, Pasch, Colton, & Starko 1990). The goal of teacher education should not be to indoctrinate teachers to behave in certain ways, but rather to help them develop their own sound premises on which to base teaching actions (Fenstermacher, 1978, 1986).

Teacher study groups have been explored as avenues for developing teachers' knowledge. Study groups can be defined as "educators studying their craft knowledge together" (Makibbin & Sprague, 1991, p. 1), where discussion is focused on pedagogical issues of common interest. Arbaugh (2003) reported that school-based study groups helped mathematics teachers develop professional relationships, connect theory and practice, understand curriculum reform, and develop a sense of professionalism. In another study, Zevenbergen (2004) found that mathematics teachers participating in study groups developed knowledge of content and pedagogy concurrently. These findings illustrate that study group discourse can provide a site for meaningful teacher learning.

Asynchronous learning networks (ALNs) have recently been explored as environments for supporting the sort of discourse needed to sustain teacher study groups. Their defining characteristics include "(1) Many-to-many communication; (2) place independence; (3) time independence (that is, time-flexible, not temporal); (4) text-based; and (5) computer-mediated interaction" (Harism, 1990, p. 43). Shotsberger (1999) reported that an ALN environment allowed mathematics teachers to engage in prolonged and thoughtful exchanges of ideas relating to reform-oriented pedagogy. In another discussion of ALN-based professional development for mathematics teachers, Newell, Wilsman, Langenfeld, and McIntosh (2002) noted that "holding a discussion over a period of days or weeks allows time to reflect, experiment with new ideas, share successes and failures, and receive feedback from others who are undergoing the same experiences" (p. 506). McDuffie and Slavit (2003) found that asynchronous discussions among preservice mathematics teachers enhanced the quality of their reflections on teaching and

encouraged less vocal students to have a voice in class discussions. These experiences highlight some of the unique benefits of ALNs as tools for mathematics teacher education.

The ALN environment differs markedly from a traditional face-to-face setting. Interaction strategies effective in a face-to-face setting often fail in an ALN. For example, while a face-to-face setting allows a discussion participant to quickly re-word a question that brings confused facial expressions from others, participants cannot see facial expressions in an ALN (Haavind, 2000). A great deal of investigation remains to be done before educators understand how individuals learn in such an environment since use of ALNs for mathematics teacher education is a relatively new idea. In particular, studies carefully tracing the development of teachers' learning while engaged in ALN discourse are needed, since successful professional development programs tend to use teachers' thinking to inform their instructional designs (Mewborn, 2003).

Purpose of the Study

The purpose of the present study is to shed some light on the nature of mathematics teachers' learning when participating in an ALN study group focused on the discussion of reform-oriented mathematics pedagogy (NCTM, 1989, 2000). The study describes the learning pathways of two different teachers who participated in such an ALN. The two cases are presented in order to provide some empirical ground that can be used to inform the design of instruction for mathematics teachers.

Theoretical Considerations

Identifying a theoretical orientation to conceptualize learning is a nontrivial matter. Sfard (1998) observed, "Nowadays educational research is caught between two metaphors...the *acquisition metaphor* and the *participation metaphor*" (p. 5). The acquisition metaphor characterizes learning in terms of knowledge gain and concept development, while the participation metaphor characterizes it in terms of participation in the activity of a community. Sfard argued that focusing exclusively on one metaphor and neglecting the other can lead to theoretical distortions. For example, exclusive reliance on the acquisition metaphor leads to the philosophical dilemma of trying to explain how individuals can want to acquire knowledge of something that is not yet known to them. On the other hand, exclusive reliance on the participation metaphor makes explaining how knowledge is carried across contextual boundaries difficult. For Sfard, the acquisition and participation metaphors offer complementary accounts of learning, just as chemistry and physics offer two different, yet compatible, accounts of physical matter.

Following Sfard (1998), the learning patterns of study participants were examined both from an acquisition and a participation perspective. From an acquisition perspective, teachers' attainment of pedagogical reasoning structures was considered. From a participation perspective, teachers' contributions to an ALN study group were considered.

Teacher Learning as Acquisition of Pedagogical Reasoning Structures

Shulman (1987) spoke of pedagogical reasoning as what a teacher engages in when "taking what he or she understands and making it ready for effective instruction" (p. 14). Therefore, from an acquisition perspective, part of mathematics teachers' learning can be conceptualized as moving away from naïve pedagogical ideas toward attaining more sophisticated pedagogical reasoning structures. Kline (1977) characterized naïve pedagogy of mathematics at the university level, stating, "Mathematicians have a naïve

idea of pedagogy. They believe that if they state a series of concepts, theorems, and proofs correctly and clearly, with plenty of symbols, they must necessarily be understood" (p. 117). Here, Kline argued the teachers cannot directly transmit mathematical concepts to students. This position is supported by a substantial body of empirical research in mathematics education (Hiebert & Carpenter, 1992). However, despite its well-known shortcomings, pedagogical reasoning associated with the naïve transmission view has persisted across generations of teachers responsible for teaching students of a variety of ages (Ball, 1988; Lortie, 1975).

Although the idea that mathematical knowledge can be directly transmitted from one individual to another contradicts research and reform recommendations, it is not the only idea characterizing a naïve pedagogical view. Ross , McDougall, Hogaboam-Gray, & LeSage (2003) identified nine different commonly held pedagogical theories that characterize traditional mathematics instruction.

1. The mathematics curriculum should focus exclusively on teaching number and operations.
2. Mathematics problems given to students should be decontextualized, require routine applications of operations, and have a single solution.
3. Mathematical knowledge should be transmitted through presentation, practice, feedback, and remediation.
4. The teacher is the sole knowledge expert in the mathematics classroom.
5. The use of calculators, computers, and manipulatives should be restricted to teacher demonstrations.
6. Student-to-student interaction is a distraction from learning.
7. Assessment consists solely of end-of-week and end-of-unit tests.
8. Mathematics is a fixed body of knowledge.
9. Teachers do not need to strive to raise all students' self-confidence to do mathematics.

These nine dimensions represent a set of small-scale theories that work together to define a larger "traditional" or "naïve" theory of mathematics instruction. Individual teachers vary in the extent to which they accept each of these small-scale theories.

Vosniadou (1994) provided a conceptual change framework for modeling individuals' movement away from naïve theories toward those that are scientifically based. When individuals encounter new information, the encounter may result in either enrichment or revision of existing cognitive structures. Enrichment is the easiest form of conceptual change, since it is "the simple addition of new information to an existing theoretical framework through the mechanism of accretion" (Vosniadou, 1994, p. 49). Enrichment occurs when new information is perceived to be consistent with existing ideas. Vosniadou and Matthews (1992) provided an example of enrichment in a science classroom where most children found it easy to learn that the moon has craters because that idea was easily appended to their existing beliefs.

Revision, on the other hand, is necessary when the new information is inconsistent with existing ideas. The new information may require the revision of a small theory held by an individual, or it may require the revision of a larger cognitive structure in which that theory is embedded. Revision of a small theory is generally easier than revision of a larger structure. Vosniadou and Matthews (1992) offered examples of each type of revision from the field of science education. Children in their study who initially believed there was water and air on the moon did not find it difficult to revise that idea when presented with information that lunar astronauts had to carry their own water and oxygen along with them. On the other hand, children generally found believing that the earth is a sphere

difficult. The idea contradicted beliefs, such as "the presupposition that space is organized in terms of the directions of up and down with respect to a flat ground, and that unsupported objects, including the earth, fall 'down'" (Vosniadou, 1994, p. 49).

Although the constructs of enrichment and revision came from the field of science education, instances of them are apparent in mathematics education research. Remillard and Bryans (2004) described the interaction of standards-based curriculum materials with the pedagogical reasoning of a teacher, Peter Jackson, who held an instrumental view of mathematics (Skemp, 1978). Jackson occasionally used the standards-based materials to supplement his course but continued to use a traditional textbook as his instructional framework. Hence, his learning from the curriculum materials can be described as enrichment. Although his existing pedagogical ideas were supplemented with ideas from the standards-based materials, he exhibited no shifts away from dimensions of reasoning associated with traditional mathematics instruction (Ross et al., 2003). Jackson is not an isolated case, as other studies show that teachers often view reform-based curricula as supplements to their existing pedagogical reasoning frameworks (Lambdin & Preston, 1995; Lloyd & Behm, 2005; Spillane & Zeuli, 1999).

Spillane (2000) showed how revision of small-scale pedagogical reasoning structures can occur while larger-scale structures supporting traditional mathematics pedagogy remain largely in tact. In interviews with school administrators, he found that many endorsed instructional reforms in mathematics, such as engaging students in more "hands-on" activities and "problem-solving." However, they advocated these reforms while still holding fast to traditional conceptions of mathematics, such as viewing school mathematics solely as the acquisition of procedural knowledge. From this perspective, "hands-on" activities and "problem-solving" were seen as useful insofar as they facilitated the mastery of mathematical procedures. Teachers at times exhibit similar reasoning patterns, as it is not uncommon for them to endorse changes in their forms of instruction while leaving the functions of their instruction largely unexamined (Saxe, Gearhart, Franke, Howard, & Crockett, 1999).

Carpenter, Fennema, Peterson, Chiang, and Loef's (1989) study of Cognitively Guided Instruction (CGI) illustrated that teachers sometimes exhibit large-scale revisions of pedagogical reasoning structures. Teachers who participated in an in-service program describing young students' thinking with regard to number and operation organized their classrooms much differently than their colleagues who had not participated. In particular, CGI teachers' students engaged in more problem-solving activities. Mathematical problem-solving was an organizing focus for instruction in many of these cases rather than a supplement to existing practices. Subsequent CGI research provided more examples of teachers who revised their pedagogical reasoning to adopt a similar perspective on teaching via problem-solving (Franke, Fennema, & Carpenter, 1998; Lubinski & Jaberg, 1998).

The constructs of enrichment and revision must be applied carefully in describing teacher learning, which hinges on the study of dynamic students and classrooms rather than the study of relatively predictable physical objects. Although it would be unreasonable for a student to reject research showing that the earth is spherical, it is not necessarily unreasonable for a teacher to resist the adoption of a pedagogical idea or innovation described by research taking place in a different setting. The results of educational research are unavoidably influenced by the contexts in which studies are conducted (Schoenfeld, 2000). Leinhart, Young, and Merriam (1995) emphasized that teachers must develop cognitive structures enabling the integration of the abstract and the particular in evaluating recommendations from research. Simply accepting educational research and recommendations at face value can be considered a lower level of reflective pedagogical

thinking than carefully examining how they may or may not apply to one's particular instructional setting (Sparks-Langer et. al., 1990). Nonrevision of pedagogical reasoning structures in response to an instructional recommendation based on empirical data should not necessarily be viewed as a low level of cognition. It may actually mark a relatively sophisticated level of cognition if a teacher's resistance to a given pedagogical idea is based on careful consideration of contextual factors in his or her instructional setting.

In the present study, the constructs of enrichment and revision of pedagogical reasoning structures were used to describe teachers' acquisition of knowledge within an ALN study group environment. These constructs were adopted because of their resonance with past research on mathematics teachers' learning. In addition, the idea of resistance to pedagogical ideas was incorporated because of the differing natures of physical and social sciences. Resistance was viewed as another construct to describe teachers' learning and not necessarily as an indicator of a higher or lower level of cognition.

Teacher Learning as Participation in a Social Network

ALNs have been conceptualized as "social networks" (Garton, Haythornthwaite, & Wellman, 1997). Aviv, Erlich, Ravid, and Geva (2003) offered the following definition for the construct:

> A "social network" is defined as a group of collaborating (and/or competing) entities that are related to each other. Mathematically, this is a graph (or a multi-graph); each participant in the collaboration is called an actor and depicted as a node in the graph. Valued relations between actors are depicted as links between corresponding nodes. Actors can be persons, organizations, or groups – any set of related entities. (p. 4)

In the case of the ALN study group, individuals in the discussion can be considered collaborating (competing) entities who are the actors in the network.

This definition suggests that learning in an ALN study group can be thought of as collaboration and competition with others in the environment. ALNs are frequently noted for their potential to facilitate collaboration, build community, and share knowledge (Kearsley, 2000). Although the educational value of this sort of interaction is widely discussed in connection with ALNs, disagreements and debates should be viewed as potential learning sites rather than nuisances or obstacles (Matusov, 1996; Matusov, Hayes, & Pluta, 2005). Disagreements among teachers can spark active knowledge construction, particularly when they are pushed to articulate the reasons behind their disagreements (Manouchehri, 2002). Li (2006) found that asynchronous discussions can provide forums for teachers to raise critical educational issues and engage in lively debates about them.

Salmon (2004) provided an overarching perspective on the nature of learning in an ALN by outlining five stages of participation. In the first stage, participants successfully join the discussion by accessing the needed technology. Second, participants learn to send and receive messages and find people with whom to interact. In the third stage, information exchange takes place. Information exchange also occurs at the fourth stage, but in the fourth stage interactions involve building new shared understandings through more extended conversations and debates among a number of participants. In the fifth stage, participants reflect on the overall process of learning, and they identify and pursue individual goals based on knowledge constructed collectively.

Salmon's (2004) stages primarily provide a typology of dynamics for ALN study groups, and not a fixed set of stages that participants are to be led through by the moderator in a lockstep fashion. This typology allows the moderator, for example, to be conscious of looking for opportunities to spark Stage 4 interactions among participants, while not necessarily discouraging Stage 3 participation if it has value for participants' learning. Since the ALN is a many-to-many communication environment, the stage of interaction of the group is usually largely in the participants' control.

A Unified Perspective

In her analysis of theories emphasizing acquisition and participation to varying degrees, Bowers (2000) suggested that learning is "a process of activity reorganization in which students continually revise their ways of knowing as they interact with others in their community and surrounding culture" (p. 390). This notion of learning emphasizes the usefulness of studying changes in individuals' ways of knowing in the discourse-context where the changes take place. For the present study, Bowers' idea of learning implied the desirability of describing changes in teachers' pedagogical reasoning structures within the ALN participatory stages where they were manifested.

Methodology

The present investigation is a collective case study (Stake, 2000). The cases of two different teachers participating in the same ALN study group focused on the discussion of middle school mathematics pedagogy are considered. The researcher adopted a participant-observer stance (Bogdan & Biklen, 1992). Therefore, the study should be understood as the search for insights from that particular perspective and not as an attempt to attain a positivistic, detached kind of objectivity about the nature of teachers' learning. The methodology is also grounded in the idea that learning should be examined within its discourse-context rather apart from it (Bloom, 2001; Edwards, 1993). Since the ALN transcripts contained a comprehensive record of the online discourse, they were drawn upon in order to describe the participants' learning.

Participants

The individuals providing the foci for the case studies were part of an ALN study group containing nine participants from a school district in the mid-Atlantic U.S. Three taught mathematics at one middle school in the district, two at another district middle school, and another taught mathematics part-time in afterschool and summer programs. The remaining three played supporting roles for teachers, as one was a district-wide resource teacher, one was a new teacher mentor, and another was the district curriculum coordinator. Since the participants were dispersed among various buildings in the school district, the ALN study group played the practical role of breaking down geographic and scheduling boundaries that otherwise would have impaired conversations among them. Graduate credit counting toward recertification was awarded for participation. The researcher moderated the group.

The two case study participants, Yvonne and Maura, were full-time mathematics teachers at two different middle schools in the district. Yvonne had 12 years of teaching experience, and Maura had 16. Yvonne taught sixth grade and Maura taught seventh. Both participated extensively in the study group and, therefore, generated a substantial amount of data for analysis.

The researcher gathered background data about Yvonne and Maura to build a frame of reference for analyzing their ALN interactions. On a questionnaire measuring implementation of reform-based teaching (Ross et al., 2003), Yvonne had a mean score of 3.7, and Maura had a mean score of 3.65, where a score of 6 theoretically indicates complete alignment of practice with reform-based teaching. The researcher also conducted a classroom observation of each teacher before interaction in the ALN took place. When asked to prepare a typical lesson for observation, each presented a lesson reflecting the traditional pattern of mathematics teaching in the U.S. (as identified by Stigler & Hiebert, 1999), which consists of learning rules and practicing procedures. The district curriculum coordinator, who sat in on the lesson observations and had previously observed each teacher, confirmed that the lesson patterns were typical for each instructor.

Although Yvonne and Maura shared similarities, there were also differences between them. At the end of the 13-week timeframe for ALN interaction, Yvonne had a mean score of 4.8 on a re-administration of the reform-based pedagogy questionnaire (Ross et al., 2003), while Maura's score increased more modestly to 3.9. During ALN interaction, the district curriculum coordinator noted growth in Yvonne's reasoning and practice while observing that Maura's reasoning and practice remained relatively stable. The researcher's ongoing analysis of each teacher's ALN participation resonated with these observations. Therefore, the two case studies described in this report represent slightly different learning pathways for participants who began the study exhibiting similarities in pedagogical reasoning.

Procedure

As mentioned earlier, ALN interaction took place over a 13-week time period. Before the 13 weeks began, participants were gathered together for two face-to-face (FTF) meetings. At the first FTF meeting, the researcher led the group in a collaborative lesson planning session. At the second FTF meeting, the researcher familiarized participants with the technology providing the environment for ALN interaction. Participants engaged in making practice posts, and difficulties with using the technology were remedied through interactions with others familiar with it. These two initial FTF meetings were held to help the group progress through the first two stages of Salmon's (2004) model for online learning, which involve becoming comfortable with the needed technology and finding others with whom to communicate.

At the beginning of the 13-week time period, the researcher set parameters for awarding credit for participation in the ALN. At least four discussion board posts per week were required. Guidelines for the content of the posts were not specified, since such moderator-imposed restrictions tend to be counterproductive to reflection (Dysthe, 2002; Wickstrom, 2003). However, at least three of the four were to be replies to posts made by others, so that the group would not become a collective monologue. Yvonne and Maura each consistently met or exceeded these course requirements. Yvonne posted 59 messages to the discussion board over the 13-week time period, and Maura posted 74.

As discussion moderator, the researcher played an active role in the ALN. Each week, the researcher selected an article from a professional journal intended to provoke cognitive conflict for participants who had expressed agreement with aspects of traditional mathematics instruction the previous week, since such conflict can be useful for promoting teachers' conceptual change (Causey, Thomas, & Armento, 2000; Limon, 2001; McFalls & Cobb-Roberts, 2001). Each article served as the basis for a fresh discussion board. One exception to this pattern came during week 12, since the discussion of a single article was extended by a week at the request of participants. A list of articles

chosen and the rationale for each is provided in the appendix. The researcher also asked participants to clarify or justify their pedagogical reasoning in discussion board conversations in some instances. Specific examples of the researcher's interactions with the participants are presented in the results section of this report.

Data Analysis

Data analysis had ongoing and retrospective phases. As ALN interaction unfolded, the researcher read each post. The articles shown in Appendix A were selected to address themes that became apparent during ongoing analysis. At the end of the study, the researcher did a retrospective analysis of the learning pathways followed by Yvonne and Maura. The ongoing analysis helped situate this retrospective analysis in a larger context. Retrospective analysis of Yvonne's data was done first and Maura's second.

To begin the retrospective data analysis, each of Yvonne's discussion board posts was coded according to Salmon's (2004) five-stage model. Posts were assigned codes from the model based on their roles in the larger context of the online discussion. Next, each discussion board post was analyzed for evidence of enrichments or revisions (Vosniadou, 1994) to existing pedagogical reasoning structures and also for evidence of resistance to changing existing structures. Excerpts providing evidence for resistance, enrichment, or revision were coded accordingly. Revision excerpts were assigned additional codes indicating which of the nine theories associated with traditional mathematics instruction (Ross et al., 2003) were revised.

After codes had been assigned to segments of text, a time-ordered matrix (Miles & Huberman, 1994) was constructed to summarize Yvonne's participation in the ALN. In the matrix, the five stages in Salmon's (2004) model formed the column headings and numerals representing the 13 weeks of ALN discourse formed the row headings. Data excerpts fitting each matrix cell were pasted in, and excerpts within each cell containing common characteristics were clustered together. Each cluster was assigned a qualitative descriptor. For example, the cluster containing excerpts in which Yvonne engaged in debates with other participants (a type of Stage 4 interaction) were given the descriptor "engaging in debates."

Segments of text coded as containing evidence for resistance, enrichment, or revision were then analyzed for common characteristics, and clusters of data were formed during the process. Each cluster was assigned a qualitative descriptor. For example, excerpts in which Yvonne voiced resistance to pedagogical ideas on the basis of her beliefs about teaching mathematics (such as the importance of teaching procedures and the importance of providing examples and practice) were assigned the descriptor "beliefs about teaching mathematics." Once data analysis for Yvonne had been completed, Maura's data were analyzed in the same manner. The clusters of data pertaining to each individual were used to construct narratives describing the learning they exhibited during the online discussions. The two narratives are presented alongside one another in the next section of this report.

Results

The narratives about the two teachers are organized according to Salmon's (2004) stages. Instances of resistance, enrichment, and revision are reported within the context of the stages of participation where they occurred. Participation characteristic of the first and second stages was not evident for either individual, suggesting that the needs of accessing the needed technology and finding others with whom to socialize were met in the face-to-

face meetings that occurred before online discourse. Hence, the summary of study results begins with Stage 3.

Stage 3: Information Exchange

Highlighting points from the articles. Yvonne and Maura each used the discussion board to highlight aspects of the articles under consideration that they felt were deserving of a place in the conversation. This type of post essentially put elements of their private discourses (see Kieran, 2001) about the assigned articles on public display. Within the context of these posts, Yvonne exhibited evidence of resistance, enrichment, and revision, while Maura exhibited enrichment and revision.

Yvonne's resistance to a pedagogical idea while highlighting information from an article occurred in regard to an article's advice to discourage students from "blurting out" answers (Reinhart, 2000). After highlighting the advice, she disagreed with it, explaining,

> They (girls) seem to be more comfortable around each other and when going over problems, they enjoy chiming in. They seem to feel more comfortable answering questions if the entire class is answering at the same time. This also helps me to know which problems they had difficulty with because many of them will call out the wrong answer.

Yvonne's resistance in this instance was rooted in considering the recommendation in light of a factor in her own professional context (teaching females in gender-grouped classes).

Both Yvonne and Maura exhibited enrichments to existing reasoning structures as they highlighted article aspects they considered important. Yvonne's belief in the importance of carefully planning lessons was reaffirmed by an article describing appropriate use of manipulatives (Stein & Bovalino, 2001). Maura found support for a host of her existing reasoning structures in the articles, including her own belief in the importance of careful planning, building students' confidence, changing just a small portion of one's teaching practices each year, using "real world" problems as part of instruction, and listening to students as they work. Some of her thoughts about the last item appeared in a discussion board post highlighting strategies used by a teacher whose students had been labeled "at-risk" (Robert, 2002):

> I agree that a teacher needs to know their students before any of the walk around assessing and conferencing-takes place. I too listen to the types of questions the students ask and when a lot of the same questions are asked than I usually take a step back and review/reteach.

Highlighting points from the various articles proved to be one natural context for participants to describe how existing reasoning structures were being reaffirmed and strengthened.

As Yvonne and Maura highlighted selected aspects of the assigned articles, both also reported enrichment of existing reasoning structures through the accretion of ideas neutral to shifts in thinking about any of the dimensions of standards-based pedagogy. Both teachers highlighted recommendations for extended "wait time" after asking a question (Frykholm & Pittman, 2001; Reinhart, 2000) and spoke of such recommendations as novel ideas that had the potential to improve their instruction. Yvonne, for example, wrote, "We have read it numerous times in our articles during the

last two months—it must work!! I, personally, am going to attempt to provide more wait time for my students in the coming school year." Maura's posts highlighting article aspects neutral to shifts in reasoning about the dimensions of standards-based pedagogy extended beyond wait time to encompass having students keep a notebook of mathematical terms and problems, using take-home letters to communicate with parents, and writing her thoughts on lessons in a journal rather than leaving them unrecorded. Although each of these article aspects had the potential to improve aspects their teaching, none of them necessarily reflected a shift away from ideas associated with traditional mathematics instruction (Ross et al., 2003). The notion of wait time, for example, is applicable to reform-based and traditional classrooms, as researchers have used wait time as an indicator of teacher effectiveness in various different classroom settings (Brophy & Good, 1986).

Revisions in participants' pedagogical reasoning related to the dimensions of standards-based pedagogy (Ross et. al., 2003) were, however, evident in some of the posts they made to the discussion board highlighting information from the assigned articles. Yvonne discussed revising her reasoning about student tasks and student confidence simultaneously in sharing her thoughts on an article about helping students make sense of word problems (Nosegbe-Okoka, 2004):

> Many students struggle in Math because they are afraid to be wrong or discouraged because they have been wrong so often in the past. Many students see Math as black and white, right and wrong. I found Principle 4 of the article particularly interesting. The author acknowledged that in his lesson no consensus or numerical answer was reached for the problem he gave to the students and that the students instead learned that in some situations there can be different solutions. The students were given the opportunity to discuss their reasoning and justify their solutions. This was more meaningful than determining how long it would take Marion Jones to run a race. If Math teachers presented more lessons like this one, it may help our students to build more confidence in the area of Mathematics. I will try to pose more questions in my own class that spark debate and discussion and that may have varying solutions.

In the excerpt, Yvonne suggested a link between building students' confidence in mathematics and posing questions with multiple solutions that spark discussion and debate. Yvonne's private discourse about these issues in the assigned article, made public on the discussion board, suggested movement in her reasoning toward the reform-oriented side of the spectrum along those two dimensions of standards-based pedagogy (Ross et al., 2003).

Like Yvonne, Maura showed evidence of revisions in her pedagogical reasoning while highlighting aspects from articles. Maura frequently highlighted instances in which authors discussed helping students think for themselves while solving mathematics problems, and discussed moving toward similar practices in her own classroom. Some of her comments along these lines included the following:

> This approach makes sense and I think what we have to do is to make time for the students to discuss and playing it out, when possible...I know that when I address Area and Perimeter again it will be done with this approach [discussing Nosegbe-Okoka, 2004].

> She also says that the students should be led and not told what to do. This article reinforced what Nosegbe-Okoka said that students need time to individualize a problem to understand it and that teacher should not just give them the answer

> [discussing Stein & Bovalino, 2001]. We cannot abandon good strategies for teaching problem solving not can we keep giving our children the answers. At some point in time they must learn how to think for themselves [discussing Robert, 2002].

Maura's remarks indicate a shift toward encouraging students to reason things out for themselves and away from the traditional characterization of the teacher as the sole knowledge expert who attempts to transmit mathematics to students. She also exhibited this type of reasoning in the context of other categories of Stage 3 and 4 participation described later in this report.

Describing personal professional beliefs and practices. Yvonne and Maura each periodically used the discussion board to describe aspects of their professional beliefs and practices. This second type of information sharing was different from the first because, although the beliefs and practices expressed were often related to the assigned articles, participants did not mine information from the articles to highlight. Instead, they drew upon their own teaching backgrounds. Yvonne's posts of this nature did not reveal additional evidence of resistance or acquisition. Instead, they were intended to be bits of teaching advice, as in a post she made in discussing the idea of using one rich problem as the basis for a lesson:

> I have had students work on one problem—and it has carried us through one whole class session and a night of homework. I felt that the problem was well worth the time spent on it. It was a brain teaser in which the students had to use clues to determine which person owned a certain kind of pet.

In this case, Yvonne then attached a file with the problem to the discussion board. These brief offerings of teaching ideas were considered examples of Stage 3 participation, because they served the function of information sharing but did not result in the types of extended Stage 4 conversations that will be described later in this report.

Maura's posts sharing professional beliefs and practices revealed resistance to pedagogical ideas under consideration in a number of different instances. When describing her own professional practices, she frequently shared her beliefs about why some of the reform-oriented ideas being discussed would not work. Maura frequently argued that students did not have the capacity to study the mathematics under discussion in remarks such as the following:

> It occurred to me that maybe these middle school aged children are not ready to solve these kinds of problems. Even Piaget says that higher order thinking skills do not arrive at this age. I know that I am teaching concepts to my sixth graders that I did not have until high school and statistic I did not have until college.

> I know years ago when I was in school and the teachers said do step 1, step 2, and step 3, that is what I did. Maybe I did not always understand but eventually I did. These students today, or most of them anyway, will not read past the first step before they go "I don't understand."

On other occasions, Maura's resistance came from constraints within her professional context, such as the required state curriculum, parents' apparent inability to help students with reform-oriented mathematics tasks, and the "school without walls" physical arrangement of her building. Her other resistances were rooted in her beliefs about teaching mathematics, such as, "Skills must be taught all the way through school. Short

reviews and practice of skills previously taught help one master what is necessary to go on." Unlike Yvonne, Maura did not explicitly request input from others when posting her beliefs and practices to the discussion board. This appears to be part of the reason that the posts played an information sharing function rather than sparking Stage 4 brainstorming or debate.

In addition to exhibiting resistance, Maura showed evidence of continuing to revise her reasoning about her role as a mathematics teacher in some posts describing her professional beliefs and practices. Her notion that teachers should guide students rather than just give them the answers to problems developed just as it had in Stage 3 posts highlighting information from the assigned articles. This thinking was most apparent in the following posts:

> I am too always too quick to answer the question or solve the problem. I will try to not carry a pencil with me tomorrow and see what happens...I need to let them work it out on their own. (Post from week 1)

> I gave my students a warm-up today that they had to match cities with train routes. I heard I don't understand, what are we suppose to do? They simply whined a lot. I ignored them and then told them to look for common cities and see if there was a pattern. I also told them that I had to solve this myself and they just had to be patient and work on the problem. Two of the classes just took off and did it without much problem. The other two I gave another hint and then some of them were able to do it as well. (Post from week 9)

Although the second post revealed logistical difficulties, frustrations, and perhaps inadequate understandings about the meaning of the reform-oriented concept of teaching via problem solving, it does reflect her effort to move away from her professed tendency to dispense answers too quickly to students. Hence, revisions to her reasoning about the role of the teacher were again apparent as she posted professional beliefs and practices to the discussion board.

Highlighting and affirming beliefs and practices of other participants. Yvonne and Maura both made use of the discussion board to highlight and affirm beliefs and practices mentioned in posts made by other participants. This type of information sharing resembled the first type of Stage 3 participation discussed, in which aspects of assigned articles were highlighted. The difference between the two types was that information shared was mined from other discussion board posts rather than the articles. As Maura highlighted aspects of other participants' posts, she showed further evidence of resistance and enrichment about issues in her reasoning discussed earlier. Yvonne, on the other hand, showed enrichments and revisions to her reasoning that did not appear in the context of either of the two other types of Stage 3 interaction.

In highlighting information contained in other participants' posts, Maura further showed how her emphasis on the importance of practicing computation crowded out reform-oriented recommendations. She expressed agreement with another participant that students often do not know how to make change when making a purchase and highlighted the other participant's joke that they should "open a store and take their money because they have no idea." To Maura, practicing the computations necessary to make change was to take precedence over other topics under discussion, such as teaching data analysis in the middle grades. Maura also exhibited further enrichment of her reasoning structures by highlighting other participants' recommendations to have students work "real world problems" and to have them keep a notebook with mathematical definitions. The former recommendation represented support for an

existing belief while the latter represented the further accretion of an idea neutral to revisions in reasoning about the dimensions of standards-based pedagogy.

As Yvonne highlighted aspects of posts of the other participants, she found support for a number of her pre-existing beliefs, such as the importance of requiring students work things out on their own, monitoring students as they work, teaching to a variety of different "learning styles," and having students work "real world" problems. On the last point, for example, she highlighted one participant's belief in the importance of "real world" problems by stating,

> I totally agree. I can not [sic] tell you how many times I have had students ask—"When will I ever use this??" If we try to connect what students are learning to what they may need in the future—they will "buy in" to the importance of learning the material.

In each instance of enrichment while highlighting aspects of the posts of other participants Yvonne found further support for existing reasoning structures.

On some occasions, Yvonne exhibited evidence of revising her reasoning about the role of the mathematics teacher as she highlighted aspects of others' posts. In one such post, she began to revise her reasoning about the teacher's role in classroom discourse, stating,

> I am going to try to have paraphrase what other students say in class. I rarely do this. I think that for me it has become a habit. I seem to automatically do it myself. I am going to make an effort to better control my own behavior from now on!!!

This reply was made to another post in which the goal of allowing students to play more of a role in the development of mathematical material was expressed. In another post, she highlighted her agreement with a participant who said that it was difficult to shift to the role of "teacher as facilitator," and went on to think through some of the implications of taking on that role:

I agree that this method does allow students to gain a greater understanding of the concepts presented and they will be better able to solve problems in the future because of the number sense acquired--they will be better able to determine whether their answers are reasonable. I also agree that the role of facilitator is a difficult one for many teachers to assume. Many of us have been accused (with or without justification) of being "control freaks." Assuming the role of facilitator does require that the teacher give up some of the control of the lesson (not management of the classroom) to the students.

These posts illustrate Yvonne's ability to make revisions to her reasoning along the dimensions of standards-based pedagogy by mining information from other participants' discussion board posts and reflecting upon their content.

Stage 4: Knowledge Construction

Collective brainstorming. On some occasions, participants constructed knowledge by engaging in collective brainstorming about solutions to pedagogical problems. The collective brainstorming that took place in the ALN environment contained elements of the information-sharing behaviors described earlier. It was distinguished from them by the larger context in which the participation took place. Although Stage 3 consisted of interactions between a participant and an article or between two participants, collective

brainstorming threads contained contributions from a number of participants. For example, Yvonne wrote, “I do have one question to which some of you may have suggestions—What do you do with that reluctant learner(s) in the class?” This question prompted the new teacher mentor, the curriculum supervisor, the district resource teacher, and Maura all to post suggestions and in some cases respond to the ideas set forth by others. The manner in which collective brainstorming threads provided contexts for resistance, enrichment, and revision is discussed in the remainder of this subsection.

During the third week of the study, Yvonne and Maura each participated in a discussion thread about the types of mathematical tasks students should be given and how they should be helped to solve them. The thread revealed revisions in Yvonne’s and Maura’s thinking about mathematical tasks. Excerpts from the thread (presented in the order they were posted) illustrate:

Teacher 1: Though I think it is good to have the students find patterns or relationships, combine and compare quantities, and draw diagrams, I don't think it is rational to throw out the key word approach. It almost goes back to the common sense discussion we already had. It seems to me that even here, common/logical thinking really becomes the issue.

Teacher 2: I totally agree with you that the common sense/logic issue is very important. When I tried to solve the word problem - I made a mistake in one of the steps and ended up with the wrong answer. I looked to see what the answer was and realized I had done something wrong and went back to my calculations to see where I had messed up. This strategy of sharing answers with a partner (this time my partner was the article) would have worked well for me in class. I could go back and process my reasoning to see where I had gone wrong.

Maura: I just finished reading [teacher 2's post] and that she went back to check an answer she got wrong. To take the "must get it correct" syndrome away, why not give them the problem and the answer some of time and have them explain how and why the answer is what it is? If they are not all frustrated about getting the answer, maybe we can get them to explain how the answer came about, or give them two answers and explain why one is correct and one is not. I think we need a better plan than what we have now and Nosegbe-Okoka and Clement and Bernhard have given us all some food for thought.

Yvonne: I really like the idea of providing students two choices. One of the choices could provide an erroneous answer that students would get by misreading the problem or choosing the incorrect operation. The students could then work cooperatively to prove and disprove the answers. Discussion among the students would increase the understanding of the problem and provide those students who were having difficulty an opportunity to have the correct solution explained by many of their peers. Good idea, Maura!!

In this thread, both Yvonne and Maura acquired a new type of student task representing a partial shift away from having students work only on routine mathematical operations with a single solution. Therefore, the thread provided a context for revisions in their thinking along the second of the dimensions of standards-based pedagogy (Ross et al., 2003).

In another discussion thread involving both Yvonne and Maura, Yvonne showed evidence of the enrichment of her reasoning structures by accretion of a strategy neutral to shifts in

reasoning about the dimensions of standards-based pedagogy. The following thread excerpts come from the seventh week's discussion board:

Yvonne:	Whenever I have planned lessons that require "self-generated solutions"—one of my greatest fears is that the students won't get it....There will be no one in the classroom (no student) who can get things started...then I spend the class period prompting—-giving hints. What if this happens and I am being observed that day (only one of two class periods a year when an administrator watches what I do)?? This didn't happen—-but what if? Anyone else??
Maura:	I always have that fear too. We have always been assured that if a lesson flopped even though it was well planned, that it would not be held against us...I am ashamed to say that I have not been that adventurous to try something that could fail.
Teacher 3:	Last year I had two great classes where I could plan such lessons. Not the case this year. I get many blank stares....Someone else in the room needs to be talking other than me. I think we all fear being observed on the one day when even the class that you can usually count on as being with it comes in but you soon find that they have left their brains at home, or don't seem to be quite awake.
Curriculum coordinator:	My response to such concerns, and I had them, was to invite Dr. [X] or Dr. [Y] into my classes on such days, explaining that I was trying something new and needed an objective eye. That way when they came in, and they invariably did, they joined in the experiment, and we debriefed afterwards. They could always come back to see the follow-up, but they never did. I determined that I could not have qualms about trying to expand my skills, and I had to enlist the support of my administrators.
Yvonne:	I had not considered inviting the administrator in to help assess the lesson--not necessarily the teacher. Great idea—that also removes the element of surprise. I wonder too if the administrator would enjoy an excuse to get away from the hallways and discipline issues in the office!??!

Yvonne's acquisition is best described as enrichment here because it did not require revision along any of the dimensions of standards-based pedagogy, although the potential for revision (or resistance or more enrichment) was present as a result of conversations with administrators.

Two other collaborative brainstorming threads in which Yvonne exhibited evidence of enrichment occurred during the 8th and 11th weeks of the study. During the eighth week, she entered a thread where participants set forth ideas for "real world" problems, writing,

> Next week, I wanted to have the students decide what type of home they would like to own, what type of car they would like to drive, etc. and from that information they will determine how much money they will need per month, per year and hopefully from that decide the type(s) of jobs they may want to get as an adult.

After receiving links to relevant Web sites to support the unit and other pedagogical ideas from participants, Yvonne acknowledged receipt of the messages by stating,

> Thanks everyone!! I'm looking forward to this project. I think that it will be really cool to do with all girls. I think that our discussion will lead to many topics--some that are not mathematically based but I think that many of my girls are in need of a "reality check."

The ideas from other participants had reinforced her pre-existing idea that "real world" problems were important. During the 11th week, Yvonne's pre-existing ideas about formal assessment of students were enhanced by engaging in a brainstorming thread about how to deal with grading students. At one point, she wrote,

> One thing that all middle/high school teachers need to think about when choosing what assignments to grade and how to grade those assignments...As [the curriculum coordinator] said—it is all about quality not quantity. If you feel as though you want to provide students with a grade for putting forth effort on any given assignment—do just that—provide them with a "grade" for completion. If it is accuracy or understanding that you are checking for—then grade the questions/problems more thoroughly.

The post demonstrated that Yvonne's existing reasoning about grading was reinforced while reading similar views expressed by the curriculum coordinator and other participants.

Debating. Yvonne and Maura each periodically engaged in debates in the ALN environment. As with collective brainstorming, debates involved several different participants. Unlike the collective brainstorming threads, the debates involved explicit differences of opinion about various issues, including, using "key-word" strategies to teach word problems, teaching basic computational skills in middle school, using a reform-oriented rather than traditional curriculum series, and folding alternative algorithms into instruction. For the most part, the debates provided contexts for Yvonne and Maura to display resistances to pedagogical ideas.

An article that recommended avoiding use of the "key word" approach for solving word problems (Clement & Bernhard, 2005) helped ignite a debate among discussion board participants during the third week of the study. Neither Yvonne nor Maura was in favor of eliminating the key-word approach from their teaching repertoires. On at least one occasion, it seemed that Yvonne swayed another participant toward her point of view, as shown in the following exchange:

Resource Teacher:	...I thought the whole point of word problems was to make students think about how the math concepts they have learned are applied in the real world. I am starting to equate using key words to mathematical mad libs. If all they need to do is replace the "key words" with the appropriate sign for the correlating function, they haven't thought about the real world application at all, AND they might be using the wrong function...
Yvonne:	... No one strategy will be effective if used exclusively. We as educators, as professionals, need to choose which teaching strategy or strategies we want to use to help students understand the concepts that we are teaching. So training students to replace the key words with operational symbols or teaching them using a quantitative analysis approach will not work for all students all of the time. We need to demonstrate and incorporate a variety of methods for the benefit of all of our students...
Resource Teacher:	I like the way you said that, Yvonne!
Yvonne:	Thanks!!:)

Maura, along with most other discussion board participants, adopted a similar position and did not deviate from it. By the end of the debate, only the researcher maintained that it was harmful to inject key-word strategies into mathematics instruction.

Two weeks later, a debate about which basic computational skills should be taught in middle school and how much time should be spent on them arose. Maura entered the debate by contributing to the following exchange between the researcher and another participant:

Researcher: ... Is there some way to re-organize our traditional patterns of teaching in order to build students' conceptual understanding so they don't forget things so readily....Are there any skills that just aren't worth the time we spend on them because they are outdated or unnecessary (e.g., long division)?

Teacher 1: Hmmm. Interesting. Long division? No, it is probably not used very often, but I'm a math teacher and I think it is useful. Yes, there are some things that have been outdated, but in my opinion, those would be hard to argue....Outdated math, just doesn't sit well with me. Maybe if you called it overstressed, overemphasized [sic], or over-evaluated, outdated math would be more agreeable. <

Researcher: In regard to long division, I wouldn't disagree with the labels "overstressed, overemphasized, or over-evaluated." I would, however, also still include the "outdated" label...Long division was introduced into the school curriculum long before any sort of calculators were available. That made it a very important skill back then, particularly for those running stores or other businesses (sometimes the label "shopkeeper arithmetic" is used for the curriculum of that era)....I don't really think the curriculum has changed much now that calculators are available--as noted in this week's article. A great deal of time and energy is still spent in the early grades on shopkeeper arithmetic.

Maura: Shopkeeper math is what I call everyday math or common sense math. Students today cannot make change without the cash register...Long division? Use a calculator? Students need some number sense before they should be given a calculator. Once they know the process, I will give them a calculator.

Maura's opposition to de-emphasizing "shopkeeper arithmetic" appeared to be partially rooted in a belief that calculators are harmful to students' learning. Yvonne agreed with Maura, largely on the basis of a belief in the importance of computational procedures in mathematics:

> If we have a large number of students in class who do not possess the skills necessary to do the type of Math that is required and we are not allowed to teach those skills, how much will they hate Math when they have sat in Math classes for several years and not understood the procedures needed to solve the problems that are given to them???

Both Maura and Yvonne held to the position that the manner in which computational skills and procedures were taught should not be altered and did not show evidence of being open to revising their pedagogical reasoning structures in this area.

A debate during the seventh week of the study helped reveal more of the sources of Yvonne's resistance to revising pedagogical reasoning structures while also providing insight into why teachers in the district had actively opposed the adoption of a reform-oriented approach to mathematics instruction:

Researcher:	Facilitating is more difficult than conventional instruction in many ways, because time needs to be taken to carefully select problems that will provide rich contexts for thinking, like the one in this article did (Although some series, like Connected Mathematics and MathScape provide such problems for the teacher and sequence them carefully--that makes it easier for the teacher to step into the role of facilitator). What does everyone think about this sort of shift--from teacher as sole dispenser of knowledge to teacher as facilitator?
Teacher 1:	I think one of the main reason why I liked the Math Scape series was because it allowed me more to facilitate the lesson as opposed to teach (stand and deliver) the lesson. The students also enjoyed the lessons from Math Scape, they said it gave them some input in the lesson and a little ownership for their learning. I must admit, it was a little difficult sometimes to do this with my students of lower ability. With them there had to be a bit more teacher direction.
Teacher 2:	I agree with you Teacher 1 that the lower students are more difficult to use facilitation. The MathScape [scapes] book did afford us more activities and many students as I used this said how quickly the time went and learning was taking place.
Researcher:	This might be a silly question, but in light of the positive comments that have been posted about the MathScape series, why is the district no longer using it?
Yvonne:	The MathScapes series does use "real world" situations and has some very good scenarios/situations to involve students. The problem is this--the text does not provide ANY examples to help students or parents to understand how to approach a problem. It provides a scenario or situation and then asks the student to create solutions from the information given...it lacks the examples and practice necessary.

In the excerpt above, Yvonne's belief in the importance of "real world" examples was not enough to convince her to wholeheartedly adopt a reform-oriented curriculum, since in her estimation, "examples and practice" needed to occur before students approached problems.

On one other occasion, a debate provided a context for both Maura and Yvonne to exhibit resistance to a reform-oriented pedagogical idea. During the last 2 weeks of the study, the group took up the topic of folding alternative computational algorithms into instruction. Maura was opposed to the idea, as illustrated in the following exchange with the researcher:

Maura:	Ever since math wings [a curriculum including alternative algorithms] was introduced into the elementary schools, I hear the same year after year from parents of incoming 6th graders, will they learn the traditional way? When I tell them yes, they breathe a sigh of relief.
Researcher:	I'm curious—why do they breathe a sigh of relief?

Maura: ...the fact that parents do not understand is why it upsets them. I tell parents that I will teach them the traditional way but students will still be able to use whatever works for them. I find that many students are glad to learn the traditional way as it is not as cumbersome and does not take as long as the other.

Maura here based her resistance on a belief that the difficulty of understanding an algorithm was directly proportional to how long it took to execute. Yvonne initially implied agreement with Maura's position about traditional algorithms at the beginning of the following exchange, but seemed to soften her position as a result of it:

Yvonne: During previous discussions, many of us have stressed the importance of our students understanding and being proficient in the basic skills (adding, subtracting, multiplying and dividing)....Would our students who are somewhat competent with computation be confused if we were to attempt to teach using some of the alternative algorithms described in the article??

Curriculum coordinator: Yvonne, I wonder if we do not confuse our students with our traditional algorithms, because the elementary math program uses different ones.

Yvonne: It is quite possible that we do. If all of us were taught and are comfortable with "traditional" methods--AND our students are taught using "non-traditional" methods in the elementary schools--wouldn't our methods be just as confusing for those students as the "alternative" methods are for us?????

After this exchange, Yvonne started asking *how* alternative algorithms might become part of instruction rather than *if* they should have a place. Therefore, it appeared as if hearing viewpoints opposing her original position had softened her initial resistance to rethinking the role of algorithms in mathematics instruction.

Stage 5: Development

Both Yvonne and Maura engaged in Stage 5 interactions during the study. Such interactions include identifying areas for one's further learning and growth. AlthoughYvonne identified areas for growth in her knowledge of mathematics and pedagogy, Maura identified areas for development in pedagogy alone.

Further Development of Pedagogy. Both Yvonne and Maura pushed for more collaborative planning of mathematics lessons among teachers in the middle schools in the district. Yvonne's push was set in the context of a critique of how professional development (PD) time available in the district had been used in the past:

> Many of the PD periods have been used for "Professional Development" rather than collaborative planning. Rarely have we had the time to plan for or even discuss lessons taught....I would agree that the PD time would be a wonderful opportunity for teachers to get together to plan lessons! If we just started planning one lesson per week, by the end of one term we would have 9 (hopefully) great lessons to help our students better understand concepts.

Maura also argued for more PD time spent on collaborative lesson planning:

> I absolutely agree that professional development days should be used for teachers to collaborate on lessons. However, for what ever reason, this is never what PD is used for.... Shouldn't PD be for collaboration with other teachers. Working together would be a way to develop good lessons and share ideas.

These comments from Yvonne and Maura came while discussing an article that emphasized the importance of careful lesson planning when one uses manipulatives in a lesson (Stein & Bovalino, 2001). Also, 5 weeks earlier, they had constructed a collaborative lesson plan with other teachers in the face-to-face meeting that took place before the online discussions began.

In addition to advocating the use of professional development time for planning, Yvonne and Maura each identified their own unique directions for further development of pedagogical knowledge. During the second week of online discussions, Yvonne asked if others would be interested in studying a book recommended by another participant with ideas for student tasks:

> [The curriculum coordinator] had mentioned two books to use as resources to develop problems that may be helpful for our students ("Getting it Together" and "United We Solve"). Would it be possible to incorporate those into this course or to include them in our Summer PD?—possibly purchasing one copy for each person in the course??

Maura's direction for further development of pedagogical knowledge was identified during the seventh week of the ALN discussions:

> I also think going to another middle school that uses a series of books that uses facilitation would also be a good idea. Is there such a school? I know that in the Dr. [M]'s class there was a school that used a book with these kinds of activities but I do not remember who.

Maura's remarks about observing teachers at other schools occurred in the context of a conversation about the shift from "teacher as dispenser of knowledge" to "teacher as facilitator."

Further development of mathematics content knowledge. As mentioned earlier, Yvonne explicitly identified areas for improvement in her knowledge of mathematics, while Maura did not. Yvonne publicly acknowledged weaknesses in her own knowledge of alternative computational algorithms, stating,

> I am elementary certified and...I only had one "Math Methods" course. I do not recall having any of this in my college preparation...I have NEVER seen this stuff before!! This may be my fault entirely—but I do believe that if this is being taught at the elementary level—I need(ed) to know. I feel that I could be so much more help to my students if I were able to help them learn the basic skills if I taught them in a variety of ways.

When a number of others agreed with Yvonne that their teacher education programs had not prepared them to fold alternative algorithms into instruction, the curriculum coordinator for the district used the discussion board to announce that she would bring in an elementary school teacher from the district whose classroom included the study of

alternative algorithms. When the date for the session with the elementary school teacher conflicted with personal plans, Yvonne sent a follow-up message asking the curriculum coordinator if it would be possible to set alternate or additional dates for the professional development session on alternative algorithms. Therefore, Yvonne actively sought to build her mathematics content knowledge in an area of perceived deficiency.

Discussion

In constructing the case study narratives, several similarities and differences between the learning exhibited by Yvonne and Maura emerged. To conclude this report, some of the most striking similarities and differences will be discussed along with the researcher's reflections on their meaning for the field of mathematics teacher education.

One similarity between Yvonne and Maura was that the changes in their pedagogical reasoning structures were mainly enrichments and small-scale revisions. For example, both teachers professed a preexisting belief in the importance of real world problems. That belief was reaffirmed by the articles and other teachers participating in the ALN, and some new suggestions for such problems were added to Yvonne's and Maura's existing reasoning structures. At the same time, however, both participants held to the idea that teachers should train students to pick out the key words in such problems, and they maintained that skills must be learned through teacher-provided examples and practice. They did not consider making real world problem-solving an organizing focus for classroom discourse and a vehicle for learning skills, as envisioned by NCTM (2000) and realized by teachers participating in programs such as CGI (Franke, Fennema, & Carpenter, 1998; Lubinski & Jaberg, 1998). Yvonne and Maura, therefore, were typical of teachers in the U.S. in their tendency to adopt reform-oriented recommendations "at the margins of teaching rather than at its core" (Jacobs et al., 2006, p. 30). Perhaps more of the large-scale revisions needed in each teacher's reasoning would have developed if the study had extended for longer than 13 weeks, since teachers usually make changes gradually over extended periods of time (Clarke, 1994).

Although large-scale revisions did not occur for either participant, groundwork for further professional development was established because both participants engaged in Stage 5 participation over the course of the study, in which they identified areas for further learning. Their requests were heard and acknowledged by the curriculum coordinator, who actively participated in the discussion group. Yvonne's request to learn more about alternative algorithms was quickly satisfied by the curriculum coordinator, who scheduled a professional development session focused on the topic. Maura's request to observe teachers in other school districts using reform-oriented approaches was also acknowledged as an important future professional development activity. Hence, having an administrator with the authority to restructure the manner in which available professional development time was used in the school district ensured that Yvonne's and Maura's Stage 5 posts resulted in action being taken. This was a significant outcome for both participants, since their discussion board posts on various occasions indicated that available professional development time was not used well in the district, reflecting a prevalent problem in U.S. schools in general (Stigler & Hiebert, 1999).

It should also be acknowledged, however, that an administrator's presence in a course for teachers may inhibit participants from being as candid as they otherwise might be. Yvonne, for example, expressed a desire to work on gaps in her content knowledge, but Maura did not. It seems unlikely that administrator participation, however, was the sole reason for this, as Maura also made various arguments why some of the mathematics being discussed should not be taught at the middle school level. Her lack of Stage 5 participation regarding further learning about alternative algorithms was also rooted in

beliefs that (i) the shorter the algorithm, the simpler it is to learn; and (ii) parents would have difficulty understanding alternative algorithms even if teachers encouraged students to use them. Yvonne, who initially held similar views, softened her resistance to alternative algorithms after engaging in a debate thread with other participants.

Although engaging in debate sparked changes in Yvonne's pedagogical reasoning in the case of alternative algorithms, Yvonne and Maura were both similar in their tendency to take one side in debate threads and adhere to it closely, as shown by the fact that they voiced mostly resistance in such contexts. From an acquisition perspective, Yvonne's and Maura's learning from the debates does not appear to be robust, since generally it did not aid the formation of reasoning structures that were more aligned with reform-oriented pedagogy. However, the debate threads did provide a context for them to voice strong statements about the teaching paradigms they held. From a participation perspective, this type of debate is not necessarily counterproductive, since it can aid in establishing a diversity of voices within a community and, therefore, make the members within it reach more harmonious relations (Matusov, 1996). Group harmony and cohesion can lead teachers to identify and pursue further professional development opportunities with one another, as in the present study. Therefore, an apparent failure in learning from one perspective should not necessarily be looked upon as an absolute failure. Debates have the potential to motivate further learning experiences, which may provide sites for the attainment of more sophisticated pedagogical reasoning structures. The ALN provides a unique environment for such debate, since it affords participants extended periods of time to construct contributions, while synchronous and face-to-face settings generally do not.

The text-based nature of the ALN also affords unique learning opportunities that both case study participants capitalized upon. Both Yvonne and Maura used the environment to make their private discourses about assigned articles and text posted by others public in some of their Stage 3 posts. Vygotsky (1962) argued that this process of changing inner speech to written speech aids learning because the transformation requires the writer to deliberately place a structure on his or her thoughts. Harism (1990) expanded on Vygotsky's idea in her discussion of online learning, stating that placing this structure on one's thought gives "the opportunity to make explicit to oneself the aspects of an activity that are usually tacit–for example, expressing the thinking process by which a decision or conclusion is reached, or the strategy for accomplishing some task" (Harism, 1990, p. 49). From this perspective, it is not likely an accident that Yvonne and Maura both exhibited evidence of enrichment and revision in making their private discourses about the articles and other posts public. The ALN provided an environment in which it was necessary for them to engage in the metacognitive activity of placing structure on their thoughts about the texts they read in order to make their ideas comprehensible to others.

Conclusion

The present study outlines a theoretical perspective and a methodology for assessing mathematics teachers' learning. In the case study narratives, the constructs of resistance, enrichment, and revision were useful for tracking teachers' attainment of pedagogical reasoning structures. Salmon's (2004) stages of participation provided a helpful structure for understanding learning from a participation perspective. Assessing learning from both perspectives is valuable, because a success from one perspective may be viewed as little or no progress from the other. An exclusive focus on either acquisition or participation would have left important details about the nature of the learning exhibited by Yvonne and Maura unexamined. Therefore, as mathematics teacher educators make decisions about online instructional design and directions for further research, priority should be placed upon the analysis of learning from both perspectives.

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Appendix A

Articles Serving as Starting Points for Weekly ALN Study Group Conversations

Week 1

Reinhart, S.C. (2000). Never say anything a kid can say! *Mathematics Teaching in the Middle School, 5*, 478-483.

Rationale: Many instances of didactic teaching were observed by the author during classroom observations prior to ALN study group discussions. Article was intended to spark consideration of having students play more of an active role in learning.

Week 2

Nosegbe-Okoka, C. (2004). A sense-making approach to word problems. *Mathematics Teaching in the Middle School, 10,* 41-45.

Rationale: Teachers expressed concern about helping students write solutions to word problems that appeared on the state assessment during class observations and ALN discourse. The article was intended to help them consider reform-based recommendations to approaching the situation.

Week 3

Clement, L., & Bernhard, J.Z. (2005). A problem-solving alternative to using key words. *Mathematics Teaching in the Middle School*, 10, 360-365.

Rationale: The key-word approach to solving word problems was advocated by some teachers during weeks 1 and 2. The article was selected to problematize the practice of teaching word problems using key words.

Week 4

Stein, M.K., & Bovalino, J.W. (2001). Manipulatives: One piece of the puzzle. *Mathematics Teaching in the Middle School, 6*, 356-359.

Rationale: During week 4, the moderator tried to spark discussion about uses of manipulatives to support the recommendations in the article but received little response. The article was intended to spark further consideration of the issue.

Week 5

Devlin, K. (1999). On my mind: Reduce skills teaching in the mathematics class. *Mathematics Teaching in the Middle School, 5*, 72-73.

Rationale: During week 5, some teachers argued that students need to master the "basics" before engaging in solving real-world problems. The article was intended to challenge that notion.

Week 6

Brahier, D.J. (2001). Understanding mathematics and basic skills. *Mathematics Teaching in the Middle School, 7*, 8-9.

Rationale: The article was intended to problematize several notions that had arisen in earlier weeks, including the idea that students' computation skills have decreased since the introduction of the calculator and that students must be taught algorithms such as "line up the decimals" and "invert and multiply" to solve real-world problems.

Week 7

Perlwitz, M.D. (2005). Dividing fractions: Reconciling self-generated solutions with algorithmic answers. *Mathematics Teaching in the Middle School, 10*, 278-283.

Rationale: Since the idea of dividing fractions without using the "invert and multiply" algorithms was a novel idea to participants during week 6, this article was intended to provoke thought about how one might teach a lesson without invoking the algorithm and how students might respond.

Week 8

Robert, M.F. (2002). Problem solving and at-risk students: Making "mathematics for all" a classroom reality. *Teaching Children Mathematics, 8*, 290-295.

Rationale: During week 7, some participants felt that the students in their school district would not have the abilities to learn mathematics through problem-solving. The article was intended to challenge that assumption by providing an example of a classroom teacher working successfully with "at-risk" students.

Week 9

Frykholm, J.A., & Pittman, M.E. (2001). Fostering student discourse: Don't ask me! I'm just the teacher! *Mathematics Teaching in the Middle School, 7*, 218-221.

Rationale: By the end of week 8, participants began to discuss how it might be possible to teach mathematics using problem-solving. The article was intended to support their transition from traditional to reform instruction by describing how one teacher had made the transition.

Week 10

Chappell, M.F., & Thompson, D.R. (1999). Modifying our questions to assess students' thinking. *Mathematics Teaching in the Middle School*, *7*, 470-474.

Rationale: Discussion of student assessment up to this point in the ALN study group had been limited to issues surrounding the state testing. This article was intended to provoke thought about how continuous formative assessment can help improve instruction.

Week 11

Cole, K.A. (1999). Walking around: Getting more from informal assessment. *Mathematics Teaching in the Middle School*, *4*, 224-227.

Rationale: The week 10 conversations saw participants wrestling with the question of how student assessments should be graded. This article was intended to help participants understand that assessment is not just done for the purpose of assigning a grade.

Weeks 12 and 13

Randolph, T.D., & Sherman, H.J. (2001). Alternative algorithms: Increasing options, reducing errors. *Teaching Children Mathematics*, *8*, 480-484.

Rationale: Previous discussions pointed to the fact that teachers' were unfamiliar with the alternative algorithms middle school students brought from the reform-oriented elementary school curriculum in the school district. Previous discussion threads often made the implicit assumption there was only one acceptable way to do computation problems.