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Supporting novice elementary mathematics teachers' induction in professional communities and providing innovative forms of pedagogical content knowledge development through information and communication technology

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Abstract

This paper reports on the needs identified as important to 27 novice elementary mathematics teachers and examines how Connect-ME, an online mathematics community, provides these supports. Qualitative data were collected using two focus groups and 16 telephone interviews. Findings validate the need for alternative teacher professional development (TPD) models and the value of professional communities and knowledge acquired through technology-facilitated learning. The results indicate that teachers actively seek formal and informal TPD experiences, opportunities for sharing and communicating, and access to quality resources. This study provides educational researchers and administrators with essential elements for effectively supporting novice elementary mathematics teachers.

Keywords: Mathematics education; Teacher professional development; Technology in education

1. Introduction

"Learning mathematics is threatening to most teachers, especially elementary teachers whose limited experiences with mathematics have often been anxiety-provoking and uninspiring" (Peterson & Barnes, 1996, p. 485). By the time they begin their professional education, teachers have already clocked more than 2000 h in a "specialized 'apprenticeship of observation' which not only has instilled traditional images of teaching and learning but has also shaped their understanding of mathematics" (Ball, Lubienski, & Mewborn, 2001, p. 437). It is not surprising, then, that despite the best efforts of teacher-education programs, "teachers are much more likely to teach as they have been taught throughout their schooling than as they have been taught in teacher-education programs" (Watson, 1995, p. 2).

In stark contrast to these observations, a group of elementary mathematics teacher candidates proactively sought opportunities to continue their Bachelor of Education (B.Ed.) experience beyond graduation through thoughtful, sustained, and ongoing professional development. This cadre asked for the opportunity to design and implement an elementary mathematics forum they could access once they were in the field. They expressed a desire

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for this support, in part, due to their lack of confidence in implementing an effective elementary mathematics program (Colgan, Higginson, & Sinclair, 1999). Through analysis of two focus groups and a questionnaire it was found that their top priority initially was discussion with experts in areas such as reform-consistent mathematics curriculum, technology integration, cross-curricular integration (links between mathematics and other subject areas such as art, music and children's literature) and special needs' students. Second, they wanted direct and immediate access to assistance about content and advice on how best to build mathematics concepts. Third, they wanted a bank of challenging and imaginative mathematics problems and lessons selected by an expert for use in the classroom. Finally, these candidates wanted to share lesson plans and activities that they themselves had created over the course of their pre-service year. Five years later, some of these needs are markedly different.

The principal purpose of this study was to give voice to 27 novice elementary mathematics teachers (teachers with less than 5 years experience) with respect to the types of supports they most valued beyond graduation. The vehicle against which participants measure their own experiences of support is Connect-ME (http://educ.queensu.ca/connectme), a unique online community shaped and self-regulated by both current teacher candidates and graduates now in the field. Connect-ME mentors novice teachers and empowers them through supports and resources that encourage standards[1]-based teaching. Since its launch, Connect-ME has served a cadre of novice elementary teachers simultaneously as a website, repository of exemplary resources, virtual meeting place, and 24-h helpline. It provides opportunities for 'just-in-time' learning and multiple levels of on-demand support—all under the control of the beginning teacher and requiring a proactive help-seeking stance. Fig. 1 provides an overview of the innovative supports Connect-ME offers. Concomitantly, the study provides evidence on the degree to which the worldwide web, while not yet a prominent feature in the existing menu of teacher professional development (TPD) opportunities can be an effective mechanism for supporting novice teachers. Finally, this study documents the local implementation of an innovation that concretizes novice teachers' intended practice and seeks to sustain the positive beliefs that play an important role in educational reform. As a repository of novice teachers' ideas about teaching and learning, Connect-ME, provides insight into the ways that novice teachers see themselves in the elementary mathematics classroom. The resources that they share on Connect-ME are strong evidentiary indicators of novice teachers' planning, instructional decisions and intended classroom practices, all of which are likely to be representations of beliefs. The Connect-ME teachers' courage in volunteering to make their personal conception of mathematics education explicit in actionable ways, i.e., curriculum units, rich learning tasks, and applications, offers educational researchers and administrators with possible next steps for in-service education and continuous professional development initiatives. Clearly, the challenge is to keep the momentum, by concentrating efforts towards building upon young teachers' pre-service education-inspired transformed beliefs and statements of intended practice. By providing them with the types of support, resources and networks they value and trust, we could design appropriate experiences to give them the necessary confidence to actualize their intended curriculum in their own classrooms, becoming the early adopters who have a key, positive role to play in influencing other teachers' adoption of innovations like the reform mathematics curriculum.

[1]The standards-based (or reform) curriculum places value on students' deep conceptual understanding within and between the branches of mathematics and across disciplines, developed through personal experience and real-world contexts (Goldsmith, Mark, & Kantrov, 2000). Contemporary teaching and learning is fundamentally different from most documented accounts of classrooms in that it features the constructivist tenet of learning as active sense-making, discourse and reflection within a community of learners. Because the guiding principles of the reform curriculum resonate with intuitive assumptions about what students need to learn and how they come to know it, and are grounded in substantive research, standards-mathematics has won general and widespread acceptance and calls for implementation (Wang & Odell, 2002).

2. Review of literature

Three bodies of literature were critical for shaping and conducting this study: TPD, communities of practice, and technology-facilitated learning, with an emphasis on novice elementary mathematics teachers. Analysis of the extant literature provides a rationale for the current study as well as a theoretical lens for identifying the supports needed by novice teachers through alternative forms of

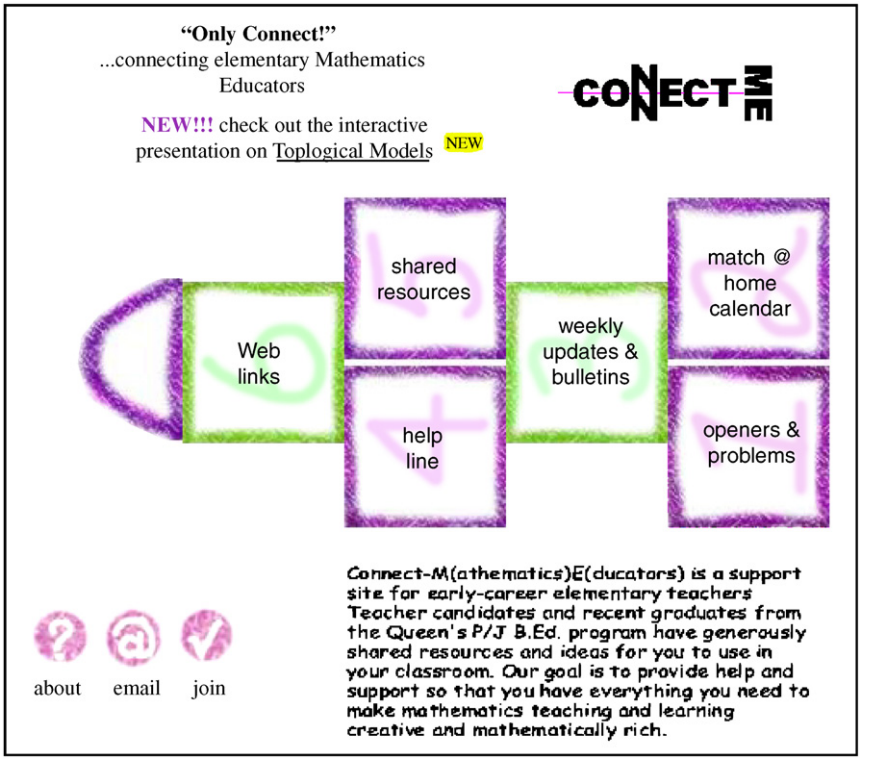

Fig. 1. Innovative supports Connect-ME offers to novice elementary mathematics teachers.

professional development and one social learning theory.

2.1. Teacher professional development

Shulman (1987) contends "teaching is, essentially, a learned profession" (p. 9). It follows then that learning to teach is a lifelong developmental process (Harrington, 1994; McCarthy & Riley, 2000) that involves the continual deepening of knowledge and skills (Cuban, 1990). Teachers are learners on their own professional journey (McCarthy & Riley, 2000) and professional development is an ongoing and continuous process that takes place throughout one's teaching career (Jones, 1995; Loucks-Horsley, Stiles, & Hewson, 2000).

2.1.1. Teacher knowledge

Shulman (1986) identified three areas of knowledge that teachers need in order to be effective. First, teachers need a deep understanding of content knowledge. Mathematics teachers who teach without this understanding (Loucks-Horsley et al., 2000) need opportunities to learn to "equip them with the mathematical knowledge and skill that will enable them to teach mathematics effectively" (Ball, 2003, p. 2). Second, teachers need pedagogical knowledge—an understanding of the methods and strategies of teaching that allows them to continually develop and refine their own practices (Kennedy, 1999). Third, teachers need pedagogical content knowledge for understanding specific methods, resources and strategies that are proven to work well when teaching a particular content area, such as mathematics (Brown & Borko, 1992; Carter & Day, 2002; Loucks-Horsley, Stiles, & Hewson, 1996). Loucks-Horsley and Matsumoto (1999) maintain that effective mathematics professional development must address all three areas of knowledge. Therefore, professional development that transforms teaching and builds substantial knowledge of mathematics content cannot be a straightforward task of "plan and implement" (Mundry & Loucks-Horsley, 1999) accomplished by simply instituting 'innovations' or adding a few strategies to teachers' repertoires (Acquarelli & Mumme, 1996; Smith, 2001):

> Many times we act as if learning happens as a direct result of exposure to new information; as if

> at the moment of hearing new information, we 'learn' it. Learning is much more complex than that, especially when the goal of learning is to build the capacity of the individual or the system (Wald & Castleberry, 2000, p. 8).

Due to the dramatic shift in curriculum content and increased focus on conceptual understanding and non-routine problem-solving (Goldsmith, 2001), professional development is central to mathematics education reform (Lee, 2001) and must begin with pre-service and novice teachers. Fundamental change can only occur over time through active engagement with new ideas, understandings and real-life experiences, and through experimentation with new behaviors and ways of doing. (Loucks-Horsley et al., 2000; National Staff Development Council (NSDC), 2002).

Education reform leaders are acknowledging the central role that TPD must play in systemic reform efforts like the implementation of the new mathematics curriculum. In practice, however, even studies of exemplary TPD efforts report that it is difficult to maintain support for teachers after an institute or workshop, or to encourage sustained discourse among participating teachers (Fennema et al., 1996; Romberg, 1997). Moreover, teachers have little time to develop and test new ideas, assess the effects, and adjust their strategies and approaches (Cook & Fine, 1996). Hence, TPD models are shifting from traditional to newer alternative approaches—a significant observation for educational researchers and administrators serious about providing effective support to novice teachers.

2.1.2. Traditional TPD models

Traditional forms of TPD, including workshops, train-the-trainer, and speaker series, have relied primarily on transmitting new ideas of teaching and learning through top-down, hierarchical structures (Ruopp & Haavind, 1993). In traditional TPD models the learning occurs in "formal, highly structured activities outside the context of [teachers'] actual work" (Schlager, Fusco, & Schank, 1998, p. 2), gives teachers little control over the content, focus and interactivity of sessions (Sykes, 1996), and are all too often scheduled at inappropriate times (Guskey, 1995). Research on such models suggest they are not sustained, generative or collaborative; do little to bring about significant change to teaching practices and student achievement; and are isolated from enacted teaching practices (Dalgarno & Colgan, 2004; Guskey, 1995; Loucks-Horsely, Love, Stiles, Mundry, & Hewson, 2003). This tradition, based on an outside expert's opinion of what teachers' need, not what they want, provides neither the content nor the opportunities teachers view as essential for their professional growth (Lieberman, 1995; Loucks-Horsely et al., 2003). Alternative TPD models may be more effective for assisting educational researchers and administrators in supporting novice teachers' needs because they address teacher identified shortcomings of more traditional approaches.

2.1.3. Alternative TPD models

TPD models are shifting "from a transmission model of information transfer to a socially and culturally situated process of knowledge construction" (Jenlink & Kinnucan-Welsch, 1999, p. 377) because studies continuously show that traditional methods are not meeting the needs of teachers (Ball & Cohen, 1999). This shift suggests that teachers profit more from the knowledge and insights they develop in their own ways through activity, discourse, reflection, inquiry and application (Jenlink & Kinnucan-Welsch, 1999; NSDC, 2002) than from prescriptions that give them little practical leeway (Kennedy, 1999). When asked, teachers request TPD content that: (a) is endorsed by research, (b) addresses both content and pedagogical knowledge within the context of the teachers' learning experiences, (c) provides opportunities to access and discuss exemplary reform-based resources, and (d) allows them to create and publish resources for new teaching practices (Ball, 1996; Cooney & Krainer, 1996; Lieberman, 1995; Loucks-Horsely et al., 2003; Sykes, 1996).

There has been a movement at the grassroots level to design local, relevant solutions to meet the needs of groups who share common challenges. These smaller, local professional development initiatives can take a variety of forms but all include at their core a community of learners who work together over time and beyond the mere sharing of information to include dialogue, reflection, and feedback to and from each other (Shaughnessy, 1998). These alternative forms of TPD adopt a structure that is predominantly informal, occurs in context (Schlager, Fusco, & Schank, 2002), and involves "consultation, problem-solving, and program development" (Little, 2001, p. 23). Book clubs are one example of this approach as they can provide opportunities for teachers to reflect with colleagues,

expand their content and pedagogical knowledge, actively engage in the learning process, and impact the isolation often experienced by teachers (Kerka, 1996). The literature specific to the unique challenges of learning how best to teach mathematics does reveal that more collaborative and communicative forms of TPD are only effective if the opportunities: (a) engage teachers in mathematical experiences similar to those they wish for their students; (b) provide teachers with leadership experiences; (c) include evaluation, critical reflection, and mechanisms for improvement; and (d) allow for collaboration with colleagues (Cooney, 1994; Darling-Hammond & McLaughlin, 1995; Loucks-Horsely et al., 2003). Lesson study is another example of a TPD strategy that promotes teachers to examine their own practices by collaboratively interacting with colleagues to plan, teach, observe, and critique lessons (Fernandez, Cannon, & Chokshi, 2003; Ma, 1999). In the Third International Mathematics and Science Study (TIMSS), Hiebert and Stigler (2000) analyzed videotapes from hundreds of classrooms worldwide. They found that Japanese students were among the highest achievers, in part, because Japanese teachers were empowered to take charge of their own professional development by implementing the process of 'lesson study' thereby enhancing their own learning as well as their students—they formed a community of teachers.

In summary, alternative TPD models not only address the weaknesses of traditional models but are also characterized by research-based activities, informal processes, critical thinking and reflection, and collaboration on creating locally relevant solutions by participating in a professional community of practice.

2.2. Communities of practice

The notion of 'community of practice' as a social learning theory (Lave & Wenger, 1991; Wenger, 1998) appears to be an essential need for teachers. Sharing, collaborating, and expanding the membership of a community are critical elements for providing teacher support.

2.2.1. Sharing and collaborating

A community of practice is defined as a group of individuals who share such commonalities as interests, knowledge, resources, experiences, perspectives, behaviors, language, and practices (Barab & Duffy, 2002; Lave & Wenger, 1991; Taylor et al., 2003). Lave and Wenger (1991) suggest that membership includes shared access to activities, resources, and opportunities for ongoing participation. Collaboration in a community of practice is achieved through dialoguing, participating, controlling decisions, and making meaning (Ruopp & Haavind, 1993; Shulha & Wilson, 2003). It is this collegial sharing and collaborating within a community of practice which results in both new collective knowledge and individual growth (Adajian, 1996; Roth, 1995).

Lawson (1997), while writing about her experiences in implementing mathematics reform in her classroom, found that the teaching profession was often lonely and isolative. In fact, first year teachers report that this isolation is compounded when they encounter a school climate that is contrary to reform; this makes it difficult to maintain positive dispositions towards alternative practices (Cooney & Krainer, 1996). There is a growing consensus, however, that these feelings can be overcome through membership in a community that allows teachers to mentor and support each other, and enrich each other's work (Ball, 1996; Loucks-Horsley et al, 1996).

Research on learning to teach has shown that substantial mentoring and coaching, follow-up, resources, and time are required to support teachers beyond graduation (Wang & Odell, 2002). As Wells (1995) states, "What we learn depends crucially on the company we keep, on what activities we engage in together, and how we do and talk about these activities" (p. 123). Therefore, a community in which teachers can do mathematics, reflect on mathematics, and reinvent their practice is an essential element of lasting teacher growth (Corwin, 1993; Watson, 1995). Alternative TPD models reflect both sharing and collaborating in their theoretical orientation and strive to include these two elements through communities of practice.

2.2.2. Expanding membership

Lieberman (2000) and McLaughlin and Talbert (1993) found that members within an educational community of practice usually include colleagues situated in the same school. Lieberman and Grolnick (1996) extended these findings to report that some communities of practice can be effective when membership includes teachers who live in diverse geographic regions. They suggest that membership begin small and grow with the

changing needs and goals of their members. These researchers do agree that communities of practice, whether small or expanding, develop when there is an environment that promotes voluntary participation, a commitment to the vision and purpose of the community, collaboration in rethinking ways of engaging students in authentic learning activities, a safe support network which promoted risk-taking, and, as in alternative TPD models, leadership opportunities for its members.

The epistemological view of learning that takes place in a community of practice characterizes TPD as both individually and socially constructed. This suggests teachers must be able to form their own community to support alternative teaching practices (Boero, Dapueto, & Parenti, 1996; Dalgarno & Colgan, 2004; Lieberman & Grolnick, 1996). Lave and Wenger (1991) do warn that any participation in a community of practice that involves technology can be extremely variable "depending on the form of participation enabled by its use" (p. 101). Understanding that, technology may enhance the role a community of practice can play in supporting alternative TPD opportunities for teachers

2.3. Technology-facilitated learning

There are challenges to offering teachers alternative forms of TPD and developing a community of practice (e.g., sustainability, inclusivity). Some of these obstacles, however, may be overcome through technology-facilitated learning.

2.3.1. Online support characteristics

Initial implementation efforts of Internet technology for TPD provided few tools and communication channels needed to support communities of practice (Laferrière, Breuleux, & Bracewell, 2000). Today, however, characteristics of online communities fit many of the TPD and community-support needs expressed by teachers including: overcoming isolation from and sharing experiences/resources with peers, providing equal access to TPD opportunities and ongoing support for the change process, a safe environment, sharing tools for professional discourse, and allowing for asynchronous communication which is more amenable to in-depth, reflective conversation (Lieberman & McLaughlin, 1992; Schlager & Schank, 1997; Shotsberger, 2000). Some educational technology advocates propose that virtual communities for TPD can help teachers learn new skills and approaches that support and sustain alternative practices (e.g., Lieberman, 1996; Shotsberger, 1999; Watts & Castle, 1992).

2.3.2. Sustainability

Various studies indicate that sustainable technology-based TPD requires certain key elements: meeting the needs of community members; being led by a qualified facilitator who gets involved with teacher needs; ensuring a connection to teachers' practices; nurturing a community of practice; providing mechanisms for reflection; discouraging isolation; ensuring activities are research-based; accessing exemplary resources; acquiring personal efficacy from the experience; and learning over time (Hoban, 2002; Leo & Cowan, 2000; Levin & Waugh, 1998; Ruopp & Haavind 1993; Schlager & Schank, 1997; Woodruff, Brett, Macdonald, & Nason 1998). Many of these elements are also cited as important to TPD and communities of practice. Laferrière et al. (2000) in their telelearning research found that approaches which included both face-to-face and online opportunities: (a) fostered a trust in the quality of the posted materials and in the supports provided; (b) developed a climate that supported collaborative knowledge building; and (c) offered an option to continue membership in the community after graduation. In addition, Watts and Castle (1992) established an online *Mastery of Learning Project* that involved teacher candidates in its design. They found that a grassroots approach to supporting these future teachers provided a sense of ownership towards the project. The TPD literature that suggests teachers' desire control over their own learning experiences and they seek those opportunities that are best aligned to their professional needs mirror the characteristics of sustainable online support.

Expedient to implement, virtual solutions (e.g., web pages, electronic bulletin boards, email) have become a common answer to the problems of offering teachers places to meet and access to resources. Early electronic TPD models, however, had disappointing results and were difficult to sustain (Watts & Castle, 1992). Schlager et al. (2002) found that some online communities failed due to a misalignment between the design of the website and the specific needs teachers have for TPD, static and outdated websites, and the difficulty facilitators have in encouraging the sustained discourse that characterize communities of practice. It is these types of challenges that can hinder the sustainability of support in online communities of practice.

This literature provides a rationale for further explicating the needs of novice teachers and examining viable alternatives to existing TPD models by focusing on one successful web-based alternative. The results of this study will inform educational researchers and administrators on how to best utilize their human and financial resources in efforts that support elementary mathematics teachers in meaningful and sustainable ways.

3. Methodology

3.1. Data collection

Two 90-min focus groups ($n = 5$ and 6) and 16 h-long telephone interviews were conducted with novice elementary mathematics teachers who were active in Connect-ME, an established virtual community with approximately 245 members. The 27 participants were selected using the following criteria: They were novice teachers (less than 5 years experience), graduates of one B.Ed. program, and members of the Connect-ME community. Some participants were founding members, while others were newer members who joined the community during their pre-service program. They varied in teaching experience, age, geography (urban, sub-urban, rural, out-of-province, out-of-country), and cultural background. A semi-structured interview script for both the focus groups (FG1 and FG2) and telephone interviews (TIs) was designed to elicit information about the supports deemed important to novice teachers and how Connect-ME offered a vehicle for meeting those needs, if at all. Table 1 lists the questions asked of the participants in both the focus groups and the telephone interviews.

The focus groups and telephone interviews were conducted over a 2-month period with the facilitators using formal protocols established by the research team. Each focus group was facilitated by two researchers while a third researcher tape recorded information, monitored the recordings, and wrote field notes (Krueger & Casey, 2002; Morgan, 1997). The telephone interviews were tape recorded and complemented by field notes prepared during the interviews (Groves, 1979; Shuy, 2002). All participants agreed to have their feedback tape recorded. Each focus group and interview was transcribed verbatim with pseudonyms used to identify each participant.

3.2. Data analysis

The inductive data analysis used for this study utilized a qualitative framework that allowed the researchers to "build patterns of meaning" from the data (McMillan & Schumacher, 2001, p. 519) (see Table 2). Four phases, as described by McMillan and Schumacher, were employed for the analysis of the transcripts: (1) continual discovery throughout the research in order to tentatively identify patterns; (2) categorizing and ordering data; (3) refining patterns through determining the trustworthiness of the data; and (4) synthesizing themes. The first level of analysis was used to identify topics from coded text segments in both the telephone and focus group transcripts. This resulted in nine topics which identified the subject of the segments and included content, structure, reflection, risk, resources and ideas, growth, frequency, connection, and on-line. The second level of analysis included creating themes by categorizing the nine topics. Five themes

Table 1
Focus groups and telephone interview questions

1.	After your B.Ed. experience at the faculty, what did you imagine your mathematics classroom would be like?
2.	Now that you have been teaching in the real world, in what ways were your ideals for assessment, instruction, curriculum, use of manipulatives, etc., realistic? unrealistic?
3.	Can you give us any examples of ways you've been assisted as beginning teachers?
4.	Are you getting more or less assistance than you anticipated? Why or why not?
5.	In what ways have you found any of these opportunities to be beneficial?
6.	*We may have missed some.* Are there any other ideas that would benefit you in your teaching?
7.	In what ways, if any, have these helped you do your job?
8.	In what ways, if any, have these enriched the math experiences for your students?
9.	How do the resources on Connect-ME compare and/or contrast to other resources you use in your mathematics classroom?
10.	What can we do more of to make you feel supported and apart of this virtual community?
11.	(a) If you had unlimited funds, how would you direct its use to Connect-ME and its extensions? (b) Would the funds be better spent elsewhere to better support early career teachers?

Table 2
Needs identified as important by Connect-ME teachers: emergent topics, themes and patterns

Topic → (subject identification)	Theme → (meaning of connected topics)	Pattern → (relationship among themes)
Content	Formal and informal	Forms of professional development
Structure		
Reflection	Personal teaching experiences	
Risk		
Resources and Ideas	Sharing	Professional community components
Growth		
Frequency	Communicating	
Connection		
On-line	Access to quality resources	Access to knowledge

represented the meaning attached to the topics and were identified as formal and informal professional development, personal teaching experience, sharing, communicating, and access to quality resources. In the final level of analysis the clustered themes were analyzed in order to identify emergent patterns (relationships) and to solidify understanding of the data. Three major patterns emerged that identified relationships found among the themes and are referred to as: (1) forms of professional development; (2) professional community components; and (3) access to knowledge. Table 2 outlines the topics, themes, and patterns that emerged from this analysis.

4. Results

This section describes the five emergent themes that characterize the needs of these 27 novice elementary mathematics teachers: formal and informal TPD, personal teaching experiences, sharing, communicating, and access to quality resources. Through these themes, the participants describe their need for alternative TPD, for a community of practice, and for access to technology-facilitated learning.

4.1. Formal and informal TPD

The majority of participant responses suggested that opportunities for TPD continued to follow traditional models (workshops, conferences, courses, professional activity (PA) days, new-teacher in-services). The structure of activities were non-contextual, isolated occurrences, and once the sessions were over so were any attempts to implement or sustain the new knowledge, learning, and reforms gained during the experience. As Joy stated,

> People go to workshops for two to three hours and get some ideas. But then get busy again and end up shelving it and [think], 'I'll explore that when I get home' and your life fills up and things get shelved and they get deeper and deeper and deeper and then you forget about them (TI).

The focus groups further revealed that formal TPD did not occur until well into the school year—long after these teachers had been struggling to develop an effective and engaging mathematics program consistent with the realigned mathematics curriculum. An example of this trend was described by Heather. She found that support for mathematics did not arrive until January and she stated that due to this timing, "Term one sucked.... What we got [during the January PA day] was good, but it would have been more helpful to get it earlier" (FG1). This data suggest that the mathematics programs and confidence levels of these teachers are negatively affected by delaying formal support.

There are, however, alternative professional development practices that have emerged recently as viable supports for novice teachers which tend to be voluntary teacher-driven events rather than mandatory ones. Most of the participants in the focus groups reported that activities which provided individual choice and catered to specific needs were more useful. Valerie appreciated her principal's technique for encouraging meaningful TPD:

> At the beginning of the year we have a meeting with the Principal and she [asks]: 'What are your goals for the year?' She'll write them down and then any time an opportunity for something within your goal area comes up she'll write to [me] and say, 'Hey do you know about this, this is in your [area] of interest for this year. Why don't you do it? (FG2).

TPD opportunities that allowed teachers control over their learning opportunities aided in transferability to their own teaching goals and practices also emerged as important to many of the participants. For example, Karen asked the facilitator of Connect-ME for professional development that would specifically help her communicate more effectively with parents. This opportunity was presented through Connect-ME in the form of a summer institute entitled *Family Math*, and Karen in reflecting on her experience viewed it as useful, practical, and applicable to the realities of the classroom (FG2). These self-selected, self-directed, and contextualized activities are consistent with alternative models of TPD.

Some of the participants revealed that informal TPD was most personally valued as a method of acquiring new knowledge and support for implementing exemplary mathematics programs when the content originated from their own professional community—their colleagues. For example, Krista stated that, "Anything I had to figure out about my math program...that I needed to know as far as assessment, especially assessment, came from learning through my colleagues" (TI). Approximately two-thirds of the telephone interview participants suggested that informal TPD interactions allowed teachers to "bounce ideas off" each other (e.g., Robert, TI) and to share resources (e.g., Anne, TI). The two focus groups further revealed that informal TPD encouraged novice teachers to proactively seek assistance during difficult and stressful times (e.g., Barb, FG2). These findings support the literature indicating that the structure and content of alternative forms of TPD can be a substantial support to novice teachers and reveal that traditional methods are not meeting the needs of these teachers.

4.2. Personal teaching experiences

The majority of participants who had taught more than 2 years and in more than one school found that knowledge acquisition and reflection resulted from their own teaching experiences (e.g., lesson plan design and implementation, classroom management, parental contact, teaching, TPD). The more teaching-related experiences the participants accumulated, the more confidence they had, and the more likely they were to engage in risk-taking activities that utilized alternative practices. This finding was exemplified in Sue's statement: "What I see for myself is as my teaching career goes along and I feel more comfortable and settled...and [gain] a little more experience, then I'm going to...have the time...[to] try out new things" (TI). Personal experiences provided the context necessary for reflective practice (Ball, 1996). Krista, a 3-year veteran, supported this literature when she stated that, "We don't know a lot of times if we are doing it [teaching] right...there is always the question, 'Could it have been done better?' and that's just through learning" (TI). Personal teaching experiences that promoted reform-based teaching assisted some of these novice teachers in reflecting on their teaching practices and providing them with enough confidence to try alternative activities that promoted student learning.

4.3. Sharing

Sharing, a key concept in the definition of a community of practice (Lave & Wenger, 1991),

plays a significant role in supporting these novice teachers. The shared resources found on the Connect-ME website offered a variety of approaches to teaching and learning, and some participants credited this to the cultural diversity and varied experiences of the members who contribute to the site, thereby keeping the resources "new and fresh":

> There are some wonderful ideas out there. I think that the thing I find the most rich about …Connect-ME is that you're getting ideas from so many different people….We all have different strengths. So, of course you know, I may think I can provide a complete and rich curriculum all by myself, without any help, but that would be very unrealistic….Anyway, that someone else's idea…that I can bring into the classroom…I think that I'm already enriching the learning experiences of these children (Joy, TI).

The data from the focus groups further revealed that a few participants shared resources and ideas with colleagues in the hopes that the membership within the community of practice would expand. For example, Carrie stated that she was,

> …going to be presenting the Connect-ME site at…our staff meeting on Monday… [be]cause…[it's] a bit of a small community that knows about [Connect-ME] and I know that there are some other new teachers, and not even new teachers, who [would] really benefit from some of this stuff on the site…so hopefully [I'll] get more people knowing about it (FG2).

The literature is consistent with this observation—communities of practice usually begin small and grow as the needs of the members change (Lieberman & Grolnick, 1996). These data demonstrate that participants are attempting to expand the membership through sharing and communicating with colleagues outside the existing community boundaries.

4.4. Communicating

The data indicate that communication plays a vital role in the success of alternative TPD practices. An overwhelming majority of participants viewed the emailed *Weekly Updates* as an important support. These updates were emailed to all community members by the project facilitator every Sunday evening, were usually read upon receipt, and were used for a variety of purposes. Many participants used them "to assist in providing ideas to build upon" (Emily, TI), "to use as a future reference" (Heather, FG1), and "to find additional resources" (Krista, TI). The participants who lived and taught overseas, however, revealed that the updates were important to keep abreast of recent mathematics news and to provide a method for staying connected to the community (Lisa, TI; Lori, TI). The focus groups further disclosed the fact that some participants view the updates as personal professional development (e.g., Tim, FG2). This type of communication provided these participants with personal efficacy and nurtured their growth as teachers. For example, as Lisa stated about receiving the updates,

> I'm always like, 'oh somebody is thinking about me and wants to help me'….I feel that I can contribute if I wish and that somebody's always there [on Connect-ME] that I can ask a question to. Whether it's…other teachers or professors—whoever (TI).

These weekly updates are a symbol of alternative TPD practices; they involve a community where the facilitator is actively involved in helping its members overcome struggles and supports them in trying new ideas (Adajian, 1996).

Many of the participants, especially those in the telephone interviews, felt that communication connected them to the virtual community of Connect-ME. For example, Lori found that recognizing names of friends who had contributed to the site made her "feel quite connected to that community…. It sounds cheesy, but I feel quite honored to be a part of that (TI). As well, Connect-ME was viewed by some as a safe and trustworthy support to be used in times of stress or when searching for solutions to problems. In Robert's case, he recognized Connect-ME as a communication tool in which he could ask questions that would "be respected no matter how stupid it would have been" (TI). These findings indicate that these novice teachers need personal and emotional supports—traits associated with alternative TPD models (Darling-Hammond, 2003).

Many of the participants in this study viewed the technology-facilitated sharing and communicating that Connect-ME offered as unique and valued supports to their professional development; the supports were self-directed, multi-purposed, convenient, and sustainable.

4.5. Access to quality resources

All participants utilized the technology-facilitated community of Connect-ME to access quality resources. The website provided a variety of alternative resources viewed as valuable to many of the participants' teaching practices (e.g., Callie, TI). For example, the online lesson plans, calendars and newsletters were viewed as quality resources and were frequently accessed by most of the participants. Beth had this to say about the menu of available lesson plans, all of which had been vetted to ensure their synchronization with reform-based practices:

> I have used a lot of the lesson plans….You know these lesson plans have been put out there by someone who has gone through the same program with the same philosophy and mindset. To me they are trusted. So I have used many of those instead of going on the Internet and hoping a good lesson comes up…I can always trust the Connect-ME lesson plans (TI).

The calendar was used to introduce lessons (openers), enrich activities, and provide students with interactive, hands-on activities (e.g., Dan, TI). The participants who helped create the calendar used it regularly for acquiring ideas to send home with their students (e.g., Kim, TI). As well, the telephone interviews revealed that the weekly newsletters created by some of these teachers were developed using the content from the sample newsletters posted on Connect-ME. In contrast, a few of the focus group participants found that the posted newsletters were not useful due to contextual issues such as the students' reading level and cultural background (e.g., Valerie, FG2).

The majority of participants in both the focus groups and telephone interviews acknowledged that using reform-based resources promoted a positive attitude, an increased level of enthusiasm, and a rich learning experience for their students. Lori provides an example of this observation through an attempt to engage her students in activities that made the properties of three-dimensional shapes concrete through kinesthetic approaches:

> Last week I noticed there was a new resource on Connect-ME. It was a play about geometry, *The Three Little Pigs*, but modified to incorporate concepts relating to geometry….I have a class of really dramatic children this year…and I try to find as many ways to…get them involved in [the] things they enjoy and the way that they enjoy learning….I just printed that out [and] I read through it. I had a great laugh reading this play that someone had taken so much time and energy to write….I [had] 19 kids [who] really enjoyed learning about geometry, so it's wonderful (Lori, TI).

Connect-ME also offered alternative TPD resources in the form of online conferences and face-to-face workshops. Participants in remote areas (rural, out-of-province, out-of-country) acknowledged feeling isolated and valued the ability to connect, communicate, and share with members in an online forum (e.g., Lisa, TI). A few less isolated community members, however, preferred face-to-face opportunities in order to accomplish the same ends (e.g., Dan, TI).

The participants had confidence in the quality of the resources because it was vetted by a facilitator they trusted and the contributions to the resource bank were made in the spirit of providing positive mathematics experiences for students; these technology-facilitated learning opportunities provided teachers with the supports they actively sought.

5. Discussion

The findings indicate that the perceived needs of today's novice elementary mathematics teachers can be met through: (1) alternative forms of TPD; (2) a professional community of practice; and (3) access to knowledge through technology-facilitated learning—all characteristics identified as important to the success of Connect-ME. These three patterns are complemented by the five themes which emerged in the analysis illustrating the necessity of both formal and informal TPD alternatives through a compendium of personal teaching experiences, opportunities to share, forums for communicating, and access to quality resources.

First, the study indicates that this group of novice elementary mathematics teachers need and actively seek alternative forms of TPD that are on-going and long-term, are in context to their own teaching experiences, provide control over their own learning experiences, and include both online and face-to-face opportunities. They want formal and informal TPD experiences that relate directly to interactions with colleagues, students, experts, self and indirectly through continuous access to quality resources

(e.g., resources found on Connect-ME). Although these findings are consistent with the extant literature, little information is provided for determining ways to meet these expressed needs. In its sixth year of existence, Connect-ME offers a method and means to meet the expressed needs of these novice teachers through mixed-method delivery mechanisms.

Second, the results suggest that a community of practice could be acknowledged as an important form of alternative TPD since this view: (a) promotes sharing ideas and quality resources; (b) offers a venue of communicating and reflecting with other elementary mathematics educators; and (c) prevents feelings of isolation that can arise within the teaching profession. Although the literature identifies these particular elements (e.g., Wenger, 1998; Lieberman & McLaughlin, 1992), it does not incorporate the social learning theory of communities of practice into alternative TPD models for meeting the identified needs of these teachers. Connect-ME provides an example of one way to weave an online community of practice into new TPD models by providing novice elementary mathematics teachers with a safe, communicative community for sharing resources and ideas and an environment where they can proactively seek the help they need. Further research, however, is needed into the role collaboration plays in supporting this group of teachers since the literature identifies collaboration as an important characteristic within communities of practice (Lave & Wenger, 1991) but the analysis did not support this notion. Rather, it was the sharing and communicating that was of greatest significance to these 27 novice teachers.

Finally, this study recognized the importance of providing teachers with sustainable access to knowledge and quality reform-based resources through technology-facilitated learning. What emerged from the findings was the significance of emotional and personal connections, in addition to pedagogical and curricular support, for sustaining an online community of practice. The literature recognizes this need (e.g., Laferrière et al., 2000), but provides little direction in how best to accomplish a genuine emotive connection. The results suggest there are possibly three essential elements necessary for these connections to exist. First, initial community members should have a personal link to, and a loyalty and respect for the project facilitator, as professional learning requires effective leadership. In the case of Connect-ME, the facilitator is the mathematics professor for all the B.Ed. candidates who are now members of this community. She is viewed by the community as a quality leader who is an expert in elementary mathematics. Second, the facilitator should continue to communicate with all members of the online community even after they graduate. For example, the Connect-ME facilitator communicates weekly with all members of the community through a group email. And third, the online forum should be created and developed at the grassroots level as identified by Watts and Castle (1992); its growth, however, ought to be the result of previous personal connections. Connect-ME was created, and continues to develop and grow, by B.Ed. students and graduates of the program. This connection provides a sense of ownership and personal efficacy towards the project. These conclusions support the literature which suggests that beginning with a locally developed online community managed by a quality facilitator is important for successful online projects (e.g., Lieberman & Grolnick, 1996).

This study provides educational researchers and administrators, interested in examining and supporting novice elementary mathematics teachers', alternatives for generating new professional development opportunities and models—ones that meet the needs of novice elementary mathematics teachers. In addition, the perceived key elements necessary for success are highlighted and this, in turn, can offer an opportunity to build upon existing explanatory models of online communities. Connect-ME provides an example of one vehicle that supports the needs of these novice elementary mathematics teachers by incorporating alternative TPD, a community of practice, and technology-facilitated learning into opportunities for learning and growth. Further research, however, is needed to increase our understanding of how online communities function and how levels of engagement can be expanded. Connect-ME is one step in moving the reform agenda forward by listening to teachers' voices, honoring the literature and trying to bridge these two domains so important for improving the quality of elementary mathematics education.

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References

Acquarelli, K., & Mumme, J. (1996). A renaissance in mathematics education reform. *Phi Delta Kappan*, *77*, 478–484.

Adajian, L. B. (1996). Professional communities: Teachers supporting teachers. *The Mathematics Teacher*, *89*(4), 321–326.

Ball, D. L. (1996). Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *Phi Delta Kappan*, *77*, 500–508.

Ball, D. L. (2003). What mathematics knowledge is needed for teaching mathematics? Paper presented at *the US Department of Education, Secretary's Mathematics Summit*, Washington, DC.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond, & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3–32). San Francisco, CA: Jossey-Bass.

Ball, D. L., Lubienski, S., & Mewborn, D. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed.). New York: Macmillan.

Barab, S.A., & Duffy, T.M. (2000). From practice fields to communities of practice. In D.H. Jonassen & S.M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 25–55). Mahwah, NJ: Lawrence Erlbaum Associates.

Boero, P., Dapueto, C., Parenti, L. (1996). Didactics of mathematics and the professional knowledge of teachers. In A.J. Bishop et al. (Eds.), International Handbook of Mathematics Education (pp.1097–1121). The Netherlands: Kluwer.

Brown, C. A., & Borko, H. (1992). Becoming a mathematics teacher. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning*. New York: Macmillan.

Carter, J. A., & Day, R. (2002). Pedagogical mentoring as tailored professional development. *NCSM Journal of Mathematics Education Leadership*, *5*(2), 1–12.

Colgan, L., Higginson, W., & Sinclair, N. (1999). Transforming professional development: An empirical study to determine the key aspects of electronic collaboration and social interaction in the elementary mathematics teaching community. *The Alberta Journal of Educational Research*, *65*, 315–319.

Cook, C. J., & Fine, C. (1996). *Critical issue: Realizing new learning for all students through professional development*. Naperville, IL: North Central Regional Education Laboratory Retrieved February 19, 2004, from http://www.ncrel.org/sdrs/areas/issues/educatrs/profdevl/pd200.htm.

Cooney, T. J. (1994). Research and teacher education: In search of common ground. *Journal for Research in Mathematics Education*, *6*(25), 608–636.

Cooney, T. J., & Krainer, K. (1996). Inservice mathematics teacher education: The importance of listening. In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick, & F. K. S. Leung (Eds.), *International handbook of mathematics education,* (pp. 1155–1185). Netherlands: Kluwer Academic Publishers.

Corwin, R. B. (1993). Doing mathematics together: Creating a mathematical culture. *Arithmetic Teacher*, *40*(6), 338–341.

Cuban, L. (1990). *How teachers taught* (3rd ed.). New York: Longman.

Dalgarno, N., & Colgan, L. (2004). *Developing and supporting elementary mathematics teacher's reform beliefs*. Paper presented at the annual meeting of the American Educational Research Association (AERA), San Diego, California.

Darling-Hammond, L. (2003). Keeping good teachers. *Educational Leadership*, *60*(8), 6–13.

Darling-Hammond, L., & McLaughlin, M. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*, *76*, 597–604.

Fennema, E., Carpenter, T. P., Franke, M. L., Levi, L., Jacobs, V. R., & Empson, S. B. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education*, *27*(4), 403–434.

Fernandez, C., Cannon, J., & Chokshi, S. (2003). A US–Japan lesson study collaboration reveals critical lenses for examining practice. *Teaching and Teacher Education*, *19*, 171–185.

Goldsmith, L. T. (2001). Spheres of influence: Supporting mathematics education reform. *National Association of Secondary School Principals Bulletin*, *85*(623), 53–65.

Goldsmith, L.T., Mark, J., & Kantrov, I. (2000). Choosing a standards-based mathematics curriculum. Portsmouth, NH: Heinemann.

Groves, R. M. (1979). Actors and questions in telephone and personal interview surveys. *Public Opinion Quarterly*, *43*, 190–205.

Guskey, T. R. (1995). Professional development in education: In search of the optimal mix. In T. R. Guskey, & M. Huberman (Eds.), *Professional development in education: New paradigms & practices* (pp. 114–131). New York: Teachers College Press.

Harrington, H. L. (1994). Perspectives on cases. *Qualitative Studies in Education*, *7*(2), 117–133.

Hiebert, J., & Stigler, J. W. (2000). A proposal for improving classroom teaching: Lessons from the TIMSS video study. *Elementary School Journal*, *101*, 3–20.

Hoban, G. F. (2002). *Teacher learning for educational change*. Philadelphia, PA: Open University Press.

Jenlink, P. M., & Kinnucan-Welsch, K. (1999). Learning ways of caring, learning ways of knowing through communities of professional development. *Journal for a Just and Caring Education*, *5*(4), 367–385.

Jones, D. (1995). Making the transition: Tensions in becoming a (better) mathematics teacher. *The Mathematics Teacher*, *88*(3), 230–234.

Kennedy, M. (1999). Form and substance in mathematics and science professional development. *NISE Brief*, *3*(3), 1–7.

Kerka, S. (1996). Book groups: Communities of learners. *New Directions for Adult and Continuing Education*, *71*, 81–90.

Krueger, R. A., & Casey, M. A. (2002). *Focus groups: A practical guide for applied research* (3rd ed.). Thousands Oaks, CA: Sage.

Laferrière, T., Breuleux, A., & Bracewell, R. (2000). Collaborative inquiries into the networked classroom. In *Proceedings of the Society for Information Technology and Teacher Education international conference*, San Diego, CA (ERIC Document Reproduction Service No. ED 444 511).

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Publishers.

Lawson, D. P. (1997). From caterpillar to butterfly: A mathematics teacher's struggle to grow professionally. *Teaching Children Mathematics*, *4*, 140–143.

Lee, H. J. (2001). *Enriching the professional development of mathematics teachers. ERIC Digest*. Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC Document Reproduction Service No. ED465495).

Leo, T., & Cowan, D. (2000). Launching professional learning communities: Beginning actions. *Issues About Change*, *8*(1), 1–15.

Levin, J. A., & Waugh, M. (1998). Teaching teleapprenticeships: Electronic network-based educational frameworks for improving teacher education. *Interactive Learning Environments Journal*, *6*(1–2), 39–58.

Lieberman, A. (1995). Practices that support teacher development. *Phi Delta Kappan*, *76*, 591–596.

Lieberman, A. (2000). Networks as learning communities: Shaping the future of teacher development. *Journal of Teacher Education*, *51*(3), 221–227.

Lieberman, A., & Grolnick, M. (1996). Networks and reform in American education. *Teachers College Record*, *98*(1), 7–45.

Lieberman, A., & McLaughlin, M. W. (1992). Networks for educaitonal change: Powerful and problematic. *Phi Delta Kappan*, *73*(9), 673–677.

Little, J. W. (2001). Professional development in pursuit of school reform. In A. Liebermann, & L. Miller (Eds.), *Teachers caught in the action: Professional development that matters* (pp. 23–44). New York: Teachers College Press.

Loucks-Horsely, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Thousands Oaks, CA: Sage.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics*, *99*(5), 258–270.

Loucks-Horsley, S., Stiles, K., & Hewson, P. (1996). Principles of effective professional development for mathematics and science education: A synthesis of standards. *NISE Brief*, *1*(1), 1–7.

Loucks-Horsley, S., Stiles, K., & Hewson, P. (2000). *Briefing for the national commission on mathematics and science teaching for the 21st century*, Washington, DC.

Ma, L. (1999). *Knowing and teaching elementary mathematics*. Mahwah, NJ: Erlbaum.

McCarthy, J., & Riley, S. (2000). A new vision for teacher professional development. *Leadership*, *30*(2), 34–36.

McLaughlin, M. W., & Talbert, J. W. (1993). *Contexts that matter for teaching and learning*. Palo Alto, CA: Context Center on Secondary School Teaching.

McMillan, J., & Schumacher, S. (2001). *Research in education: A conceptual introduction* (5th ed.). New York: Addison Wesley Longman.

Morgan, D. L. (1997). *The focus group guide*. Thousands Oaks, CA: Sage.

Mundry, S., & Loucks-Horsley, S. (1999). Designing professional development for science and mathematics teachers: Decision points and dilemmas. *NISE Brief*, *3*(1), 1–7.

National Staff Development Council (NSDC). (2002). *By your own design: A teacher's professional learning guide (CD-Rom version)*. Oxford, OH: Author.

Peterson, P. L., & Barnes, C. (1996). Learning together: The challenge of mathematics, equity, and leadership. *Phi Delta Kappan*, *77*, 485–491.

Romberg, T. (1997). Mathematics in context: Impact on teachers. In E. Fennema, & B. Nelson (Eds.), *Mathematics teachers in transition* (pp. 357–380). Mahwah, NJ: Lawrence Erlbaum Associates.

Ruopp, R., & Haavind, S. (1993). From current practice to projects. In R. Ruopp, S. Gall, B. Drayton, & M. Pfister (Eds.), *LabNet: Toward a community of practice* (pp. 21–57). Hillsdale, NJ: Lawrence Erlbaum Associates.

Schlager, M. S., Fusco, J., & Schank, P. (1998). Cornerstones for an on-line community of education professionals. *Technology and Society*, *17*(4), 15–21.

Schlager, M. S., Fusco, J., & Schank, P. (2002). Evolution of an on-line education community of practice. In K. A. Renninger, & W. Shumar (Eds.), *Building virtual communities: Learning and change in cyberspace* (pp. 129–158). New York: Cambridge University Press.

Schlager, M. S., & Schank, P. K. (1997). TAPPED IN: A new on-line teacher community concept for the next generation of internet technology [Electronic version]. Paper presented at *the second international conference on computer support for collaborative learning*, Toronto, Ontario, Canada.

Shaughnessy, J. (1998). *Initial guidelines on becoming a learning community*. Portland, OR: Northwest Regional Educational Labs (ERIC Document Reproduction Service No. ED442174).

Shotsberger, P. G. (1999). The INSTRUCT project: Web professional development for mathematics teachers. *Journal of Computers in Mathematics and Science Teaching*, *18*(1), 49–60.

Shotsberger, P. G. (2000). The human touch: Synchronous communication in web-based learning. *Educational Technology*, *40*(1), 53–56.

Shulha, L., & Wilson, R. J. (2003). Collaborative mixed-methods research. In A. Tashakkori, & C. Teddlie (Eds.), *Handbook of mixed methodology,* (pp. 639–670). Newbury Park: Sage.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–22.

Shuy, R. W. (2002). In-person versus telephone interviewing. In J. F. Gurbrium, & J. A. Holstein (Eds.), *Handbook of interview research: Context & method* (pp. 537–555). Thousand Oaks, CA: Sage.

Smith, M. S. (2001). *Practice-based professional development for teachers of mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Sykes, G. (1996). Reform of and as professional development. *Phi Delta Kappan*, *77*, 465–467.

Taylor, J., Munby, H., Chin, P., Hutchinson, N. L., Berg, D. H., & Dalgarno, N. (2003). Co-op students' access to shared knowledge in science-rich workplaces. Paper presented

at *the annual meeting of the Canadian Society of Education*, Halifax, NS.

Wald, P. J., & Castleberry, M. S. (Eds.). (2000). *Educators as learners: Creating a Professional learning community for your school [Monograph]*. Alexandria, VA: Association for Supervision and Curriculum Development.

Wang, J., & Odell, S. J. (2002). Mentored learning to teach according to standards-based reform: A critical review. *Review of Educational Research*, *72*(3), 481–546.

Watson, G. A. (1995). Middle school mathematics teacher change: Social constructivism climbs a step. Paper presented at *the annual meeting of the National Council of Teachers of Mathematics*, Boston, MA.

Watts, G. D., & Castle, S. (1992). Electronic networking and the construction of professional knowledge. *Phi Delta Kappan*, *73*, 684–689.

Wells, G. (1995). In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 111–129). Washington, DC: American Educational Research Association.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, UK: Cambridge University Press.

Woodruff, E., Brett, C., Macdonald, R., & Nason, R. (1998). Participation in knowledge-building communities to promote teaching competency in mathematics. Paper presented at *the annual meeting of the Canadian Society for Studies in Education*, Ottawa, Canada.