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Evaluating the Effectiveness of a Telepresence-Enabled Cognitive Apprenticeship Model of Teacher Professional Development

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EVALUATING THE EFFECTIVENESS OF A TELEPRESENCE-ENABLED COGNITIVE APPRENTICESHIP MODEL OF TEACHER PROFESSIONAL DEVELOPMENT

by

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ABSTRACT

Evaluating the Effectiveness of a Telepresence-Enabled Cognitive

Apprenticeship Model of Teacher Professional Development

by

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This exploratory research used a mixed-methods design to compare the effectiveness of a telepresence-enabled cognitive apprenticeship model of teacher professional development (TEAM-PD) to that of a traditional workshop model by examining outcomes in teacher pedagogy and student achievement. Measures of the degree to which teachers in both groups enacted mathematics pedagogy provided mixed results. Both groups demonstrated similar patterns of behavior and cognition, indicating modest levels of pedagogy implementation. Although the experimental group demonstrated higher levels of enactment of the mathematics pedagogy, the comparison group demonstrated a faster rate of growth. Student outcome data were clear: students of teachers in the experimental group scored substantially higher on a test of relevant mathematics content than students of teachers in the comparison group.

Collectively the results suggest that TEAM-PD has potential to be an effective model of teacher professional development.

(160 pages)

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CHAPTER I

INTRODUCTION

In 1981, United States Secretary of Education Terrel H. Bell announced that "...something is seriously remiss in our educational system" (National Commission on Excellence in Education [NCEE], 1983, p. 6). He subsequently appointed the bipartisan NCEE to assess the quality of teaching and learning in U.S. schools. Secretary Bell's fears were well founded. After funding more than 40 studies, analyzing the most current data, and conferring with administrators, educational experts, teachers, and students, the NCEE produced a 1983 report entitled *A Nation at Risk* that presented the following conclusion:

> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves.... We have, in effect, been committing an act of unthinking, unilateral, educational disarmament. (p. 10)

Unfortunately, since this assertion was made, the situation has not greatly improved. Despite an estimated $400 billion[1] spent on education annually, the U.S. educational system is still in need of improvement (Kirkpatrick, 2003). The 1994 U.S. Congress noted that most public schools are failing to prepare students to achieve the National Education Goals and that students are currently not competent in core content areas (Goals 2000: Educate America Act, 1994). More recently, the 2000[2] National

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[1] $400 billion per year is an estimate that includes Federal, state, and local funds (Kirkpatrick, 2003). The Federal component alone is $56 billion in 2006.

[2] The 2000 NAEP was the most recently available nationwide assessment available for 12th graders.

Assessment of Educational Progress (NAEP) found that 35% of twelfth graders scored below the "basic" level and the 2003 NAEP found that 23% of fourth-grade students and 32% of eighth-grade students scored below the "basic" level. With so much that needs to be done to improve quality of education in this country, where should limited resources be focused? The U.S. Department of Education, educators, administrators, and educational researchers have argued that the answer to this question is, in large part, *teacher professional development* (Corcoran, 1995; Darling-Hammond, 2000; National Commission on Teaching for America's Future [NCTAF], 1996; No Child Left Behind Act, 2002; Rebora, 2004). For the purposes of this research, teacher professional development is defined as ongoing, intentional, systemic educational and training opportunities available to educators in their schools and districts (Guskey, 2000).

However, many current teacher professional development activities are criticized for having little impact on student outcomes (e.g., Consortium for Policy Research in Education, 1996; Frechtling, Sharp, Carey, & Baden-Kierman, 1995; Guskey, 2000). This is partly because they fail to incorporate key components of effective adult learning such as modeling, observation, and feedback (Fullan & Stiegelbauer, 1991; Lewis et al., 1999; Mullens, Leighton, Laguarda, & O'Brien, 1996; Rebora, 2004). What then, makes teacher professional development effective?

For decades, educational researchers have argued that teacher professional development should provide collaborative learning environments, research and inquiry, engagement in practical tasks of instruction and assessment, and consistent feedback and follow-up activities. Although such a cohesive and coherent professional development model is widely recognized as ideal, it is rarely practiced (Bull, Buechler, Didley, & Krehbiel, 1994; Joyce & Showers, 1980; Loucks-Horsely, Hewson, Love, & Stiles, 1998; Rebora, 2004; U.S. Department of Education, 2000). A new approach to professional development is needed—one that capitalizes on the current state of knowledge about cognition and learning. The research described herein describes and evaluates such an approach.

Typically, teacher professional development presents abstract pedagogical concepts independent of an authentic context, ignoring evidence that the ability to learn and use information is dependent upon context (Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978) to the degree that an individual integrates the context and the learning (Eich, 1985). The *cognitive apprenticeship model of teacher professional development* presented in this dissertation follows a three-stage learning process (Collins, Brown, & Newman, 1987). First, an expert consultant (e.g., in mathematics) models instructional strategies for teachers in an authentic context (i.e., those teachers' classrooms) while explaining the tacit cognitions and behaviors underlying the strategies. Second, the teacher attempts to implement the strategies in the classroom with support of the consultant through coaching, observation, and corrective feedback. Finally, the consultant fades into the background, providing support as necessary, as the teacher begins to confidently practice the newly learned strategies competently on his own. A cognitive apprenticeship approach to professional development will address the shortcomings of traditional professional development by contextualizing learning, allowing complex skills to be explicated, and enabling the distributed practice of skills.

The principles of cognitive apprenticeship place at least two requirements on the interaction between a master and an apprentice: (a) they must interact a great deal, and (b) these interactions must take place at frequent intervals. Both of these requirements are problematic for the expert consultants—college professors and other specialists—who typically deliver the workshops common in today's professional development model. These consultants often spend a large proportion of their time traveling from one school to another and time spent traveling is time that cannot be spent teaching.[3] It is important that professional development for teachers involves the assistance of these experts. They are qualified to serve as the master teachers that the cognitive apprenticeship framework requires; school districts rarely have the resources to locate, train, and evaluate these staff (Maldonado, 2002; Wong & Nicotera, 2003). The U.S. Department of Education (2000) stated that "districts do not have the infrastructure to be able to manage and implement effective professional development" (p. 63). One possible approach to make a cognitive apprenticeship model of professional development economically and practically feasible is to use video-conferencing technology to enable the necessary interactions between teachers and distant consultants.

While video-conferencing opens the possibility, legacy[4] technology does not adequately provide key elements of face-to-face interaction: appropriate social distance, life-size imagery allowing for hand gestures and other body language, and mutual eye

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[3] Rachel McAnallen, the mathematics consultant featured in this research, spends approximately 40% of her time traveling.

[4] The term legacy refers to extant technology.

gaze (McNelley, 2000, 2005; Weinstein & Lichtman, 2005). Legacy video-conferencing systems suffer from several limitations. In addition to not providing life-size images, not adequately allowing for hand gestures and body language, not "placing" the speakers an appropriate social distance from one another (proxemics) and not depicting the movement and speech in a lifelike manner, these systems also do not allow for eye contact. Because of the distance between the image of the person with which one is communicating and the camera that is capturing one's image, it is impossible to maintain eye contact with that person. The importance of eye contact in human communication has been well established through decades of empirical studies (Aguinis, Simonsen, & Pierce, 1998; Argyle, 1969; Argyle & Dean, 1965; Droney & Brooks, 1993; Kendon, 1967; Kleinke, Staneski, & Berger, 1975; Serber, 1972; Wheeler, Baron, Michell, & Ginsburg, 1979). If video-conferencing technology is going to successfully enable a cognitive apprenticeship model of teacher professional development it should support interaction of sufficient quality to approximate actually "being there." Essentially, what is required is *telepresence.* Telepresence has been defined as "the use of technology to establish a sense of shared presence or shared space among geographically separated members of a group" (Rose & Clarke, 1995). The research described herein evaluates the effectiveness of a telepresence-enabled apprenticeship model of professional development (TEAM-PD).

CHAPTER II

REVIEW OF THE LITERATURE

This literature review presents evidence intended to support the logic underlying the purpose and methods of the research. The review will first summarize the literature describing the current state of teacher professional development, how these methods are widely viewed as inadequate, and the impact these inadequacies have on teacher preparation and retention. Second, the literature describing the nature of effective teacher professional development will be reviewed. Third, a presentation of the cognitive apprenticeship literature will illustrate how cognitive apprenticeship can be used as the scaffolding for an effective model of teacher professional development. Finally, the logistical problems associated with a cognitive apprenticeship model of teacher professional development will be described, followed by a technological solution and the literature relevant to supporting the nature of that technology.

The Importance and Current State of Teacher Professional Development

NCTAF (1996) noted that the most important influence on what students learn in school is what teachers know and what teachers do. Of the five recommendations for change in the educational system proposed by NCTAF, one of them was to develop higher quality teacher professional development. This highlights the growing evidence for and recognition of the importance of professional development in equipping educators to meet the challenges faced by our schools (Abdal-Haqq, 1995; Corcoran, 1995; Darling-Hammond, 2000; Guskey, 2003; Maldonado, 2002; National Center for Education Statistics [NCES], 2001; NCTAF, 1996; Plecki, 2000; Rebora, 2004; Wilson & Berne, 1999). For example, a comprehensive analysis of state-level data from all 50 states conducted by Darling-Hammond found that well-prepared teachers can have a greater impact on student achievement than poverty, language background, and minority status. Similar results have been found in other studies (Armour-Thomas, Clay, Domanico, Bruno, & Allen, 1989; Darling-Hammond & Ball, 1997; George Lucas Educational Foundation [GLEF], 2001). Critically evaluating the effectiveness of common professional development practices is, therefore, important to ensure the success of our educational system.

For years, educators and education researchers have lamented the fact that the majority of professional development is delivered to teachers in the form of inservice workshops. These one- to three-day workshops, often referred to as "drive-by workshops,"[5] are presented by content area specialists such as college professors and independent consultants (Darling-Hammond, 2000; Guskey, 1997, 2000; Maldonado, 2002; Plecki, 2000; Rebora, 2004). The Education Commission of the States (1997) found in an analysis of teacher professional development expenditures that 75% of school-district resources allocated for professional development are spent on these types of inservice workshops and conferences.

However, a review of the professional development literature produces substantial criticism of these inservice workshops for failing to have lasting effects and

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[5] Other colorful terms used by education professionals to refer to this practice include: "sit and get," "drill and kill," "pray and spray," "sage on the stage," "chalk and talk," "yell and tell," "the flying consultant."

for leaving teachers feeling unprepared for the classroom (Corcoran, 1995; Darling-Hammond, 2000; Fullan & Steigelbauer, 1991; Guskey, 2000, 2003; Hawley & Valli, 1999; Lewis et al., 1999; Maldonado, 2002; Mullens et al., 1996). Rebora (2004) summarized these sentiments by stating "Experts variously say that [teacher professional development] lacks coherence, that it misconceives of the way adults learn best, and that it fails to appreciate the complexity of teachers' work." Similarly, based on their review of the literature, Hawley and Valli concluded, "Conventional approaches to professional development, such as one-time workshops, typically do not lead to significant change in teaching methodologies" (p. 127)

Despite the fact that these workshops are widely implemented and heavily criticized, empirical studies investigating the impact of workshops on student outcomes are rarely conducted. This shortcoming has been repeatedly noted by influential educational researchers (e.g., Guskey, 1997, 2000; Killion, 1999; Little, Gerritz, Kirst, & Marsh, 1987; Smylie, 1989; Wilson & Berne, 1999;). Wilson and Berne sum up the nature of this problem:

> [A]lthough most workshops are accompanied by evaluations—typically consisting of filling out a form about what was enjoyable—efforts to measure what teachers learned have not been part of typical evaluation fare. Hence...we have little sense—save the collective and negative self-reports of generations of teachers about traditional in-service programs. (p. 174)

Although workshops do not commonly include student outcome-based evaluations, empirical research has been done to investigate the effectiveness of professional development training practices, including those practices used in traditional workshops. Bennett's (1987) systematic integrative review of the literature examined the effectiveness of six mechanisms of professional development delivery: information presentation, theory presentation, demonstration, practice, feedback, and coaching. The effectiveness of these approaches was measured in terms of four teacher characteristics: attitudes, knowledge, skills, and transfer of either attitude, knowledge, or skill from training to the classroom. The meta-analysis included 112 experimental studies relating to the training of teachers located in Educational Resources Information Center (ERIC), Dissertation Abstracts International (DAI), papers presented at the annual meetings of the American Educational Research Association (AERA), and the bibliographies of research articles and books. Studies were included in the review if they met several criteria, including: they were experimental research designs, they provided enough information to calculate an effect size (*ES*), they provided an adequate description of the components of the training, and they used quantitative dependent variables. From this integrative review, Bennett concluded that the inclusion of theory, demonstration, practice, *and* feedback collectively, which comprise the approach of most traditional teacher professional development workshops, does not lead to meaningful transfer of knowledge to teacher classroom behavior ($ES = 0$). However, the addition of follow-up support such as coaching to teacher training clearly resulted in transfer of teacher training to the classroom ($ES = 1.3$).

Several large-scale teacher surveys have also been conducted to gauge teachers' opinions of various professional development experiences. Collectively, these surveys indicate widespread dissatisfaction with the quality and effectiveness of inservice workshops. For this dissertation's review of the literature reporting these surveys, the characteristics of each were analyzed to make a determination of their quality and validity. The characteristics considered were item and response scale construction, survey methodology, and data analysis. Surveys were judged to be of poor, fair, good, or excellent quality based on these characteristics. It is important to recognize that each of these studies consisted of self-report data and were not based on observations of actual classroom behavior and are limited in that respect.

In the first of these, the NCES (2001) conducted a survey of 5,253 full and part-time elementary, middle, and high school teachers in the 50 states and the District of Columbia. The researchers conducting the survey demonstrated careful attention to selecting a sample of teachers who were representative of the population of teachers nationwide and the use of appropriate statistical analyses. The responses to the survey indicated that a majority of the teachers were dissatisfied with the lack of time spent on professional development activities and that necessary follow up was lacking. When presented with a list of content areas, the majority of these teachers said that they had spent less than 8 hours on that activity in the preceding 12 months. Ironically, these teachers also indicated that the extent to which they felt prepared for the classroom varied with the amount of time they spent in professional development activities. Sixty-five percent of the teachers surveyed indicated that their professional development experiences were not adequately followed up with needed additional training: 33% reported that their professional development experience was only followed up to a small extent and 32% reported that it was not followed up at all.

Smylie (1989) found similar results when he mailed a survey to a random sample of 2,530 National Education Association member teachers in which he asked them to rank 14 learning opportunities available to them in terms of effectiveness. Inservice training provided by the school district was at the bottom of this list, receiving the lowest average ranking by the teachers that completed the survey. It should be noted that, even though it was ranked last of 14, inservice training received an average rating of 2.55 on a scale of 1 to 4, where 1 indicated "definitely ineffective," 2 indicated "more ineffective than effective," 3 indicated "more effective than ineffective," and 4 indicated "definitely effective." Thus, although it was ranked last, the teachers' average rating of in-service workshops indicated that it fell somewhere in the middle of the scale. Because the frequencies for each of the individual responses are not given and because the definitional clarity of the response scale is lacking, the results of this survey are difficult to interpret even though the actual methodology was rated as good. The sample of teachers surveyed was random and appeared to be representative of the larger population of teachers nationwide, and appropriate statistical analyses were employed.

The results of these surveys are supported by the results of a 3-year longitudinal study conducted by the U.S. Department of Education (Porter, Garet, Desimone, Yoon, & Birman, 2000). This study purposefully selected a sample of 287 teachers from 30 schools in 10 districts in five states and examined the quality of their professional development experiences and its effects on their teaching practice from 1996 through 1999. Based on the findings of a national dataset used as part of the study, the authors identified six key features of quality professional development: reform versus traditional, duration, collective participation, active learning, coherence, and content focus. Based on these quality characteristics, the study demonstrated that although there was substantial variation in the quality of professional development received by teachers, the typical professional development received by these teachers was not of high quality. Very few of these teachers received the consistent, high-quality professional development experiences that have been identified in the literature as making a positive impact on teachers' instruction. In addition, during the 3 years covered by the longitudinal study, there was little change in teachers' overall teaching practice.

Teacher Professional Development and Teacher Attrition

Inadequate teacher professional development and training also plays a role in teacher attrition. According to the NCTAF (1996), "it's as if we were pouring teachers into a bucket with a fist-sized hole at the bottom" (p. 8). In the 1999-2000 school year, 232,000 new teachers were hired into U.S. schools. The following year 287,000 teachers were lost—*24% more than were hired the year prior* (NCTAF). Newly hired teachers comprise a large proportion of this exodus. According to one study conducted by the North Carolina Department of Public Instruction, 50% of teachers will leave within their first five years on the job (NCTAF). The constant scramble by school administrators to find new, qualified teachers to replace those leaving for other jobs is an increasing drain on the educational system's human and financial resources. Providing better teacher training and professional development may be one solution to the teacher attrition crisis. This notion is supported by a recently conducted survey of beginning teachers in North Carolina that found that teachers' second biggest need in the classrooms is to learn more effective methods of delivering curriculum (unpublished survey cited in Roukema, 2004).

What, then, are the characteristics of *effective* professional development? It has been widely recognized that effective teacher professional development should emphasize "collaborative learning environments, teacher research and inquiry, engagement in practical tasks of instruction and assessment, and consistent feedback and follow-up activities" (Rebora, 2004). Joyce and Showers (1980, 2002), after conducting a meta-analytic review of the professional development literature, concluded that professional development must combine theory, modeling, practice, feedback, and coaching in order to lead to classroom implementation. This sentiment has been repeatedly and widely emphasized (Ball, 1994, 1996; Bull et al., 1994; Loucks-Horsely et al., 1998; US DOE, 1996). For example, the U.S. Department of Education (2000) conducted a longitudinal study indicating that both duration and active learning opportunities are essential to effective professional development.

One example of the empirical evidence supporting the need for follow-up, practice, and support in teacher professional development comes from an experimental study conducted by Crowther and Cannon (2002). In this pretest-posttest design, one group of experienced teachers received a professional development workshop consisting of three weekend sessions. Another group of experienced teachers received a two-week summer workshop *with a follow-up session.* Teachers in the latter group returned to their classrooms after a two-week workshop where they practiced what they had learned before returning for the follow-up session. The authors concluded that it was because of the intensive, sustained nature of the professional development with the follow-up session that these teachers demonstrated significantly higher ratings on a measure of teaching outcome expectancy.

Based in part on studies such as this, researchers and reviewers of the teacher professional development literature have developed various lists of characteristics of effective teacher professional development (e.g., Abdal-Haqq, 1995; Ball, 1994, 1996; Little, 1988; Putnam & Borko, 1997). These lists are derived from a variety of sources including empirical data, large- and small-scale studies, anecdotal case studies, and literature reviews. Guskey (2003) recently analyzed 13 of the most cited of these lists, obtained from the publications of the American Federation of Teachers, Association for Supervision and Curriculum Development, Education Development Center, Educational Research Service, Educational Testing Service, Eisenhower Professional Development Program, National Governor's Association, National Institute for Science Education, National Partnership for Excellence and Accountability in Teaching, National Staff Development Council, and U.S. Department of Education. Based on his analysis, Guskey concluded that the lists have commonalities, but are also somewhat inconsistent. Table 1 presents the 21 characteristics found on all of these lists along with the frequency with which each was cited by the lists.

Although several of the characteristics presented in Table 1 appear on multiple lists, no characteristic appears on *all* of the lists. Many of the characteristics presented

Table 1

Frequency of Characteristics of Effective Teacher Professional Development

	Characteristic/trait	Number of lists citing trait (out of 13)
1	Enhances teachers content and pedagogic knowledge	11
2	Provides sufficient time and other resources	10
3	Promotes collegiality and collaboration	9
4	Includes procedures for evaluation	9
5	Aligns with other reform initiatives	8
6	Models high quality instruction	7
7	Is school or site based	6
8	Builds leadership capacity	6
9	Based on teachers'' identified needs	5
10	Driven by analyses of student learning data	6
11	Focuses on individual and organizational improvement	5
12	Includes follow-up and support	5
13	Is ongoing and job-embedded	4
14	Based on best-available research evidence	3
15	Takes a variety of forms	2
16	Provides opportunities for theoretical understanding	2
17	Helps accommodate diversity and promote equity	3
18	Driven by an image of effective teaching and learning	1
19	Provides for different phases of change	1
20	Promotes continuous inquiry and change	1
21	Involves families and other stakeholders	1

on the list are also inconsistent with the prevalent traditional workshop professional development model. For example, typical in-service workshops do not include follow-up and support (characteristic 12), are seldom ongoing and job embedded (characteristic 13), rarely include sufficient evaluation (characteristic 4), and are not based on teachers' individual identified needs (characteristic 9).

In a review of the K-12 professional development research, Maldonado (2002) identified five key structural characteristics common to effective professional development (Table 2). The first of these characteristics is *prolonged contact*; professional development activities are more likely to be effective when they are sustained and intensive. The second key characteristic is the *model type*. Maldonado and Victorneen's review identified several effective models in the literature. The *training* model places teachers in the role of students: expert trainers model effective teaching for teachers. The *observer/assessment* model provides teachers with the opportunity to be observed and to receive feedback based on those observations.

The *individually guided model* puts teachers in control of their professional development experience by allowing them to have control over their learning experiences. The third structural characteristic is the *availability of follow-up support.* Finally, effective professional development should incorporate continuous evaluation and assessment. In addition to these characteristics, Maldonado's review of the literature found that effective professional development must incorporate

Table 2

Key Structural and Activity Features of Professional Development[a]

Five key structural components	Key activity features
1. Prolonged contact	1. Content-specific material
2. Model type	2. Inquiry-based learning
3. Association of attending educators	3. Collaborative grouping
4. Follow up support	4. Established learning communities
5. Continuous evaluation	

[a]Maldonado (2002)

activities such as content-specific material, inquiry-based learning, collaborative grouping, and established learning communities.

Peer Coaching

One area of research in teacher professional development that has emphasized the characteristics identified as being critical to effective professional development is called *peer coaching* (also referred to in the literature as technical coaching, team coaching, collegial coaching, cognitive coaching, and challenge coaching). In peer coaching, teachers work together in self-directed, collaborative teams to plan instruction, observe each others' teaching practices, and provide feedback to each other. Since the early 1980s, Joyce and Showers have been conducting meta-analyses of the professional development literature in an attempt to identify the characteristics of effective professional development and have found that peer coaching is among the most important of these characteristics (Joyce & Showers, 1981, 1983; Showers, Joyce, Bennett, 1987). The more than 200 studies that currently are included in this meta-analysis were located through a comprehensive search of ERIC, dissertation abstracts, indices of relevant journals, and other indexes for experimental research on staff development, curriculum implementation, training in education, and other related topics. Those experimental studies that provided sufficient information to calculate *ES* were used to associate *ES* to several different training elements. The authors found that when professional development activities incorporated informational or theory-only treatments (lectures, discussion, and readings), demonstration, practice, and feedback, the *ES* in terms of teacher behavior change in the classroom was 0. However, when coaching was added to an initial training experience, in conjunction with theory, demonstration, practice, and feedback, the *ES* was 1.42. Thus, although theory, demonstration, practice and feedback are *necessary* components of effective professional development, without the inclusion of *coaching* elements, they appear to be insufficient.

However, peer coaching may also have its limitations. Teachers *are* likely to benefit from professional development activities that occur in a community of practice, in which teachers support each other in their professional growth. But effective coaching requires effective coaches. A recent study conducted by Everton and Smithey (2000) compared the effectiveness of mentors trained in a formal mentoring program to mentors with no formalized mentoring preparation. Forty-six experienced teachers participated in the research. Half of the teachers were assigned to a treatment condition in which they received extensive and ongoing training on how to be an effective mentor. The other half received no such training. Both groups of teachers then mentored new teachers for several months and were then assessed on their effectiveness as mentors. In addition, student outcomes of the two groups' protégés were compared. The research results showed that protégés of the trained mentors were better able to organize and manage instruction at the beginning of the year and establish more workable classroom routines. The student of the protégés coached by the trained mentors also displayed better classroom behavior and greater engagement than the students of the protégés coached by the untrained mentors. Overall this research appeared to be of high quality. However, there was no indication of the methodology used to assign the 46 teachers to the experimental conditions. This leaves the threat of preexisting differences between the two groups unaddressed.

The need for qualified, trained mentors presents a substantial problem for school districts with very limited professional development resources. The resources required to train teachers to become mentors, to provide substitute teachers in their absences, and to continually evaluate their performance and effectiveness are often unavailable (Everton & Smithey, 2000; Holloway, 2001; Perkins, 1998; Wong & Nicotera, 2003).

Cognitive Apprenticeship

Cognitive psychologists have proposed a constructivist approach to learning called *cognitive apprenticeship* that provides many of the characteristics identified as effective in the teacher professional development reform literature (Collins et al., 1987). This constructivist approach to learning provides a compelling framework and theoretical basis for a much-needed *effective* model of teacher professional development. A cognitive apprenticeship model of teacher professional development would, by definition, incorporate critical components of effective professional development identified in the literature such as modeling, continuous, individualized feedback delivered in context, and the distribution of practice.

Constructivist theories of learning have provided abundant evidence that learners are not passive slates onto which information is written. Rather, learners actively construct their understanding of the world by contrasting new information with their current knowledge (Driscoll, 1994). The implication is that learners are not all experiencing a single reality; each person filters and interprets incoming information through their individual experience and thus constructs their own understanding. Constructivist theory has been deeply influenced by the work of Vygotsky (1978, 1985) and Piaget (1952a, 1952b) and has strong support in the cognitive psychology literature (e.g., Cobb, 1994).

Constructivist approaches to human learning have led to the development of a theory of *cognitive apprenticeship* (Brown, Collins, & Duguid, 1989; Collins et al., 1987). This theory holds that masters of a skill often fail to take into account the implicit processes involved in carrying out complex skills when they are teaching novices. To combat this tendency, cognitive apprenticeships "...are designed, among other things, to bring these tacit processes into the open, where students can observe, enact, and practice them with help from the teacher..." (Collins et al., p. 4). This approach is supported by Bandura's (1997b) theory of modeling, which posits that in order for modeling to be successful, the learner must be attentive, must have access to and retain the information presented, must be motivated to learn, and must be able to accurately reproduce the desired skill.

By using processes such as modeling and coaching, cognitive apprenticeships also support the three stages of skill acquisition described in the expertise literature: the cognitive stage, the associative stage, and the autonomous stage (Anderson, 1983; Fitts & Posner, 1967). In the cognitive stage, learners develop declarative understanding of the skill. In the associative stage, mistakes and misinterpretations learned in the cognitive stage are detected and eliminated while associations between the critical elements involved in the skill are strengthened. Finally, in the autonomous stage, the learner's skill becomes honed and perfected until it is executed at an expert level (Anderson, 2000).

Like traditional apprenticeships, in which the apprentice learns a trade such as tailoring or carpentry by working under a master teacher, cognitive apprenticeships allow the master to model behaviors in a real-world context by means of cognitive modeling (Bandura, 1997a). By listening to the master explain exactly what she is doing and thinking as she models the skill, the apprentice can identify relevant behaviors and develop a conceptual model of the component processes involved. The apprentice then attempts to imitate those behaviors with the master observing and providing coaching. Individualized coaching provides assistance at the most critical level—the skill level just beyond what the teacher could accomplish by his/herself. Vygotsky (1978) referred to this as the Zone of Proximal Development and believed that fostering development within this zone leads to the most rapid development. The coaching process includes additional modeling as necessary, corrective feedback, and reminders, all intended to render the apprentice's performance increasingly similar to that of the master's. As the apprentice becomes more skilled through the repetition of this process, the master "fades" the feedback and instruction they provide until the apprentice is, ideally, independently performing the skill at a level approximating that of the master (Johnson, 1992).

Part of the effectiveness of the cognitive apprenticeship model is attributable to the contextualized learning opportunities it affords. Cognitive scientists maintain that the context in which learning takes place is critical in enabling recall of learned material (e.g., Godden & Baddeley, 1975). Based on findings such as these, Brown and colleagues (1989) argued that cognitive apprenticeships are less effective when skills and concepts are taught independent of their real-world context and situation. As they state, "Situations might be said to co-produce knowledge through activity. Learning and cognition, it is now possible to argue, are fundamentally situated" (Brown et al., p. 32). In cognitive apprenticeships, the activity being taught is modeled in real-world situations.

Another important component of an effective cognitive apprenticeship model is the distribution of practice. The robust psychological literature supporting the benefits of distributed versus massed practice has roots nearly a century deep (e.g., Ebbinghaus, 1913). Today, researchers continue to produce evidence that repeated exposure to information over time, as opposed to all at once, builds relatively stronger memory associations. Combined with learning in context, these strong associations make learned information more accessible in and more adaptable to situations in which it could be used (Dempster, 1988; Dempster & Farris, 1990).

Practical Limitations and Technological Solutions

Taken together, the literature from cognitive psychology suggests that a model of cognitive apprenticeship will be most effective if it incorporates modeling, feedback, distributed practice, and learning in context. The cognitive apprenticeship framework presents a potentially effective model of teacher professional development; however, practical limitations present an intriguing challenge. In order for such a model to be practical in teacher professional development, technology must be utilized to enable consultants to interact with teachers frequently, efficiently, reliably, and with a quality that accommodates the subtle and intricate complexities of human communication.

The use of technology to enable practical models of cognitive apprenticeship was visualized years before technology existed to support it. Researchers have attempted to utilize networking technologies such as the Internet to enable teleapprenticeship learning models (Collins et al., 1987; Levin, Riel, Miyake, & Cohen, 1987; Levin, Waugh, Brown, & Clift, 1994; Thurston, Secaras, & Levin, 1996). Teleapprenticeships are network-based learning frameworks that enable apprenticeship-like environments (Levin et al., 1987, p. 255).

Such teleapprenceships have relied on technologies that *augment* and *support* face-to-face apprenticeships. In order for a technology-enabled model of teacher professional development to be maximally effective and efficient, it may be important to provide communication and interaction between the master and the apprentice that approaches the same quality and richness of face-to-face interactions. Bandura (1997b) argued that an important component of effective modeling is motivation; only a motivated learner will attend to and benefit from modeling. One way to achieve this motivation is to develop a trusting relationship between apprentice and the master, which would be facilitated by a facile, face-to-face communication medium. Video-conferencing technology provides one potential solution to this problem. However, several serious shortcomings of legacy video-conferencing technology limit its effectiveness and practicality in a teacher professional development context.

First, legacy video-conferencing equipment is often installed in a fixed location and is not very portable, making observations, expert modeling of student interaction, and dynamic multigroup interaction in classrooms difficult or impossible. Also, although the quality has improved greatly in recent years, legacy video-conferencing technology transmits fairly poor-quality images and sound that limit the quality of communication. Recent developments in networking and data compression technology have thrust video-conferencing firmly into the 21st century, potentially allowing it to achieve its long-standing promise: providing high-quality, face-to-face communication. In addition to providing a "just like television" quality of service, recent technological developments also address one of the most fundamental characteristics of human communication that has not previously been accounted for by the video-conferencing industry: mutual eye gaze.

Mutual Eye Gaze

Numerous studies have shown that eye gaze (or lack thereof) is associated with perceptions of timidity, embarrassment, shyness, and uncertainty (Edelmann & Hampson, 1979). Eye gaze has also been shown to be important in establishing relationships (Argyle, 1969; Argyle & Dean, 1965); monitoring, regulating, and expressing during communication (Kendon, 1967); assertiveness (Serber, 1972); and credibility (Aguinis et al., 1998; Droney & Brooks, 1993; Kleinke et al., 1975; Wheeler et al., 1979).

One research study typical of those investigating the role of eye gaze in human interaction was conducted by Argyle, Lefebvre, and Cook (1975). In this experiment, 40 college students interacted with 10 confederates displaying various eye gaze patterns to determine how these patterns affected social perceptions. The confederates were trained to interact with the participants while displaying five different gaze patterns: looking while talking, looking while listening, normal gaze, and nearly zero gaze. This high-quality, well-controlled experiment controlled for the potential effects of gender, order of conditions, gaze patterns, and conversation topic. The research findings showed that participants rated confederates more favorably when eye gaze was continuously maintained than when it was not maintained at all or at lower levels.

Other studies have demonstrated important links between mutual eye gaze and various aspects of learning, such as information recall. For example, Sherwood (1987) enlisted the participation of 146 college students to experimentally investigate the facilitative effects of eye gaze upon learning. In a series of five experiments, the researcher demonstrated that students' that received eye gaze during an oral presentation demonstrated significantly better recall than students receiving the same information without eye gaze. Otteson and Otteson (1980) found similar results in a study involving younger learners. In two experiments using a repeated-measures design, 46 primary-school students were read children's stories under two conditions: presence versus absence of teacher's gaze. The researchers found a significant positive relationship between teacher's gaze and students' ability to recall the information presented in the stories. These studies indicate that eye gaze not only plays a significant role in social interaction, but also in the recall of information and learning.

However, legacy video-conferencing systems have not enabled mutual eye gaze (McNelley, 2000, 2005; Weinstein & Lichtman, 2005). Video-conferencing systems typically place the cameras in the two-way video systems some distance away from the image of the person with which one is communicating (e.g., on the top of the monitor). With these systems, if the user looks into the eyes of the person with whom he or she is communicating, that person is always looking away because he or she is looking at the image of the other person and *not into the camera*. This distance between the camera and the image of the person's eyes is known as *parallax* (see Figure 1).

In a recent study of the effects of parallax on the quality of video-conferencing, McNelley (2005) asked 43 business professionals to experience two video-conferencing systems: one with parallax and one without parallax. During a first trial, participants were asked to compare the images produced by the two systems and to select the image in which an interviewer (i.e., the researcher) was looking at them "in the eye." In a

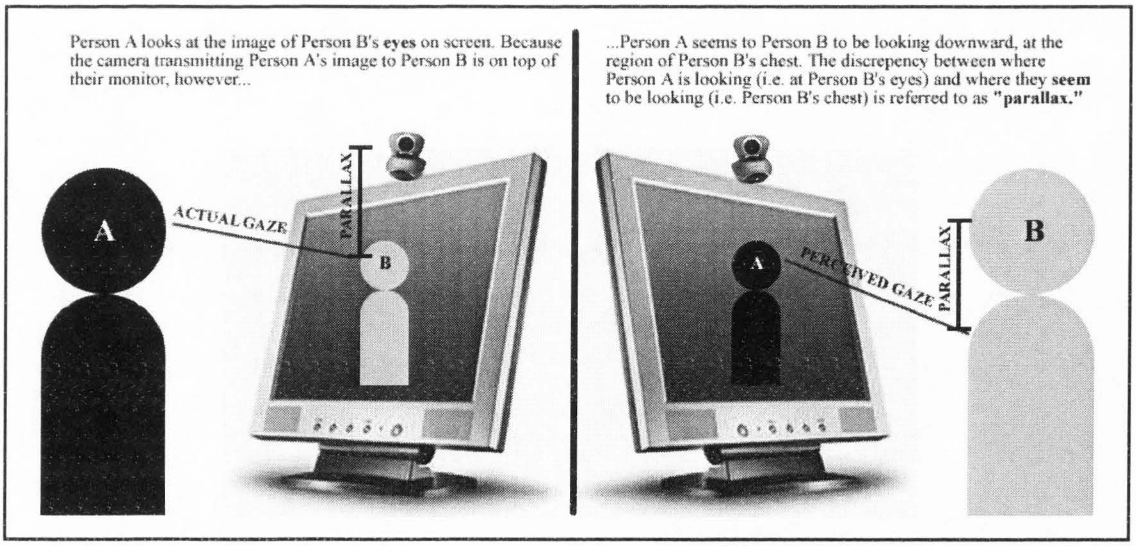

Figure 1. Parallax—typical in legacy videoconferencing.

second trial, the same participants were asked which image they would prefer to see if they were to use the systems to communicate regularly. Ninety-three percent of the participants were able to correctly identify the image that did not have parallax. In addition, 93% of the participants indicated a preference for the video-conferencing system that did not have parallax. When explaining their preference for the system without parallax, participants responded with comments such as "it feels more intense," "it really feels like he is looking at me," and "feels more immersive and engaging" even though they were "blind" to the independent variable under investigation. The research design description does not indicate that it was well-controlled for potentially extraneous factors. For example, it is not clear if participation in trial one influenced participants' responses obtained from trial two. In addition, there is no indication that the researcher (with whom the participants communicated via the systems) was blind to the experimental condition and to what degree this lack of blindness may have been a factor in the results.

A more carefully controlled experiment, also conducted by McNelley (2000), found similar results. In this study, 50 graduate students participated in a structured interview via desktop videoconferencing. Interviews were conducted by a research assistant that was kept blind as to the experimental conditions. In addition, participants were kept blind to the nature of the independent variable under investigation in the research. In part one of the research, the participants was randomly assigned to two groups. One group was interviewed using a video conferencing system that enabled mutual eye gaze and the other group was interviewed using a system with parallax.

Both groups were asked to rate their level of satisfaction with the videoconferencing and their perceptions of the interviewer. The results showed no practical or statistically significant difference in the participants' ratings of satisfaction or in their perceptions of the interviewer. In part two of the research, all participants were exposed to a side-by side comparison of two video conferencing systems: one that enabled mutual eye gaze and one with parallax. They were then asked to select the image they most preferred and to provide reasons for their decision. In this side-by-side comparison 88% of the 50 participants indicated a preference for the eye-contact videoconferencing. Although the participants were not informed that the research was about eye contact, 69% of those participants indicated that they preferred the eye-contact system and identified that the reason for their preference was the presence of eye contact.

In sum, video-conferencing technology that does not account for the parallax problem may present a barrier when attempting to use it to enable a cognitive apprenticeship model of teacher professional development. Given the importance of eye contact in human communication, and research results suggesting dissatisfaction with parallax in legacy videoconferencing, any technology developed to augment teacher professional development should not impede mutual eye gaze. In order for technology to be effective in this context, it must be flexible, portable, reliable, simple, and most importantly, impart the sense that the consultant is *actually present* when they are not: *telepresence* (Rose & Clarke, 1995).

In summary, our educational system can benefit from improved professional development delivery methods. The literature on peer coaching and cognitive apprenticeship suggest that one of the most effective means of delivering professional development is via mentoring or coaching. The resource requirements of training, evaluating and enabling peer coaches to work with teachers are often beyond the capabilities of school districts. Telepresence technology can be used to enable highly skilled, expert mentors to work with teachers in a cognitive apprenticeship model of professional development (TEAM-PD).

Hypotheses

Prior to the beginning of this research, several hypotheses were set forth. It was hypothesized that, as a result of their use of the TEAM-PD model, teachers and students participating in the experimental condition would demonstrate greater gains in learning and achievement than teachers and students in the comparison condition. Because teachers in the experimental condition received mentor-delivered follow-up training that was individualized, distributed over time, and in context, these teachers were predicted to enact those instructional strategies more successfully than teachers in the comparison group. As a result of this greater enactment, these teachers' student were also predicted to demonstrate a greater mastery of the relevant mathematical concepts. Specifically, it was hypothesized that, as a result of receiving TEAM-PD, teachers and students in the experimental condition would demonstrate the following:

1. The teachers will demonstrate concerns (as measured by the Stage of Concern instrument, described below) about the innovation consistent with those of experienced users whereas the comparison group teachers will demonstrate concerns

consistent with relatively inexperienced users. Specifically, it is hypothesized that the teachers in the comparison group will *not* progress past the "Personal" stage by the end of the study and that teachers in the experimental group will progress to the "Refocusing" stage by the end of the study.

2. The teachers will demonstrate more advanced usage patterns (as measured by the Levels of Use instrument, described below) than those in the comparison group. Specifically, it is hypothesized that the teachers in the comparison group will *not* progress past Level III by the end of the study, whereas teachers in the experimental group will have progressed to Level VI by the end of the study.

3. The teachers' classroom behavior and classroom artifacts (e.g., assignments, lesson plans) will reflect a change in instructional approach that emphasizes Rachel McAnallen's instructional strategies. Teachers in the comparison group will demonstrate few if any of these changes.

4. The teachers' scores on a content knowledge test of mathematics concepts will be statistically significantly higher than those of teachers in the comparison group.

5. The students' scores on a content knowledge test of mathematics concepts will be statistically significantly higher than those of students in the comparison group.

CHAPTER III

METHOD

Purpose

The primary objective of this research was to evaluate the effectiveness of TEAM-PD by comparing it to a traditional, inservice workshop model of teacher professional development in terms of impact on teacher behavior and student outcomes. The experimental and comparison groups of fifth- and sixth-grade teachers participated in the same traditional, inservice workshop in which they were presented with a mathematics instructional strategy. The experimental group of teachers then participated in the TEAM-PD model whereas the comparison group of teachers received only a follow-up inservice workshop covering the same instructional strategy presented during the first workshop. A mixed-methods research design was used to compare the two groups in terms of student performance and teacher behavior relevant to the mathematics instructional strategy.

Research Design

In this exploratory study, a mixed methods design was used to compare a new form of teacher professional development (TEAM-PD) to a traditional inservice experience. Teachers in the comparison group received mathematics instructional strategies through a traditional inservice workshop and teachers in the experimental group were delivered mathematics instructional strategies via TEAM-PD. Dependent variables included the degree to which teachers enacted the instructional strategies in their classroom instruction as well as student and teacher mastery of mathematical content.

Qualitative and quantitative data collected from a variety of sources were triangulated to provide a comprehensive description of the experimental and comparison conditions and the differences between their outcomes (Johnson & Onwuegbuzie, 2004). The nature of this research design limits the ability to make *causal* interpretations from the resulting data (Campbell & Stanley, 1963). However, the findings illustrate trends and patterns that provide justification for future causal research. Quantitative findings will be judged to be statistically significant if their associated p values are less than .05.

Participants

The participants in the study consisted of two small groups of elementary school teachers assigned to an experimental and a comparison condition. The teachers were selected as intact groups from two separate schools in the same school district. The focus of this research was to explore the potential effectiveness of TEAM-PD rather than providing evidence for the generalizability of the research findings to some larger population of teachers. The selection of participants for this research reflects this purpose.

A total of 11 teachers participated in this research. The experimental group consisted of six self-contained[6] fifth- and sixth-grade teachers at an elementary school

[6] Self-contained teachers are those that teach all subjects to their students including mathematics.

located in northern Utah. The comparison group of teachers consisted of five self-contained fifth- and sixth-grade teachers at a school in the same school district and located within a few miles of the experimental school. The comparison school was selected because of its similarities to the experimental school (e.g., student-teacher ratio, student socioeconomic status, student and teacher ethnicities, and geographical location). Table 3 illustrates the similarity of these two schools in terms of these characteristics. The characteristics of the individual teachers comprising the experimental and comparison group are presented in Table 4.

Table 3

Experimental and Comparison School Demographics

Variable	Experimental school	Comparison school
Total # of students	564	465
% male	53	53
% female	47	47
Total classroom teachers	23	21
Teacher student ratio	1:25	1:22
Ethnicity		
% American Indian	1	-
% Asian	1	-
% Hispanic	6	2
% Black	1	-
% White	91	98
% Eligible for free lunch	17	16
% Eligible for reduced lunch	12	13
% of Migrant students enrolled	-	-

Table 4

Experimental and Comparison Teacher Characteristics

Variable	Experimental teachers	Comparison teachers
Female	4	3
Male	2	2
American Indian	-	-
Asian	-	-
Hispanic	-	-
Black	-	-
White	6	5

All data were collected, stored, and have been reported in such a way as to protect the confidentiality of the participating schools, administrators, teachers, and students. Student data were also only reported in aggregate form and are not attributed to specific classes. Teacher data were, by their very nature, not anonymous (i.e., interviews and observations), but were kept confidential and were reported only in aggregate form. Paper-based data were stored in locked filing cabinets and electronic data were transmitted over secure private networks and stored in password-protected computers. Due to the use of the highest levels of encryption available and its unique, private nature (as opposed to the public Internet), the security level of the network used in this study exceeded that required by the United States Federal government. All figures in this dissertation that depict teachers or students have been altered as necessary to protect their identities.

Telepresence Equipment

A comprehensive description of the telepresence technology that enabled TEAM-PD is beyond the scope of this dissertation. However, an overview of the primary components is necessary to adequately explain the research methodology. See Appendix A for a more thorough description and additional photographs.

The telepresence equipment used to enable TEAM-PD was fundamentally, both in purpose and in architecture—videoconferencing equipment. The equipment used in this research differs from legacy videoconferencing in that it uses very high-quality, life-size imagery, and supported mutual eye gaze. The resulting level of videoconferencing is referred to as "telepresence" in the videoconferencing industry (Weinstein & Lichtman, 2005). Three pieces of telepresence equipment were used to enable TEAM-PD: the Telepresence Center, the Virtual Observer, and the Virtual Teacher.

The purpose of the Telepresence Center (TC) was to enable teachers to conference with Rachel to discuss their implementation of her instructional strategies. With Ms. McAnallen sitting in front of a TC unit at her home in Denver and a teacher sitting in front of a TC unit at Pioneer Elementary, teachers received corrective and directive feedback, suggestions, and instructional advice from McAnallen as if they were in the same room sitting across a table from each other (see Figure 2). Document cameras allowed those communicating to share paperwork or mathematical manipulatives.

Figure 2. A teacher meets with Rachel McAnallen via the telepresence center.

The Virtual Teacher (VT) allowed McAnallen to model her instructional strategies for the experimental group teachers in their classrooms. Rachel appeared as a "holographic"[7] image displayed so that she appeared to be standing behind a podium at the front of the classroom (see Figure 3). A camera and microphone built into the wheeled podium allowed her to clearly see and hear the classroom as if she were actually standing in it. As with the TC, Rachel was able to display manipulatives through the VT document camera.

The Virtual Observer (VO) allowed McAnallen to capture video of teachers from the experimental group as they implemented the instructional strategies they had previously learned. The VO is a wheeled locker containing an auto-tracking camera (see Figure 4). The camera automatically followed the teachers around the classroom it

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[7] The term holographic emerged as a colloquial, descriptive term for this image during the research project. By definition, a *true* hologram is a three-dimensional image. The image on the VT is two-dimensional and only holographic-looking because of its "ghostly" nature.

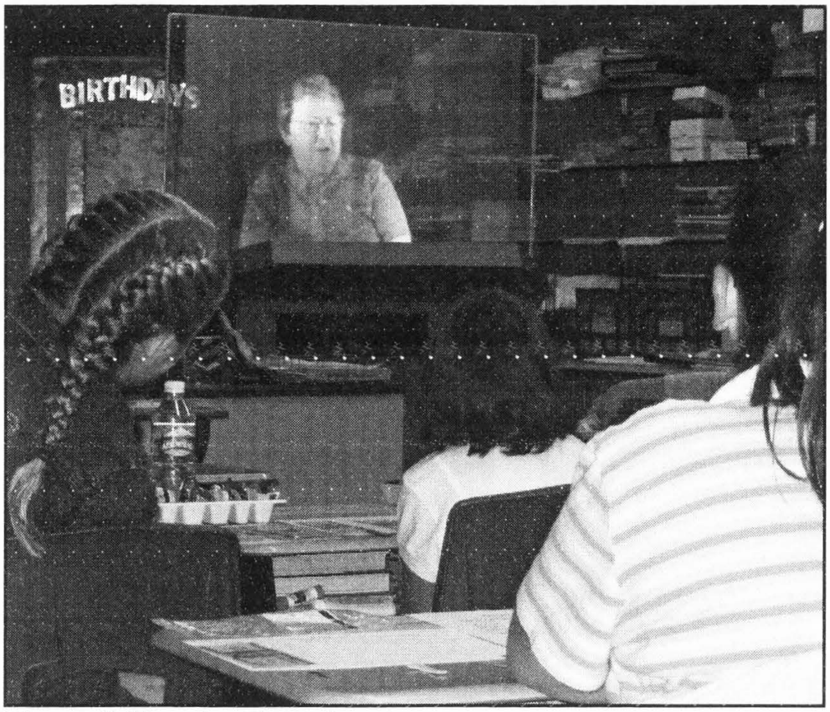

Figure 3. The virtual teacher.

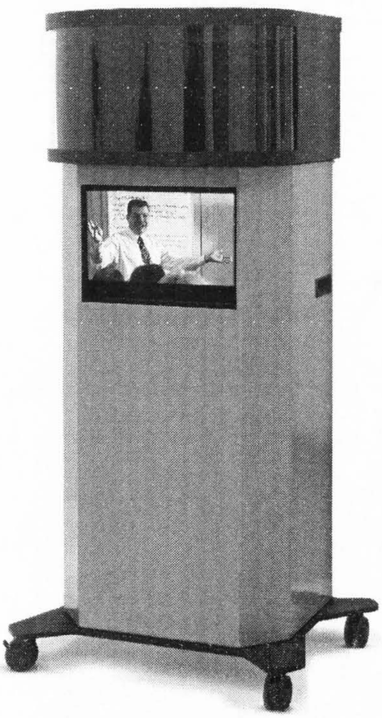

Figure 4. The virtual observer (photo courtesy of Digital Video Enterprises, Inc.).

recorded the teaching session onto a DVD. Ms. McAnallen later watched each of the DVDs.

Rachel McAnallen's Instructional Strategies

Because of the integral role that Rachel McAnallen played in the implementation of the independent variable (i.e., TEAM-PD) in this research methodology, it is important to briefly describe her background and expertise as a mathematics educator. Rachel (known to her students as "Ms. Math") has worked professionally as an educator for 45 years. During this tenure she has served as a teacher, principal, associate principal, department head, school board member, and teacher trainer. She has obtained a B.S. and M.S. degrees including coursework in mathematics, education, and doctoral work in administration. At 70 years of age, Rachel now travels extensively around the country and the world delivering teacher training, workshops, and keynote addresses. Rachel's full curriculum vitae can be found in Appendix H.

The mathematics instructional strategies presented by Rachel McAnallen to the experimental and comparison groups throughout this research are collectively called *Dancing Decimals.* The primary dependent variable in this research was the degree to which, and the fidelity with which, the teachers in both groups enacted these strategies. *Dancing Decimals* is a mathematics instructional strategy developed by McAnallen that presents students with a collection of manipulatives (e.g., foam numbers, bogus paper money, various die) used to play a mathematical game (see Figure 5).

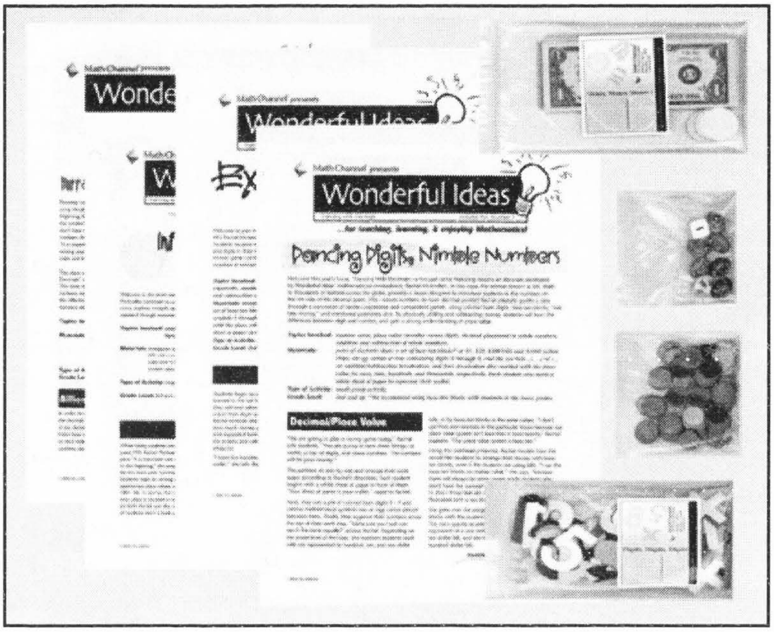

Figure 5. The *Dancing Decimals* instructional materials and manipulatives.

The basic mechanics of this game require students to manipulate the money in their "wallets" (represented by a piece of paper divided into place value columns: hundreds, tens, ones, tenths, hundredths, and thousandths) by following a teacher's instruction or by working together with other students in pairs. After mastering the mechanics of the game through teacher-led activities, students are encouraged to play cooperative and competitive games using various die (e.g., addition/subtraction hexahedron, place-value decahedron) to manipulate the monetary values in their wallets. As an instructional strategy, this game provides a foundation for the teacher to cover a wide variety of mathematical concepts and can therefore be used throughout an entire school year. Because the game allows for student-directed play, it also presents opportunities for the teacher to deliver individualized instruction to students with specific needs. For example, while the majority of a class is playing the game and thereby practicing some newly learned content knowledge, the teacher can deliver individualized instruction to a small group of students. Students eventually take the knowledge gained from playing the game with the manipulatives and apply it using pencil and paper. Table 5 presents a list of the topics covered by this instructional strategy.

Dependent Measures

This multimethods research design utilized several qualitative and quantitative dependent measures to evaluate the impact of TEAM-PD. Two of the quantitative dependent measures were obtained from Concerns Based Adoption Model: the Stages of Concern and the Levels of Use. Together, these instruments provide an assessment of the degree to which, and the fidelity with which, teachers in the experimental and

Table 5

Mathematical Concepts Presented in Rachel McAnallen's Dancing Decimals Instructional Strategy

#	Topic
1	Number sense
2	Place value
3	Numbers versus digits
4	Decimal placement in whole numbers
5	Addition and subtraction of whole numbers
6	Speaking and writing in different forms of expression
7	Prime factorization
8	Exponents
9	Addition and subtraction of decimal fractions
10	Reading amd expressing tenths, hundredths, thousandths in different forms
11	Justification of operations using different forms of numerical expression

comparison groups were implementing McAnallen's instructional strategies. The final qualitative instrument was a mathematics test designed to evaluate teachers' and students' mastery of the content presented by McAnallen. Qualitative data were collected primarily via video recordings of telepresence interactions between McAnallen and teachers and students in the experimental group. All of these dependent measures are described in detail in the following sections.

The concerns-based adoption model. Two instruments that were used to compare the outcomes of TEAM-PD to that of the traditional workshop were part of the Concerns-Based Adoption Model (CBAM) developed by the Southwest Educational Development Laboratory (Hall, George, & Rutherford, 1998; Loucks et al., 1998). This model describes the adoption of an educational innovation (in the case of this research, teaching mathematics via Rachel McAnallen's *Dancing Decimals*) as a characteristic sequence of concerns experienced as an innovation is implemented. According to the instrument's authors, "concerns" are a composite of feelings, preoccupation, thought, and consideration given to the innovation. Thus, CBAM hypothesizes two dimensions along which individuals grow as they become more familiar with and sophisticated in using innovations: *Stages of Concern About the Innovation* and *Levels of Use of the Innovation* (Loucks et al.). The data collected from the experimental and comparison groups using these instruments provide a dependent measure of the degree to which these two groups of teachers have enacted McAnallen's instructional strategies.

Stages of Concern About the Innovation. A central dimension of CBAM is the Stages of Concern about the Innovation (SoC). This dimension describes the feelings, thoughts, and information needs of the innovation "adopter." The developers of the SoC have demonstrated that, as people adopt new innovations into their professional activities, they typically progress through a series of concerns.

The 35-item SoC questionnaire (see Appendix B) was developed to assess the seven hypothesized SoC (Hall et al., 1998). As users of an innovation become more familiar with an innovation their concerns change. Early concerns typically deal with the self (e.g., ability of the user to meet the demands of the innovation), then become task-related (e.g., focusing on the processes and tasks required to use the innovation), and finally shift towards the potential impact of the innovation (e.g., evaluation of student outcomes). High scores on the SoC instrument indicate how advanced users are in their use of the innovation. These seven SoC stages were identified using a multistage development process including Q-sort and factor analytic techniques (Hall et al.) and are presented and described in Appendix C. It is important to emphasize that the innovation about which the teachers responded on the SoC questionnaire was defined as "Rachel McAnallen's teaching strategies" in the SoC instructions.

The SoC assumes that, as they become more familiar with an innovation, users' concerns about it change. The early concerns of the *nonuser* typically deal with the self (stages 0 through 2). The concerns of the *inexperienced user* become task-related (stage 3) and finally shift towards the potential impact of the innovation (stages 4 though 6) as the user becomes *experienced.* Figure 6 depicts this growth over time as a progressive wave that moves from left to right as the user more fully adopts the innovation into their professional practice and becomes more experienced.

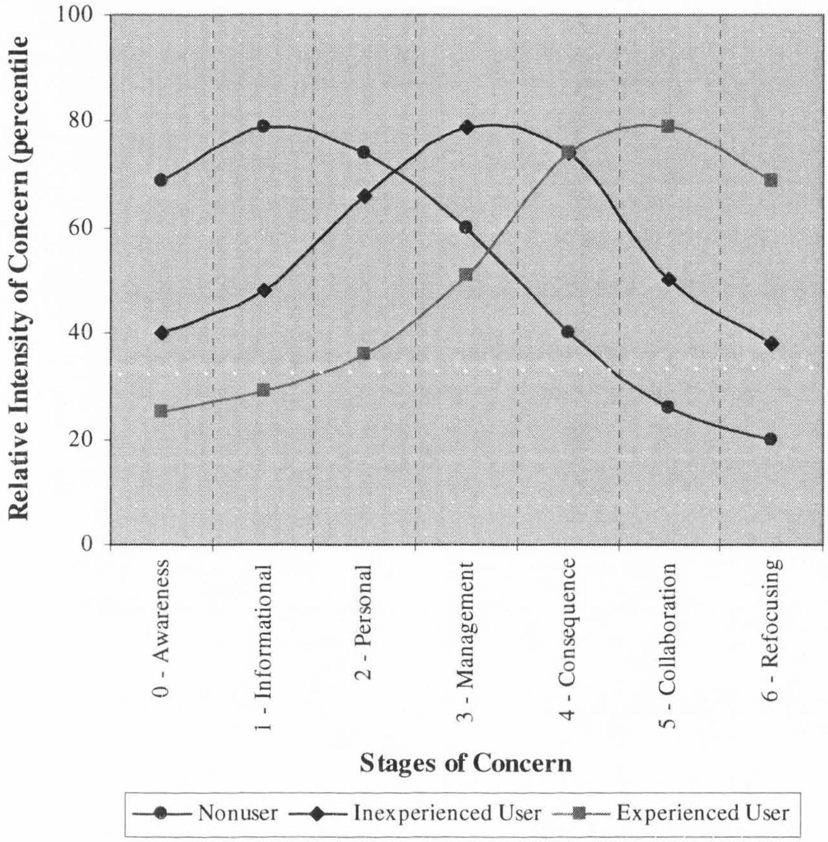

Figure 6. The hypothetical development of the Stages of Concern.

The authors of the SoC instrument (Loucks et al., 1998) identify different ways in which to interpret SoC scores to determine if these hypothesized shifts are occurring. The first of these methods was to simply identify individuals' "peak" (highest) stage scores relative to their other stage scores. The same analysis was conducted for the *average* SoC scores of each group. These peak scores indicate the areas of greatest relative concern and are directly related to the stage definitions, presented in Appendix C. The second analysis employed used graphs of individual and group SoC scores to create profiles that illustrate overall patterns of use. These analyses are applied to the first and second SoC measurements below.

An assessment of the validity and reliability of the scores derived from the SoC questionnaire provided good evidence that the instrument consistently measures what it is intended to measure. Test-retest reliability (Pearson *r)* for the seven scales of the instrument has been found to range from .65 to .86. Test of the internal reliability found that alpha coefficients (KR-20) for each of the subscales ranged from .64 to .83. Investigations of the validity of the instrument were conducted by determining if the correlations among the seven instrument scales followed a pattern that would be predicted by the underlying theory (Hall et al., 1998). In addition, evidence for the validity of the SoC questionnaire for measuring concerns has been demonstrated by comparing scores to in-depth interview data (Hall et al.). Intraclass correlation coefficients were used to estimate the reliability of these two assessments; six out of seven showed acceptable levels of reliability.

In the current research, the SoC questionnaire was administered to the experimental and comparison groups via the Internet on the World Wide Web. Although research participants completed the questionnaire by clicking "radio buttons" as opposed to circling their answers on a piece of paper, the web-based version of the instrument was (in every way possible) consistent with the original instrument. A growing body of literature provides substantial evidence that data collected from Web-based instrument and their paper-based counterparts are psychometrically equivalent (e.g., Buchanan, 2003; Buchanan & Smith, 1999; Farvolden, Mcbride, Bagby, & Ravitz, 2003; Lin et al., 2003; Riva, Teruzzi, & Anolli, 2003). The web-based SoC questionnaire was administered to the experimental and comparison groups both at the beginning and at the end of the implementation of the research study so that changes in their scores over time could be observed.

Data collected from the SoC instrument were automatically entered to a database from which the responses were summed by subscales, converted to percentiles based on conversion charts provided by the instrument's authors, and graphed into SoC Profiles. A SoC profile was generated for each individual research participant. In addition, data from each group were averaged together to produced SoC *group* profiles. Each of these profiles was then interpreted based on the procedures outlined by the authors of the instrument.

Levels of use of the innovation. The second central dimension of CBAM is the Levels of Use of the Innovation (LoU). Whereas the SoC is cognition focused (e.g., thoughts, feelings), the LoU focuses on the *behaviors* of individuals as they become more familiar with and more skilled in using an educational innovation. Essentially, the LoU measures the extent to which a teacher has implemented the instructional strategies in his classroom. LoU ratings of innovation users are achieved through individual, focused interviews conducted by trained interviewers (see Appendix D for a list of interview questions). Each of the eight Levels of Use identified by this instrument focuses on behavior that is characteristic of the innovation user at a particular stage of use development. Each level of use is attached to a *category* that represents central functions that users of the innovation carry out when they are using the innovation. The category descriptions at each level typify the behaviors in which users at that level are engaged. The categories, Levels of Use, and the rating sheet into which these rating are recorded are presented in Appendix E and definitions are found in Appendix F. After establishing an LoU for each category on the LoU, the trained interviewer then determined a *gestalt* or global picture of the LoU of each user.

Each of the experimental and comparison group teachers received LoU ratings based on structured interviews conducted by Debbie Hobbs, Ph.D. Doctor Hobbs was trained and certified by the authors of the instrument, the Southwest Educational Development Laboratory. After conducting the interviews, Dr. Hobbs independently gave each teacher an overall LoU rating. The principal investigator then used Dr. Hobbs' interview notes to independently give each teacher an overall LoU rating. Cronbach's alpha was calculated as an indicator of inter-rater reliability.

Logistics prevented Dr. Hobbs from being blind to the experimental condition. That is, the interviewer was aware of the group assignment of each teacher during the interviews. Each interview lasted approximately 35 minutes and resulted in an overall rating of the teacher's LoU of the *Dancing Decimals* educational innovation. These interviews were conducted both at the beginning and the end of the research study so that changes in individuals' scores over time could be observed. Based on the information provided during the interviews, the interviewer established an LoU rating for each category as well as an overall LoU rating. The average overall LoU ratings were then used to compare the experimental and comparison groups.

In addition to LoU scores, the interviews also provide an opportunity to collect qualitative data from teachers to illustrate conclusions. The comments made by the teachers were written down during the interview. These data were then used to help triangulate and illustrate research findings.

Math Content Pre- and Posttests

The teachers in the experimental and comparison conditions and their students were administered pre- and posttests to assess their understanding of the mathematical concepts associated with Rachel McAnallen's instructional strategies. This 5-item test was created by Rachel McAnallen to assess understanding of a variety of concepts; including those listed in Table 5. The test required respondents to generate the answers—it was not multiple choice. These tests were administered via pencil and paper, graded manually, and entered into a database for analysis. After the administration of these tests, Cronbach's alpha will be computed for the students' and teachers' tests individually to determine the degree to which the items on these tests represents some underlying dimension of mathematics knowledge, The complete content test is presented in Appendix G.

Video Data

Interactions between Rachel McAnallen and the students and teachers (e.g., modeling, conferencing) at the experimental school were digitally recorded. A 1.0 gigabyte (GB) Memory Stick Pro was used in conjunction with the videoconferencing codecs in the VT and TC to record the images and sounds passing through the telepresence equipment. The resulting MP4 files displayed Rachel McAnallen's image as well as a "picture-within-a-picture" image of the teacher or classroom with which she was interacting. This configuration captured the entirety of the interactions by showing what was seen and heard at both "ends" of the communication. Figure 7 shows a screenshot of Rachel conferencing in private with a teacher and Figure 8 shows a screenshot of Rachel modeling instructional practice for a teacher in his classroom.[8] Approximately 30 hours of video data were recorded and transferred to a laptop computer with a Universal Serial Bus (USB) memory stick reader. Each MP4 video clip was labeled, categorized, and stored in digital folders to be analyzed. Analysis of the video data was initiated by watching all of the video and taking notes to document salient themes, patterns, and phenomena. This analysis resulted in two separate outputs:

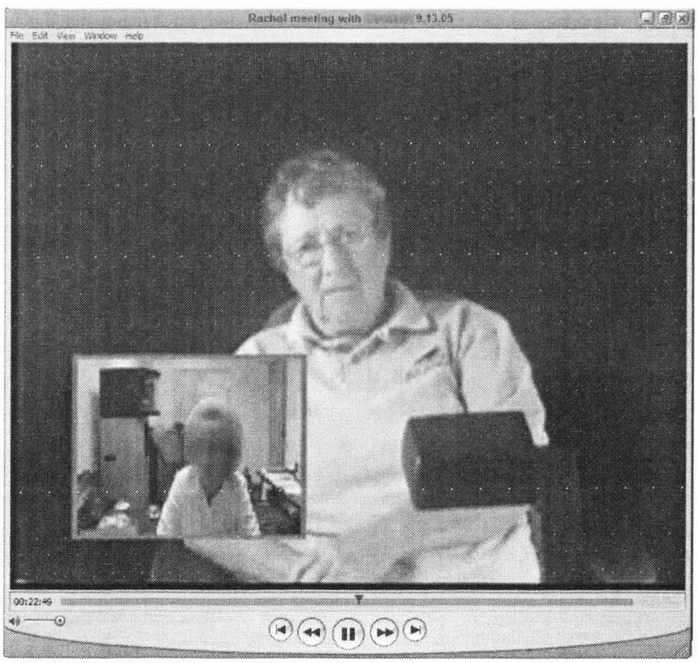

Figure 7. Screenshot of video data captured while Rachel McAnallen met with an experimental group teacher.

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[8] These figures have been digitally manipulated to conceal the identity of the teachers and students pictured.

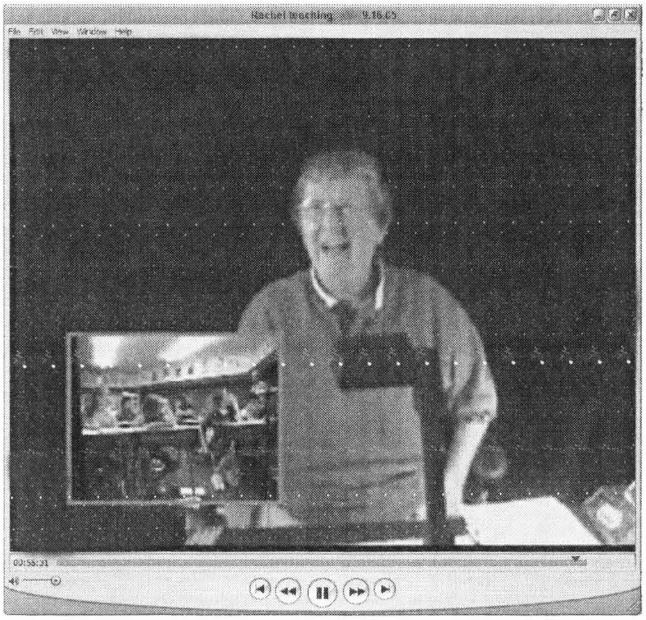

Figure 8. Screenshot of video data captured while Rachel McAnallen modeled instructional strategies in an experimental group classroom.

(a) content coding, and (b) thematic transcripts. After watching the video, it was concluded that only video of Rachel conferencing with the teachers was appropriate for analysis using *content coding*. However, *all* of the video captured (e.g., Rachel modeling for teachers, observing teachers) was appropriate for analysis using the *thematic transcripts* process.

After all of the video data had been viewed and notes were taken documenting themes and patterns, these notes were then used to develop a coding scheme that allowed for the categorization of every second of video of Rachel conferencing with the experimental group teachers. The coding scheme was developed using a method referred to in the qualitative analysis literature as open coding. Open coding is a grounded theory approach in which each element (i.e., a second of video) is placed into a particular phenomena category (Glaser & Strauss, 1967). The categories—consisting of code labels, code definitions, and code examples—were developed based on a theory that evolved inductively during the coding process. The initially developed coding scheme was used in short pilot tests during which sample video was categorized. These pilot tests resulted in refinements to the coding labels and definitions until a satisfactory scheme was developed.

There were three primary purposes for this analysis process. First, it was important to observe that the experimental group actually received the appropriate independent variable: mentoring in mathematical instructional strategies. Too often, the effects of educational innovations are misinterpreted because of failure of researchers to verify the implementation of the independent variable (for a discussion, see Shaver, 1983). Second, the distribution of time spent discussing various categories of information may shed light upon important characteristics of telepresence-enabled cognitive apprenticeship. For example, it was important to determine to what degree technology issues (e.g., problems) detracted from conversation about instructional practice. Finally, the distribution of time spent discussing various categories was intended to triangulate with data collected via other methods to develop a more complete picture of the effects of TEAM-PD.

Each video code fell within two broad categories: *instructional content* and *noninstructional content*. Instructional content refers to conversation that was, in any way, related to instruction, mathematics or otherwise (e.g., behavior management strategies, instructional philosophy). Noninstructional content refers to conversation that did not relate to instruction in any way (e.g., casual banter, discussion about telepresence technology). Within each of these broad categories are several specific categorization codes. Their labels, definitions, and examples are presented in Table 6. The transcript examples presented in this table are actual excerpts from the video transcripts that exemplify the particular codes.

After finalizing the coding scheme, every second of the video data recorded of Rachel interacting with teachers in conferences (approximately nine hours) was categorized according to this scheme. Figures 7 and 8 show a counter clock in the Apple Quicktime movie player (lower left-hand corner) that was used to record the length of time spent discussing topics within each of the conversation codes. These coded time values were then summed by category to provide information regarding the distribution of time during these conferences.

Thematic Transcripts

Throughout the process of repeatedly viewing and coding video data, patterns and themes emerged regarding the nature of the cognitive apprenticeship process. The themes were developed using a method referred to as open coding (Glaser & Strauss, 1967). Evidence for these themes consisted of behavior and communication and was documented through note taking. As these notes developed they were modified, refined, and distilled into several salient themes. Prototypical excerpts were taken verbatim from video transcripts to illustrate these themes.

Procedures

Figure 9 illustrates the procedural method of the research. This diagram and the

Table 6

Video Coding Scheme

Code label	Code definition	Code example (R=Rachel, T=Teacher)
Noninstructional codes		
Banter	Social conversation not related to instructional practice	*(discussing hurricane Katrina)* R: I know that the people in Utah will have done something... T: We don't get real good press. R: No, you don't... we only hear about the extremists. We never hear about what service you have. So I'm spreading the word. T: Actually the church had trucks there, going out of Salt Lake to take supplies in 20 minutes after it happened... We have a huge welfare center and they took sleeping bags and water and food...
Professional relationship building	Casual conversation that develops the professional relationship. Discussion about professional practice and experience that build the professional relationship by sharing and validating experiences, establishing credibility, reassurance	R: You're old enough now that you probably could be parent of some of (your students') parents. T: Yeah, easy. R: The cool thing about getting older as a teacher is that you gain credibility. So that when you have a conference with the parents of kids that are still (counting on their fingers), you can say 'I'd like you to practice this (technique) with your child.' That's what I love about being old.
Technology	Conversation related to the technology, such as technology problems,	R: What did you think of the class yesterday... T: Technically [regarding]... the use of the equipment, we had a little problem with that, as you know. There was a delay [with the camera] R: That's a difficulty with new technology...
Logistical	Conversation related to logistical issues such as the scheduling of cognitive apprenticeship activities.	R: I did work with your kids, didn't I? On Monday? T: Yes. You worked with my class. R: And then you got observed by the "Mr. Robot" behind you, right?

(*table continues*)

Code label	Code definition	Code example (R=Rachel, T=Teacher)
Instructional codes		
Behavior management	Conversation related to the behavior of children, behavioral management strategies, time organization / allocation	R: Have you ever talked to (your students) about behavior standards in your classroom? T: Yes, we did that the first week... see, I teach with (another teacher)... she's really tough with them. The first two weeks we (taught) together to establish that we're both teachers. Then she took last week and this is my first solo week. This is the week I really need to let (the students) *know*. R: They are *testing* you. T: They are. R: ...when I go in and model teach... the first thing out of my mouth tells them who I am.
Content knowledge / instruction	Conversation about teachers' content knowledge or lack thereof and/or Rachel delivering content-related instruction to teachers	R: Did you take algebra...or did algebra take you? T: ummm... yeah (laughs). This is taking me back to junior high! R: Now, this is called the numerical coefficient. Two, three and four coincide with two, three and four up here (refers to arithmetic on document camera). The digits are the coefficients. Do you see? It's holistic. T: Yes.
Instructional technique / assessment	Conversion about specific instructional strategies, lesson plans, success and failures at delivering instruction, assessment of progress towards delivering instruction to students	R: Why don't you tell me what happened when you taught the lesson? Tell me some of your concerns. T1: One of my concerns was that I didn't know the terminology well enough. T2: That was mine, too. We just don't feel real comfortable with the terminology because we've never used that before.
Instructional philosophy	Conversation about broad educational or teaching practice issues and/or philosophy	T1: Did you know it's hard for teachers to teach differently than they have for 25 years? R: Of course. T1: That's hard. Teachers basically don't want to stretch out and do something different, you know, they want to teach like they already have because it's comfortable. It's hard to go out of the comfort zone. R: I think that's the human condition T2: I think the only way we'll ever change is if we're forced to do it. I think this (kind of professional development) is good because it forces us to do something different than we've been doing for a long time.

(*table continues*)

Code label	Code definition	Code example (R=Rachel, T=Teacher)
Student Assessment / Performance	Conversation related to student assessment and performance	T: We get to the tens and they start subtracting and there's three or four of them that can't do it. They can't... subtract the numbers... R: They don't know how to take 9 out of 10. T: That's right. They didn't know how to do that. A lot of them did, but there were two or three groups that couldn't do that.
Procedural Knowledge	Conversation about teachers' knowledge of the structure of the lessons / procedures / procedural documentation (e.g., Rachel's booklets), materials and mechanics and their use	T: What do you suggest for division—how to teach that? R: This was also in the kit...here (shows an instructional booklet on the document camera). This first lesson is for younger grades, but I carry this the whole way through. Here's place value versus face value... this is basically what I did yesterday with your kids...the difference between a number and a digit. T: Yeah, that was very good. R: And here's adding without carrying (refers to instructional materials under document camera)

following overview are intended to give the reader an understanding of the overall research process.

The research began when both the experimental and comparison groups of teachers participated in a workshop administered by Rachel McAnallen in January of 2005. This two-day workshop was held in a conference room at the school district's central office. McAnallen, a renowned math expert, presented approximately 80 teachers from throughout the school district an instructional strategy designed to teach students a wide variety of mathematical concepts. As the literature on teacher professional development illustrates, this workshop format, in which a large number of teachers are delivered large amounts of content in a brief period of time, is typical of traditional teacher professional development. Each teacher participating in the workshop was given the materials necessary for them to implement the instructional

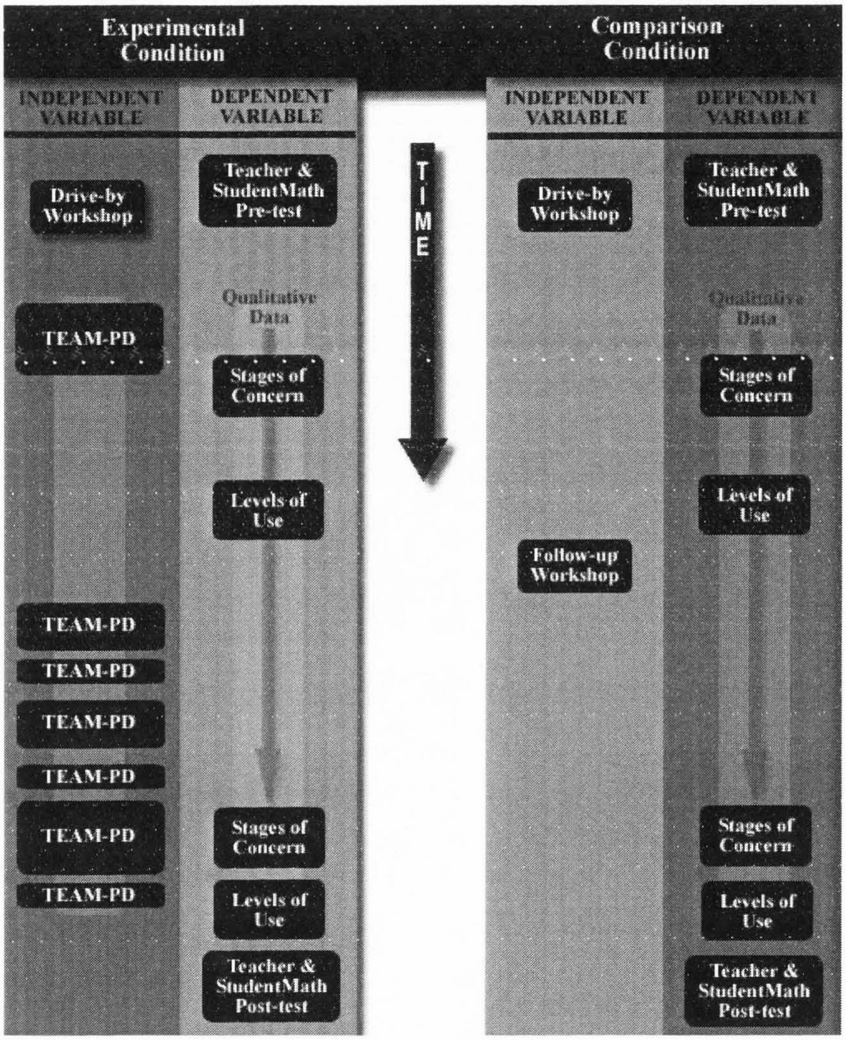

Figure 9. Overview of research procedures.

strategy in their classrooms. Immediately prior to this workshop, both the experimental and control group teachers were administered the math content pretest, constructed by Rachel for the purpose of assessing their mathematics content knowledge as related to the workshop material.

As is typical of traditional professional development, the teachers in the comparison and the experimental groups did not *initially* receive any post-workshop information, support, or follow up from Ms. McAnallen. The teachers returned to their classrooms with the implicit understanding that they were to implement the instructional strategy into their mathematics lessons.

Beginning in May of 2005, teachers in the experimental condition began implementing TEAM-PD by using telepresence equipment to work with Rachel at their school in the cognitive apprenticeship model. Before the end of the 2004-2005 school year in June, Rachel was able to model her instructional strategies in each of the 5th and 6th grade teachers' classrooms. On the first day of September in the 2005-2006 school year, Rachel picked up where she had left off with TEAM-PD, continuing to work with the experimental teachers in individualized mentoring relationships. Throughout the entire post-workshop phase of the research, the *only* contact that Rachel had with the experimental teachers was via telepresence. From September through November of the 2005-2006 school year, Rachel modeled her instructional strategies in each of the experimental teachers' classrooms, observed them as they attempted to implement the strategies, and then conferred with them about the process. The total amount of time, per teacher, spent on these activities throughout the research was approximately eight hours. This time was distributed in small "blocks" ranging from 30 to 90 minutes.

Throughout the time period that the experimental group was implementing the TEAM-PD model, qualitative and quantitative data relating to the implementation and outcomes of the instructional strategies presented at the workshop were collected. The qualitative data consisted of observations and recordings of all the interactions between Rachel and the teachers. Shortly after the experimental group began implementing the

TEAM-PD model, both the experimental and comparison groups were administered the SoC questionnaire. After several more weeks, both groups of teachers completed LoU interviews.

One potential threat to the experimental design resulted from the relative amount of time teachers in the experimental and comparison groups spent interacting with Rachel. By definition, the TEAM-PD model required more time spent between the "master" and "apprentice" than is typical in the traditional workshop model. Because additional time is an integral part of TEAM-PD the two variables are fundamentally confounded in a research design. A research design that failed to control for the additional time factor would be unable to distinguish effects due to the additional time from effects due to the other characteristics of TEAM-PD. Therefore, to control for the additional amount of contact time that the experimental teachers spent with Rachel, the teachers in the comparison group participated in a follow-up workshop in early October of 2005. Although the format of this workshop was essentially the same as the initial workshop (e.g., one-to-many, nonindividualized instruction), Rachel expanded upon the instructional strategy presented at the first workshop and provided technical support and follow up. This additional experience provided the comparison group with a total of 12 hours of interaction with Rachel, approximately four more hours per teacher than the experimental group spent interacting with Rachel.

The final data collection for the research occurred in November of 2005. Teachers in both groups were administered a second SoC questionnaire, a second LoU interview, and a mathematics content posttest.

CHAPTER IV

RESULTS

This research utilized several dependent measures—including the SoC instrument, the LoU instrument, video-recorded observations, and student and teacher mathematics content tests. After briefly describing the results related specifically to the deployment of telepresence equipment, this chapter will be organized around the results derived from each of these instruments. The chapter will conclude by presenting results that were unexpected but are nonetheless important to the research.

Telepresence Equipment Deployment

Although much of the technical information related to the development and deployment of the telepresence equipment is beyond the scope of this dissertation, there are some relevant results to report. First, over the course of the several months that the equipment was in use there, were surprisingly few technical problems associated with the equipment. The few problems that were encountered were easily and quickly solved (e.g., replacing a microphone battery) and never prevented planned activities from taking place. Second, the equipment required little or no operation by teachers; teachers used the equipment simply as a "window" to access Rachel McAnallen and interacted with it as such. They were never required to directly control the equipment and were therefore spared any associated training. As the researcher, I facilitated all of the TEAM-PD interactions by operating the equipment. Similarly, Rachel McAnallen experienced no serious technical problems with her telepresence equipment. Although

Rachel began this study with no prior knowledge of videoconferencing technology, she quickly learned how to operate the equipment and to solve minor technical issues at her location in Denver. Third, there were few logistical difficulties associated with the use of the equipment. The problems that were encountered (e.g., locating nearby electrical outlets, moving heavy equipment around the school) were easily addressed.

Stages of Concern

Recall from the Methods chapter that the SoC describes the feelings, thoughts, and information needs of the innovation "adopter" with Stages ranging from 0 (nonuser) through 6 (experienced user; see Appendix C for a complete definition of each SoC.

The SoC questionnaire was administered to the experimental and comparison teachers on two occasions: once at the beginning of the research and once at the end (see Figure 9). It was expected that both the comparison and the experimental groups' SoC scores would resemble those of the *nonuser* (e.g., high early-stage concerns) at the first measurement of the SoC. As the implementation of the TEAM-PD model progressed, it was hypothesized that the SoC scores of the comparison group would shift slightly towards that of the *inexperienced user* (e.g., high middle-stage concerns), while the SoC scores of the experimental group would shift towards that of the *experienced user* (e.g., high late-stage concerns).

Stages of Concern Measurement #1

The first measurement of the SoC was administered in the early stages of the research (see Figure 9). At the time of this measurement, both groups had participated in the first traditional workshop and the experimental group had begun implementation of TEAM-PD. The implementation at this time consisted of one classroom modeling session by McAnallen for each teacher in the experimental group. Table 7 presents the experimental and comparison individual and group percentile SoC scores. This table shows that both groups' average peak SoC scores were at the *awareness* stage (81^{st} percentile for the experimental group and 96^{th} percentile for the comparison group). Peak scores are the stage scores on which the teachers scores the highest. However, the average *awareness* score for the comparison group is 15 percentile points higher than

Table 7

Experimental and Comparison Group Stages of Concern Percentile Scores

	Stages of concern percentile scores						
Group/participant #	0	1	2	3	4	5	6
Experimental							
1	86 [a]	80	83	30	30	44	65
2	91 [a]	80	70	90	33	28	34
3	46	43	45	77 [a]	27	40	60
4	72 [a]	54	70	15	21	22	30
5	89	88	91	92 [a]	66	76	69
6	99 [a]	90	92	99 [a]	75	72	97
Means	81	73	75	67	42	47	59
Comparison							
1	99 [a]	57	63	56	13	55	73
2	99 [a]	51	85	65	9	76	69
3	89	96 [a]	59	80	4	76	57
4	98 [a]	88	83	97	21	93	97
Means	96 [a]	73	73	75	12	75	74

[a] = highest SoC score.

that of the experimental group, indicating their lower interest in the innovation. High scores on this stage indicate that a user has not progressed past the initial need for information gathering and is aware of, but generally disinterested in the innovation. In addition, three of the experimental group teachers' peak scores were at the *management* SoC. Taken together, these peak SoC data are consistent with the experimental group beginning to shift away from the pattern of the *nonuser* and towards the pattern of the *inexperienced* user. However, an analysis of the SoC data is incomplete without first considering the SoC profiles.

Profile interpretation of SoC scores utilizes line graphs of the scores of individual teachers and group average scores. These scores are interpreted collectively to obtain an overall picture, or *gestalt,* of innovation use development. Figures 10 and 11 present the SoC profiles for each of the experimental and comparison group teachers, respectively (see Appendix C for descriptions of subscales).

These two figures show that within each group there was substantial variability between individual teachers' scores at several stages. For example, two of the experimental group teachers scored very low on the *management* stage whereas the other four teachers scored very high, resulting in a 70 percentile within group range on that stage. Other stage scores, such as the comparison group's *consequence* scores, showed little variability. One way to enable a meaningful comparison between these two groups' scores is to examine the groups' *average* profiles. However, because of small sample sizes, the averages of each SoC can be heavily influenced by the scores of

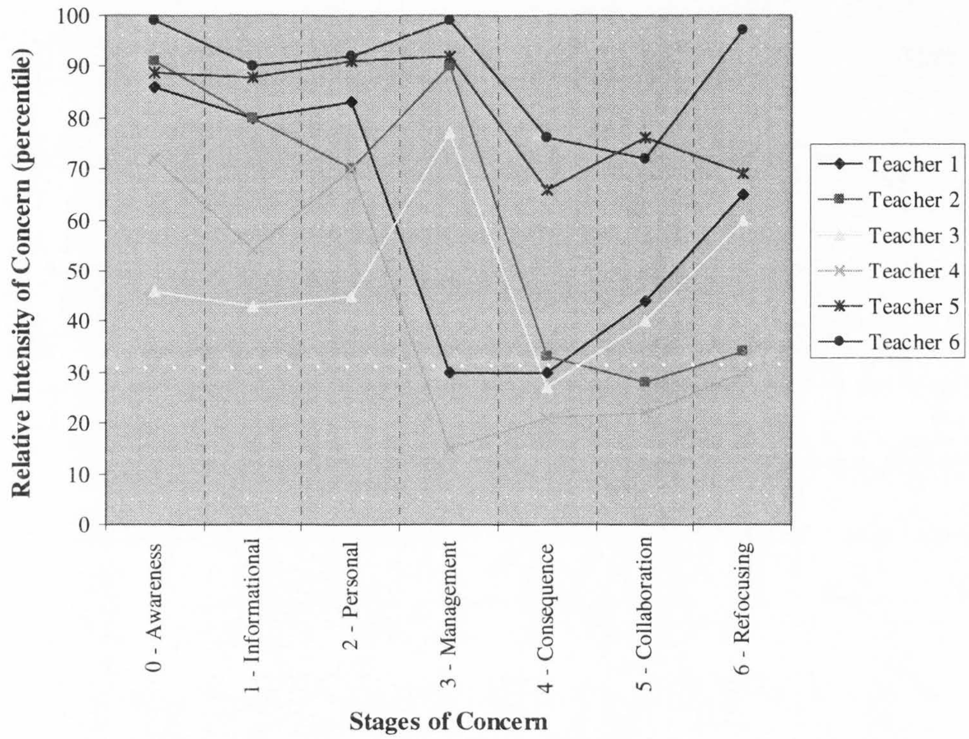

Figure 10. Experimental teacher group SoC profiles, Measurement #1.

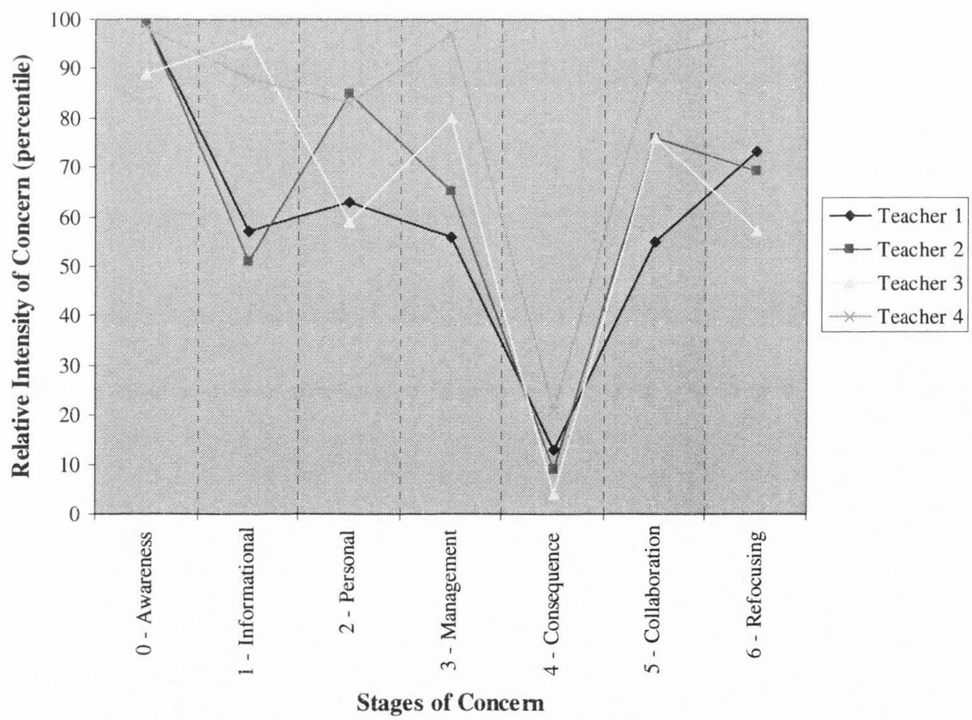

Figure 11. Comparison teacher group SoC profiles, Measurement #1.

one individual. Figure 12 presents the experimental and comparison groups' average SoC profiles.

The experimental group's averaged SoC score profile is generally consistent with that of the *nonuser*, where the first four stage scores are higher than the last three stage scores. The average stage two score for this group is slightly higher than that of stage one, a profile characteristic referred to by the SoC authors as a "negative one/two split" (Hall et al., 1998, p. 36). These users' personal concerns (stage two) regarding the use of the innovation are greater than their concerns related to learning more about the substantive nature of the innovation (stage one). Essentially, this profile pattern

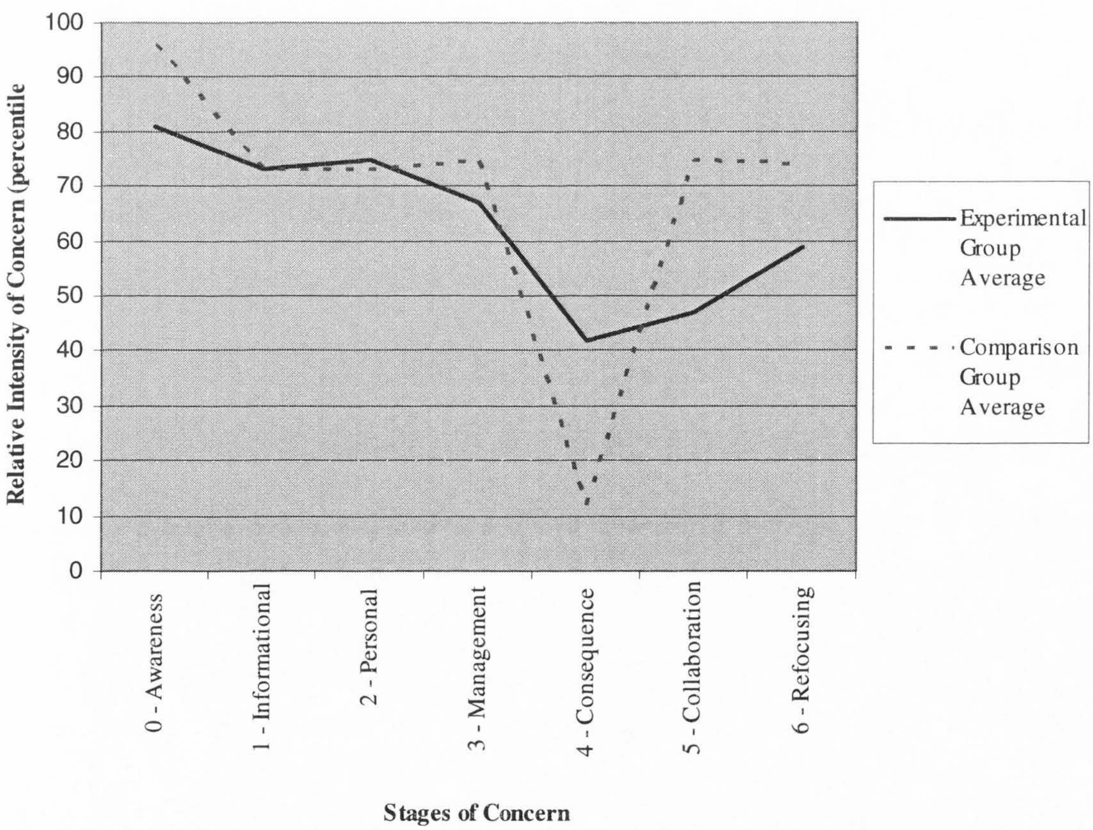

Figure 12. Experimental and comparison group average SoC profiles, Measurement #1.

indicates a substantial degree of doubt and resistance towards the innovation. The "tail-up" pattern found in the experimental groups' relatively higher stage six concern indicates further skepticism about the innovation. This profile characteristic indicates that, in addition to being doubtful about the proposed innovation, the users have clear alternatives in mind that they believe will be more effective. In sum, after Rachel McAnallen's workshop presentation and a brief exposure to TEAM-PD, the experimental group teachers' average scores on the SoC indicate that they are skeptical of the implementation of the innovation and that they have alternative innovations in mind they believe would be more effective.

The comparison group's averaged SoC score profile is generally the same as that of the experimental group—a "negative one-two split with tailing up." Much like the experimental group's profile, the comparison group's profile indicates skepticism and doubt about the proposed innovation and that these teachers had clear ideas about other innovations that they believed would be more effective. However, the comparison group's profile is more pronounced than that of the experimental group in several ways. Their 15 percentile point-higher stage zero concern indicates substantially *less* knowledge of, attention to, or interest in the innovation than that of the experimental group. The authors of the SoC instrument indicate that a difference in scores as small as 7 to 10 percentile points can represent a significant difference (Hall et al., 1998, p. 40). The dramatic drop in stage four indicates that the users were unable to consider the impact of the innovation on their students until their concerns and doubts about the nature of the innovation, how it would affect them individually, and how it would be managed were addressed. The severe "tail-up" in the comparison group's averaged profile suggests that these teachers are very resistant to the innovation, particularly because they are aware of approaches that they believe have more merit. In sum, although both the experimental and comparison groups' profiles are indicative of *nonuse*, the comparison group's profile is consistent with significantly more resistance to the adoption of Rachel McAnallen's instructional strategies.

Stages of Concern Measurement #2

The second measurement of the SoC was administered at the end of the study (see Figure 9). Table 8 presents the experimental and comparison individual and group percentile SoC scores. This table shows that both groups' average peak SoC scores were at the *awareness* stage (80^{th} percentile for the comparison group and 78^{th} percentile for the experimental group). Recall that SoC Measurement #1 was consistent with a development of the experimental groups' concerns about the instructional strategy (presumably due to TEAM-PD), relative to that of the comparison group. SoC Measurement #2 *did not* support or indicate the continuation of this trend. A peak analysis suggests that both groups appeared to be most concerned with the personal management, and implementation issues related to the instructional strategies (i.e., the concerns of a nonuser). A profile comparison was also conducted to determine if a different analysis perspective would support or conflict with the peak analysis.

As with the SoC Measurement #1, *Profile interpretation* was used to analyze the SoC Measurement #2 data. This analysis utilizes graphs of the SoC scores of individual teachers and group average scores. Figures 13 and 14 present the SoC profiles for each

Table 8

Experimental and Comparison Group Stages of Concern Percentile Scores

	Stages of concern percentile scores						
Group/participant #	0	1	2	3	4	5	6
Experimental							
1	53	63	76 [a]	18	30	19	65
2	86 [a]	84	52	23	13	16	65
3	72 [a]	12	5	15	3	5	34
4	84	99 [a]	80	77	21	68	65
5	89 [a]	88	55	80	21	25	42
6	84 [a]	51	55	65	11	14	47
Means	78 [a]						
Comparison							
1	72 [a]	48	5	34	5	28	38
2	91	93	99 [a]	99 [a]	21	22	20
3	93	95	94	97 [a]	27	22	77
4	89	93 [a]	89	83	48	91	77
5	53 [a]	43	21	15	3	12	6
Means	80 [a]						

[a] = highest SoC score.

of the experimental and comparison group teachers, respectively. These two figures illustrate a tremendous degree of within-group variability. For example, in the comparison group one teacher's percentile score was 99 and another's was 5. Given the small sample size, this variability makes group interpretation, and therefore determining effects of the independent variable, extremely difficult. A comparison between these two groups' average SoC scores was also conducted, although the within group variability makes requires cautious interpretation. Figure 15 presents the experimental and comparison groups' average SoC profiles.

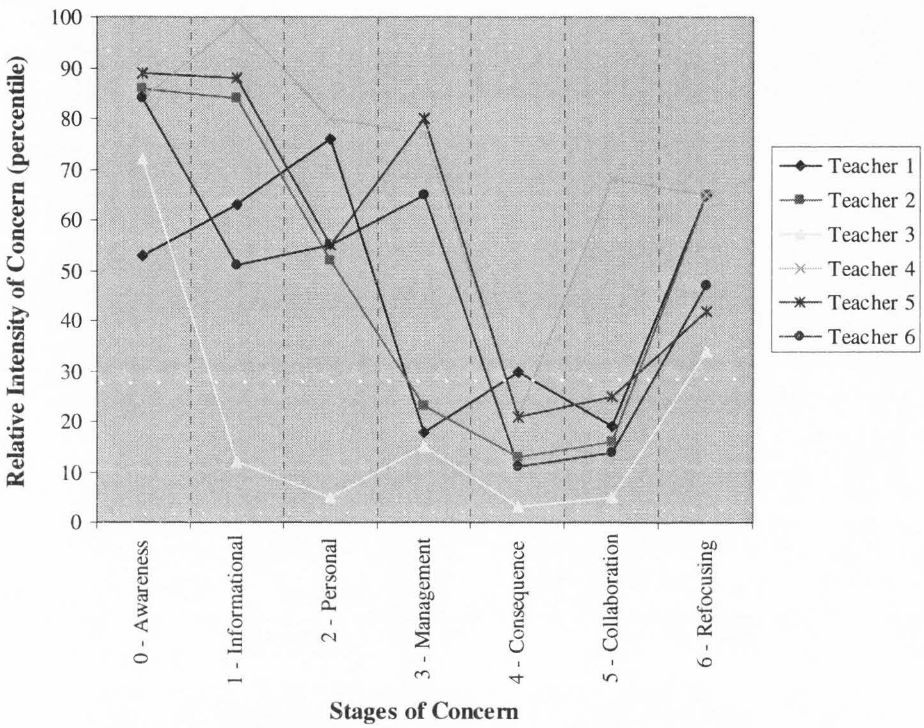

Figure 13. Experimental teacher group SoC profiles, Measurement #2.

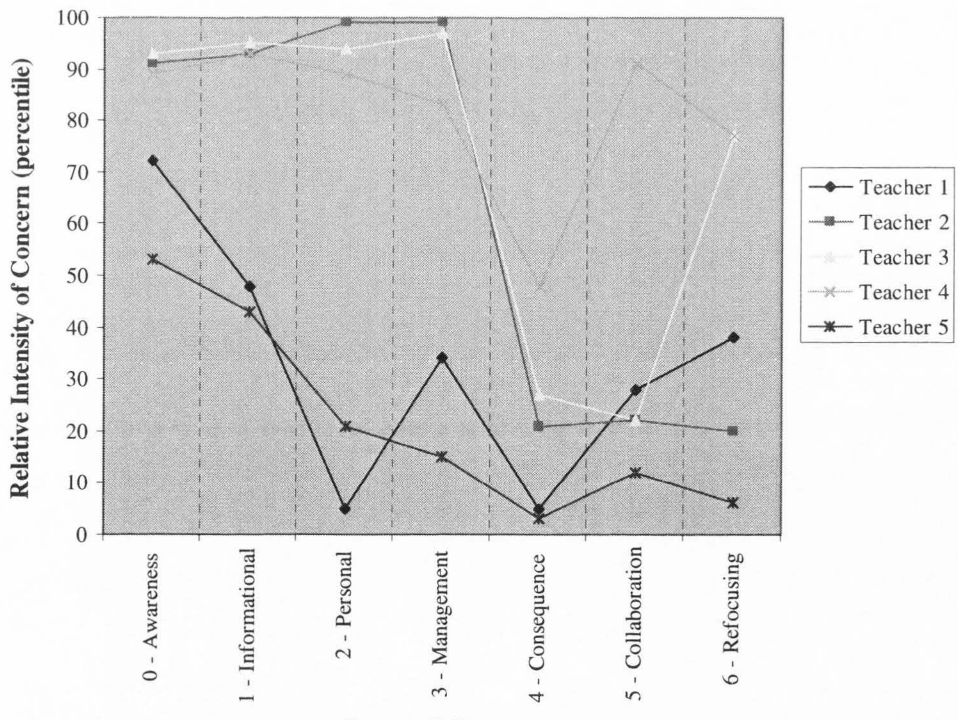

Figure 14. Comparison teacher group SoC profiles, Measurement #2.

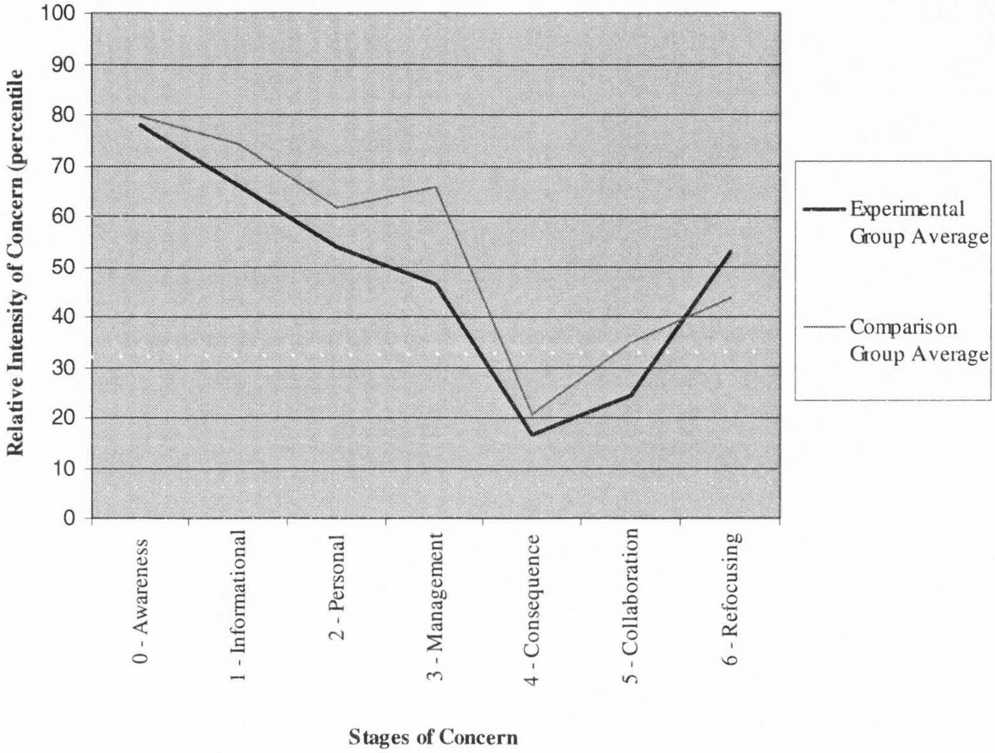

Figure 15. Experimental and comparison group averaged SoC profiles, Measurement #2.

Even more so than with SoC Measurement #1, the two groups' averaged Measurement #2 SoC score profiles represent a similar pattern of concerns. According to the authors of the SoC instrument's guidelines for profile interpretation, these are the profiles of inexperienced users with a "tailing-up" (Hall et al., 1998, p. 40). This indicates that these users were beginning to address issues related to the efficiency, organization, management, scheduling, and time demands of McAnallen's instructional strategies, but their concerns had not yet progressed to the later stages.

Both groups' profiles are different in important ways from their Measurement #1 scores, indicating developmental trends in their concerns about the adoption of

McAnallen's instructional strategies. One difference is that the "negative one/two split" observed in both groups' Measurement #1 scores is no longer apparent. Recall that this profile type is indicated by stage two concerns higher than stage one concerns. The fact that this pattern was not apparent in the second measurement suggests that both groups of teachers have fewer personal concerns regarding their adoption of the instructional strategies. Having reduced their concerns regarding the demands of the adoption on them personally, the teachers can now address their concerns regarding its management and consequences.

There is also another notable difference *between* the experimental and comparison groups' Measurement #2 SoC scores. The comparison group's averaged stage two profile score (60^{th} percentile) was 20 percentile points higher than the experimental group's (40^{th} percentile). This suggests that the comparison group's concerns regarding McAnallen's instructional strategies may be progressing faster than those of the experimental group. Again, making valid interpretations of between-group differences is difficult when within-groups variability is so high.

In sum, both the experimental and comparison groups' Measurement #2 profiles correspond to that of *inexperienced users,* indicating a development in concerns since Measurement #1. This development was modest but suggests that both groups of teachers' concerns were shifting from self-focused to task oriented. The comparison group's profile also indicated a growth pattern slightly more progressed than that of the experimental group. Given the substantial variability and the small number of teachers in each group, all conclusions from these data are very tentative.

Levels of Use

Recall from the Methods chapter that the LoU focuses on the *behaviors* of individuals as they become more familiar with and more skilled in using an educational innovation. LoU ratings of the teachers were obtained through individual, focused interviews. Each of the eight LoU identified by this instrument focuses on behavior that is characteristic of the innovation user at a particular stage of development (Appendix F provides a complete list of the levels).

LoU interviews were conducted with experimental and comparison group teachers on two occasions: once at the beginning of the research and once at the end. The first assessment occurred in early September, 2005. At this time, McAnallen had modeled instructional strategies for each of the experimental group teachers one time. Hypothesis #2 predicted that teachers in *both* groups would be identified as having a low overall level of use initially (e.g., Levels 0 through I). The experimental group would then progress to Level VI by the end of the study, whereas the comparison group would not progress past Level III.

Levels of Use Measurement #1

Table 9 shows the overall LoU ratings for the experimental and the comparison groups as measured on the first occasion. Five of the six teachers in the experimental group were rated as Level III—mechanical use. This indicates that these teachers were using McAnallen's instructional strategies, but focusing most of their efforts on the day-to-day use of the innovation while spending little time on reflection, and collaboration.

Table 9

Experimental and Comparison Groups' Overall LoU Ratings—Measurement #1

	Overall level of use							
Group/participant #	0	I	II	III	IVa	IVb	V	VI
Experimental group								
1				X				
2				X				
3				X				
4				X				
5				X				
6		X						
Comparison group								
1	X							
2	X							
3	X							
4		X						
5	X							

In the comparison group, four of the five teachers were rated as Level I—orientation. This indicates that these teachers were still in the process of acquiring information about McAnallen's instructional strategies and exploring the demands it would place upon them.

Levels of Use Measurement #2

At the end of the study, teachers in both groups were administered a second LoU interview (see Table 10). As predicted, the LoU scores of the comparison group teachers did show *some* development in their LoU of McAnallen's instructional strategies but, as predicted, none of them moved beyond Level III. Four of the

Table 10

Experimental and Comparison Groups' Overall LoU Ratings—Measurement #2

	Overall level of use							
Group/participant #	0	I	II	III	IVa	IVb	V	VI
Experimental group								
1				X				
2					X			
3					X			
4						X		
5				X				
6			X					
Comparison group								
1			X					
2				X				
3				X				
4				X				
5				X				

comparison group teachers received a Level III score and one teacher received a Level II score. Contrary to the prediction of Hypothesis #2, three of the experimental group teachers' LoU scores were a Level III and one was a Level II. However, the other experimental teachers' scores were consistent with the prediction of the hypothesis. Two of the experimental group teachers progressed to Level IVa—routine. These scores indicate that these two teachers' use of the innovation had stabilized and that few changes were being made in their enactment of the instructional strategies. One experimental group teacher reached a Level IVb—refinement. This indicated that this teacher was varying the use of McAnallen's instructional strategies to increase their impact on her students. The customized variations were based on both short- and long-term consequences for the students.

Cronbach's alpha was calculated as an indicator of the inter-rater reliability of the LoU scores obtained by the principal investigator and Dr. Hobbs. This intraclass correlation (.84) indicated a very high level of consistency in the ratings.

The results of the LoU measurements are somewhat mixed. Although the experimental group demonstrated slightly higher LoU scores overall, the comparison group's scores indicated a faster progression in their concerns patterns. The lack of clarity in these results may be attributable to the small number of teachers in each group and the short implementation period.

Interview Data

In addition to providing quantitative scores, the LoU interviews also provided qualitative data in the form of teachers' responses to interview questions. These responses were collected and sorted into two relevant themes. These data are helpful to illustrate and triangulate conclusions reached by analyzing data collected from other sources. The themes that emerged from these data include technology concerns, and comments related to various aspects of cognitive apprenticeship.

As reported at the beginning of this chapter, the deployment and use of the telepresence equipment was not problematic. However, this fact does not address the perceptions of the teachers who used the equipment. Although the experience provided by telepresence is better than that of traditional videoconferencing, the teachers noted that it is still not quite the same as being there "live." The teachers were generally impressed with the equipment; as one teacher said, "The technology is excellent."

However, providing classroom instruction as a projected image does have its limitations. The teachers participating in TEAM-PD made several comments that indicate that telepresence is, to some degree, lacking compared to actual presence. One teacher noted, "Sometimes the picture (of Rachel) is 'off,' but it cleans up." This comment refers to a technical issue regarding the document camera used by Rachel. When she used the document camera, the image of her would diminish in quality. Although a solution for this problem was located, it was not corrected during the research. Other comments by the teachers during the interviews acknowledged the limitations of the technology. Comments such as, "Rachel sometimes misreads the class because she's not there" and "It's hard to be on TV and not able to walk around the class" suggest that there is a physicality associated with classroom instruction that is missed when the instructor appears via telepresence.

Other comments made by the teachers during the interviews related to the cognitive apprenticeship model. The teachers acknowledge that the follow-up to the workshop provided by TEAM-PD was valuable in helping them to enact what they had learned. For example, one teacher said, "If I hadn't had the follow-up, I probably wouldn't have pursued it. It has forced some to do what they might not have." Similarly, the value of the observation component of the model was also noted by the teachers. As one teacher put it, "Rachel's instructional strategies require good classroom management.... Rachel modeled how to manage the classroom." This observation/feedback loop provided by TEAM-PD allowed teachers and students to attempt to implement what Rachel taught and then receive direct acknowledgment of their successes and failures so that they can be addressed. One of the teachers said, "The primary feedback the teacher and the students receive about their success is feedback from Rachel. Rachel has said, yes, you have this, let's move on."

Coding of Video Data Content

In mid-September of 2005, after teachers in the experimental group had been working with McAnallen for several weeks, they each sat down and conferenced with Rachel via telepresence. These conferences were intended to be unstructured discussions between Rachel and the teachers in which each teacher could privately ask Rachel to address their individual concerns about enacting the instructional strategies.

Each of these conferences was recorded, resulting in a total of four hours and 49 minutes of video data. These data were observed and coded for content using the coding scheme presented in Table 6. Figure 16 shows the percentage of time that Rachel and the teachers spent discussing topics in each of the categorized areas.
As Figure 16 illustrates, 83% of the time during these conferences was spent discussing instruction, including the categories of behavior management, content knowledge, instructional technique, instructional philosophy, student assessment, and procedural knowledge. This observation verifies that this aspect of the independent variable (i.e., direct, individualized mentoring related to mathematics instruction) was actually administered to the experimental group. The remaining 17% of the time was spent discussing noninstructional content: banter, professional relationship building, technical issues, and logistics.

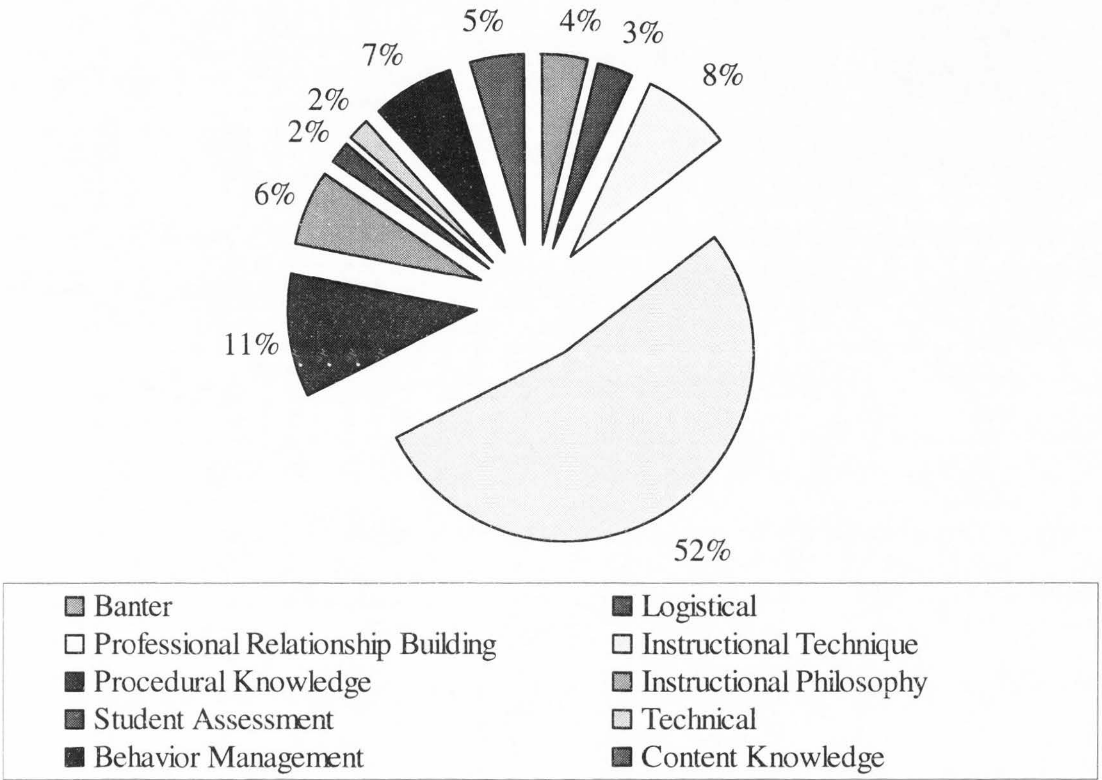

Figure 16. Time distribution of master/apprentice conferences at Time 1.

Specifically, more than half of the time (52%) during these conferences was spent discussing instructional technique. The second largest portion of time was spent discussing procedural knowledge (11%), followed by professional relationship building (8%), behavior management (7%), and instructional philosophy (6%). Little time was spent providing content knowledge (5%), in conversational banter (4%), discussing logistical issues (3%), student assessment (2%), or technical issues (2%). This last category is an important verification that technical problems with them equipment did not impede the conferences.

More than one month later, McAnallen and each of the teachers met individually via telepresence again for a total of four hours and 29 minutes. Again, these conferences were recorded and categorized to verify the implementation of the independent variable and to observe changes in the distribution of time. Figure 17 shows the percentage of time that Rachel and the teachers spent discussing topics in each of the categories during this second round of conferences.

Several characteristics of the distribution of time during this second round of conferences are notable. First, as with the first round of conferences, verification of the independent variable was demonstrated by the fact that 93% of the time was spent discussing instruction. The remaining 7% was spent discussing noninstructional content. Specifically, the largest category of discussion was instructional technique (61%). It was also notable that the time Rachel spent delivering content knowledge to

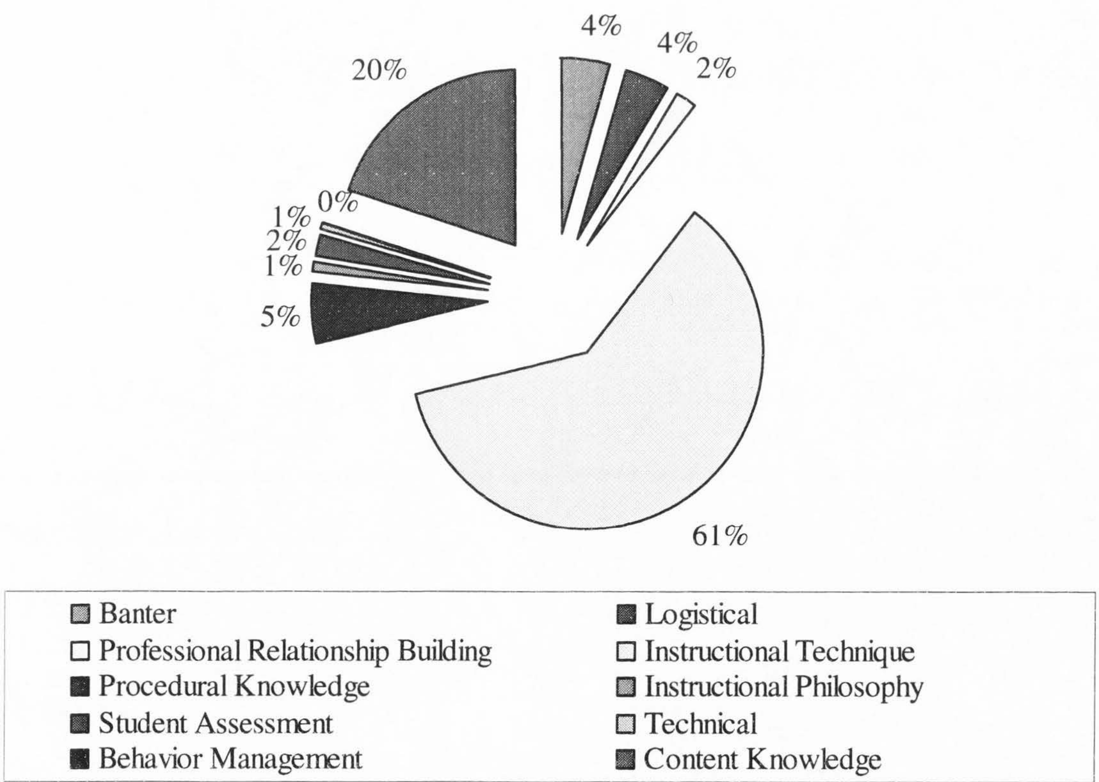

Figure 17. Time distribution of master/apprentice conferences at Time 2.

the teachers increased to 20%. This was because McAnallen, having watched the recorded observations of the teachers delivering her instructional strategies to their students just prior to these conferences, recognized that some of the teacher lacked some of the necessary content knowledge depth to adequately enact the strategies. Therefore she spent one fifth of this second round of conferences addressing short-comings in the teachers' mathematics knowledge. This fact illustrated the importance of the observation component of TEAM-PD. Without direct observation of the teachers attempting to deliver the instruction, McAnallen might not have been able to identify that lack of content knowledge among teachers was a barrier to their successful enactment of her instructional strategies. The remainder of the time was spent discussing procedural knowledge (5%), logistical issues (4%), bantering (4%), student assessment (2%), instructional philosophy (1%), and technical issues (1%).

Mathematics Content Test

Just prior to participating in Rachel McAnallen's initial workshop in January of 2005, students and teachers in both the experimental and comparison groups completed a mathematics concepts test developed by McAnallen. In November of 2005, near the end of the study timeline, teachers and students in both groups completed a second mathematics content test.

Teachers' Content Test

The teachers in the experimental and comparison groups' pretest scores on the mathematics content test were not significantly different ($t = .24$, $p = 0.82$, $d = -0.14$).

The experimental group's average score was 36% correct and the comparison group's average score was 32% correct. Cronbach's alpha for these items was .80, suggesting that the items consistently represent an underlying domain of mathematics knowledge.

Because of the similarity of the two groups' pretest scores, the pretest scores were not included as a covariate in the posttest analysis in order to conserve statistical power. An independent samples *t* test was conducted to evaluate the relationship between the second administration of the teachers' content knowledge test and the independent variable. Although this difference was not statistically significant ($p = .25$), the associated *d* effect size is considered large by conventional standards (Cohen, 1988). The results of the teachers' pre- and posttests are presented in Table 11.

Students' Content Test

The students of the teachers in the experimental and comparison groups' pretest scores on the mathematics content test were not significantly different ($t = -1.06$,

Table 11

Teachers' Mathematics Content Pre- and Posttest Performance

Group	*N*	*M*	*SD*	*t*	*p*	*d*
Pretest						
Experimental	6	1.83	1.6			
				.24	.82	.13
Comparison	5	1.6	1.7			
Posttest						
Experimental	4	3.75	.5			
				1.27	.25	.78
Comparison	4	2.75	1.5			

$p = 0.3$, $d = -0.14$. The experimental group's average score was 19% correct and the comparison group's average score was 21% correct. These data indicate that both groups of students had little mastery of the domain of mathematics knowledge assessed by this test prior to the administration of the independent variable. Cronbach's alpha for these items was .67, suggesting that the items consistently represent an underlying domain of mathematics knowledge.

Because of the similarity of the groups' pretest scores, they were not included as a covariate in the posttest analysis in order to conserve statistical power. An independent samples *t* test was conducted to evaluate the relationship between the second administration of the students' content knowledge test and the independent variable. The students of the teachers in the experimental group scored significantly higher on the mathematics posttest than students of teachers in the comparison group ($t = 13.56$, $p < .001$, $d = 1.72$). Students in the experimental group answered an average of 64% of the questions correctly whereas students in the comparison group answered an average of 25% of the questions correctly. This difference is both dramatic and practically significant as suggested by the following comparisons. However, it must be considered in light of the fact that, on average, McAnallen provided 3 hours of direct instruction to the experimental group students and no direct instruction to the comparison group students.

Using 60% correct as a pass/fail cutoff, only 5% of the students in the comparison group passed the test, whereas 72% of the students in the experimental group passed the test. Within-groups *ES* show that that the comparison group's test score improvement was only one fourth of a standard deviation ($d = 0.25$), whereas the experimental groups test score improvement was more than two standard deviations ($d = 2.12$). The results of the students' pre- and posttests are presented in Table 12.

Video Data

The video recordings of McAnallen's modeling and conferences with the teachers revealed a variety of important themes, drawn inductively from the data via an open coding procedure (Glaser & Strauss, 1967; Strauss & Corbin, 1990). These themes describe the impact of the evaluative nature of cognitive apprenticeship, the impact of modeling, observation, and individualized instruction in supporting teachers as they adopted McAnallen's instructional strategies. Selected quotes exemplifying these themes are presented below.

The Evaluative Nature of Cognitive Apprenticeship

Throughout the conferences between the teachers and McAnallen there were

Table 12

Students' Mathematics Content Pre- and Posttest Performance

Group	*N*	*M*	*SD*	*t*	*p*	*d*
Pretest						
Experimental	161	.96	.75			
				-1.06	.29	-.12
Comparison	121	1.05	.71			
Posttest						
Experimental	123	3.2	1.35			
				13.56	<.001	1.72
Comparison	125	125	.86			

many references to and examples of the benefits of the cognitive apprenticeship approach to professional development as contrasted with the traditional workshop approach. Some of these references highlighted the "evaluative" nature of the model. That is, because McAnallen's workshop was followed-up with face-to-face interactions with McAnallen herself, teachers felt compelled to learn and enact the instructional strategy. As the review of the literature suggest, teachers participating in traditional workshops are rarely held accountable for their understanding or enactment of the learned content. The following statement, made by an experimental group teacher during a telepresence conference with McAnallen, illustrates the power of the evaluative nature of TEAM-PD:

> *Teacher:* I think the only way we'll ever change is if we're *forced* to do it. I think this (kind of professional development) is good because it forces us to do something different than we've been doing for a long time.

These comments indicate that follow-up provided through the cognitive apprenticeship model provides an accountability and evaluation that encourages teachers to enact what they have learned. Knowing that they would be meeting with McAnallen again, face-to-face, to discuss the workshop content created an expectancy effect.

Cognitive Apprenticeship: The Power of Observation

The conversation also highlighted the important benefits of the observation component of cognitive apprenticeship. Prior to meeting with each teacher via telepresence, Rachel watched the teacher's most recent observation DVD recorded by the VO. Based on notes that she took while viewing the DVDs, she was able to refer to the teachers' specific behaviors in the classroom and address them during the conference. For example:

> *McAnallen:* As I watched [your DVD], I thought it was great that you explained the [telepresence] technology to the kids.
>
> *Teacher:* OK. They *were* interested. They were.
>
> *McAnallen:* Of course they are. When I saw that, I thought that was wonderful. There's also something else that I liked that you did—you demonstrated the game. You brought the kids around and you demonstrated how the game should go.
>
> *McAnallen:* By the way, you gave positive reinforcement at the correct times.

McAnallen's ability to observe each teacher enacting the instructional strategies she had presented created a powerful learning tool that is not available in traditional professional development experiences. As Rachel said during one conference,

> *McAnallen:* It's really nice that I can follow up with the teacher afterwards. In normal staff development we can't do that. You know, in the past I've come and done a workshop...and then I leave. So here I can be in the classroom with you and then I can come back to the class again or the Virtual Observer will come in and watch you do it and you and I can watch (the observation) together.

As might be expected, these observations did appear to produce some tension and apprehension amongst the teachers. Several of the teachers voiced discomfort about being observed, noting that such observations have historically been tied to performance evaluations that play a role in determining their salary increases. This discomfort was observable when the teachers were around the video and audio recording equipment and was typically expressed in terms of concerns about physical appearance. The following comments illustrate these concerns:

> *Teacher:* [Looks at herself on the screen, laughs]. I *hate* looking at me!

> *McAnallen:* I *love* seeing *you…*
>
> *Teacher:* We just don't like seeing ourselves.
>
> *McAnallen:* Oh, I know, I hate seeing myself. It took me a long time to be able to look at my own videos.

Although this concern about physical appearance was likely genuine to some degree, it's my belief, based on many hours of observations of the teachers participating in the cognitive apprenticeship model, that these concerns also indicate deeper concerns about being evaluated and judged as professionals. There was some indication, however, that the VO was less obtrusive than a live observer would have been.

> *McAnallen:* How do you feel about being observed (by the Virtual Observer)?
>
> *Teacher:* [Being observed is] always nerve-wracking. They used to tie our observations to money and our job…so whenever you're observed…it's not a fun experience. But the [Virtual Observer] didn't bother me. The machine was fine.

The importance of these observations is supported by the distribution of time spent during the conferences between Rachel and the teachers. In the first round of conferences, prior to Rachel first observing the teachers' DVDs, only 5% of the conversation was dedicated to Rachel providing mathematics instruction directly to the teachers. After watching these DVDs it became apparent to Rachel that one of the barriers preventing teachers from implementing her instructional strategies was their lack of understanding of the relevant mathematics. As a direct result of these observations, during the second round of conferences, the amount of time spent discussing content knowledge increased to 20%.

Cognitive Apprenticeship: The Power of Modeling

By using the VT, McAnallen was able to model her instructional strategies to teachers with their students in their classrooms. The transcript excerpt below is from one such modeling session.

> *McAnallen:* Everyone show me ten fingers. Hold ten fingers u.... Wait! [looks at student playing with manipulatives]. Young lady, *leave those alone!* You're focused *here* [points to herself]. You leave that alone...Everybody show me ten fingers [pauses]. Now show me nine fingers [pauses]. Show me ten [pauses]. Now show me eight fingers [pauses]. Good. Some of you did this and some of you did this [shows two different combinations of eight fingers]. Now, show me ten fingers [pauses]. Subtract nine [pauses]. How much do you have left?
>
> *Student:* One.
>
> *McAnallen:* Good. Show me ten fingers [pauses]. Put down eight [pauses]. Good. Show me ten fingers [pauses]. Subtract seven [pauses]. Put your hands in your lap. Where's [the teacher]? [Teacher], here's what I look for with that. And this is an evaluation that you can never do on paper.
>
> *Teacher:* Okay.
>
> *McAnallen:* You can only *see* this [by having students use manipulatives].... If I say to a student, 'show me ten fingers. Now subtract seven'. I look to see if they do this [holds up 3 fingers on one hand all at once]. Or, if they go like this [counts *down* seven fingers, one by one until three are remaining].
>
> *Teacher:* Okay.
>
> *McAnallen:* I look to see if they have to count down seven. If they have to do *that*, it means, probably they weren't allowed to count on their fingers when they were young.
>
> *Teacher:* Right [laughs].
>
> *McAnallen:* If we allowed kids to use these manipulatives in the beginning [holds up her fingers] then they wouldn't have to always be counting them.

This excerpt illustrates several important aspects of the modeling component of cognitive apprenticeship. First, it illustrates the complex nature of teaching and the importance of an expert being able to model and explicate the necessary behaviors and cognitions. In this example, Rachel demonstrated the classroom management skills necessary to teach using manipulatives and a simple technique to assess an aspect of students' mathematical understanding using manipulatives. Second, although Rachel was directly teaching the students, she actively involved the teacher by providing instruction to her as well. Throughout the TEAM-PD process McAnallen frequently addressed the teachers directly and explained what she was thinking as she taught the students and the rationale (i.e., her cognitions) underlying her instructional strategy.

Cognitive Apprenticeship: Telepresence and Individualized Instruction

Analysis of the telepresence conferences further differentiated cognitive apprenticeship from the traditional model of professional development by illustrating TEAM-PD's ability to enable individualized instruction, a practice not typically possible in the traditional workshop model. The telepresence equipment allowed McAnallen to interact with each teacher individually and in private to address the needs specific to their background, their classroom, and their individual students. When McAnallen began conferencing with the teachers individually, she commented on the ability of this model to enable differentiated instruction:

> *McAnallen:* I really like this medium [telepresence center] for talking to teachers because we sort of can differentiate. You're the fifth teacher I've talked to today...and every one of you have been different. You're like kids—every one of you has different questions to ask.
> *Teacher:* Well I've enjoyed it and I've learned a lot.

In an interview between Rachel and myself after her first experience conferencing with teachers and providing them individualized instruction, I asked her to describe the TEAM-PD experience and to contrast it with how she typically delivers instruction via the traditional workshop model. Rachel was excited about her experience that day. Even though she has been working in education for 45 years, her first day working with teachers in the TEAM-PD model was clearly a standout:

> *McAnallen:* I can't explain how great I felt...when the day was over... I just was walking on air because of the individualization with the teachers and how comfortable they were in opening up with me. I've had that experience with kids before, when kids have really learned and at the end of the day you know you've really done a great job. (This) was probably one of the first times that's ever happened when I have just been working with adults. This was a personal relationship with each one of the teachers. It was such a great day for me.
>
> I was so excited...because it was so *individualized.* I think, like kids, (teachers) are afraid to talk about their weaknesses in a group. You have to be really, really secure to say 'I don't know how to teach this' if you've been teaching 21 years.
>
> Each teacher had different issues they wanted to deal with. The first teacher... I gave her some techniques if kids don't have a (grade-level understanding). The second teacher...he and I talked philosophy. He told me what he did his Master's work on and that was just wonderfully stimulating for me.... With (another teacher), she's a first year teacher...her issue...was classroom management. Her kids are running all over her. So we basically talked about classroom management.... Each teacher had their own individual concerns which I attempted to address at their developmental level.

In the hours of recorded conferences between teachers and McAnallen, there were many examples of McAnallen actually providing differentiated instruction to teachers. In the following excerpt, a teacher came to McAnallen with several specific questions.

> *Teacher:* I have some questions for you...we've got some 6^{th} graders that are really struggling on dividing two digits into three digits or even one digit into three digits.... I wonder if you have another way to show us [how to teach] that? There's three kids that really just aren't grasping it, and I don't know if there's a way to do it with money [manipulatives] or what...

Rachel: [Big smile] Yes, *there is*!

Teacher: The other question I want you to answer is: the kids get really confused when you do estimating, mental math, and exact math. And then once they figure out mental math they don't want to write down the process anymore because they can do it in their head… they kind of have a hard time understanding the concept behind all those.

Rachel: Which one do you want me to (explain) first?

The individualized instruction also allowed Rachel to address the specific needs of these teachers' students. The following interaction occurred between Rachel and another teacher.

Teacher: I have one little girl…her I.Q. is very low…she just can't [play the game] on her own. So I just put her with a [student] that she could follow.

McAnallen: Were those the two little girls in front?

Teacher: Yeah.

McAnallen: I could tell.

Teacher: You could tell, huh?

McAnallen: OK, here's what I'd do with them [she pulls up the manipulatives under the document camera. Teacher directs her attention to the secondary monitor.]

McAnallen: You're going to have to be real discreet with them on this…. I'd say to these kids, 'I'm going to have you work with my special money' [indicates the number blocks]. See, I teach this same lesson with these blocks [instead of the paper money] to second and third and beginning fourth graders before I ever go to the money. Those two girls you have are still on the second grade level, so you're going to have you use second grade manipulatives…. Do you think they have the concept of add means to put into your wallet and subtract means to take away?

Teacher: Add yes, subtract no…they're having a very hard time seeing subtraction. It's real interesting. I'm sure [using the blocks] will help better than just the numbers.

McAnallen: Ok. I'd have them just still roll the ones. Do they know that every time they… have at least ten of these that they have to trade in ten ones for a ten?

Teacher: They can do it in addition, but subtraction, they can't figure how to take tens and change it to ones…

McAnallen: Here's the advantage of…the place value game. While the [rest of the class] is playing, you can spend some time with these kids. You can do this; I call this the cover up finger method. [She goes on to explain the method in detail for about 20 minutes.]

McAnallen: …I've seen kids at this level so many times.

Teacher: And I haven't. I've only taught 3rd, 4th, and 5th. I don't know what 1st or 2nd graders are like. I don't know what to do with them.

McAnallen: That's right. Actually, you're probably a kindergarten or 1st grade teacher with the two of them.

Teacher: Yes, yes.

This dialogue illustrates several important characteristics of the telepresence-enabled cognitive apprenticeship model. First, if telepresence is defined as being "present" where one is not, this example makes clear that the equipment used for this research was, at least to some degree, enabling telepresence. Not only was McAnallen able to instruct a classroom of students from 500 miles away, she was able to observe their behaviors, responses, and written work with enough clarity to accurately make subtle distinctions in their understanding of mathematics. Because Rachel was able to be "telepresent" with this teacher and her students in the authentic context of their classroom, she had a very clear understanding of their abilities and needs that she might not have had otherwise. This insight, combined with the individualized conference, enabled her to provide a specific instructional strategy tailored for that specific teacher, in that classroom, with those two specific students. Second, this interaction illustrates the benefit of having a true master teacher delivering individualized professional development. Although the teacher in this interaction has been teaching for 16 years, she has only taught fifth- and sixth-grade students. This leaves her at a considerable disadvantage when she has students in her class that have a first-grade level understanding. As Rachel points out, she has experience teaching students in kindergarten through twelfth grade and was therefore able to offer some insight into this particular problem.

Unexpected Additional Instruction

There is a final, unexpected result of the TEAM-PD implementation to be addressed. Although the experimental teachers were interested and involved in TEAM-PD throughout the research process, there was some indication that they wanted to expand upon the application of TEAM-PD to additional mathematics instruction beyond the instructional strategies described in the Methods chapter. Each teacher had individual interests and needs regarding teaching mathematics and often expressed interest in applying McAnallen's expertise and the telepresence equipment to address those needs and interests. However, the research methodology required that McAnallen and the teachers focus their attention on an operationally defined pedagogical strategy in order to measure the effects of the model.

Just prior to the end of the experimental implementation, McAnallen, the experimental group school principal and teachers began discussing additional ways in which the telepresence equipment and McAnallen's expertise could be utilized. After examining several options, they concluded that McAnallen would deliver a mathematics lesson involving origami to a class of Gifted and Talented fifth graders. These students were trained by Rachel to teach the rest of the fifth grade what they had learned from Rachel. These activities occurred over three days in November 2005. As the researcher, I was not directly involved in the design of these activities, although I facilitated and observed throughout. The experience was clearly a great success and provided a nice capstone to the TEAM-PD model. It allowed Rachel, to whom the students and teachers had become personally attached, to say farewell with a final creative and fun mathematics activity.

This spontaneous instruction design and delivery illustrates several important aspects of TEAM-PD. First, the teachers, principal, and students became so accustomed and comfortable with the use of the equipment in their school that applying it in other ways came naturally to them. Second, it illustrates the power of bringing an expert with a wide range of expertise and knowledge into a school. Teachers immediately understood that she represented a great opportunity to provide their students with access to a depth of mathematical knowledge that they might not possess themselves. Finally, this last instruction illustrates that the telepresence equipment, once installed and integrated into daily school life, can be used for a variety of educational purposes, thereby maximizing its utility and its cost-effectiveness.

CHAPTER V

DISCUSSION

This research evaluated the effectiveness of a teacher professional development model that utilized a cognitive apprenticeship approach. A review of the professional development and cognitive psychology literature revealed empirical and anecdotal evidence that the fundamental characteristics of cognitive apprenticeship are consistent with what is widely believed to be effective in teacher professional development. A technological solution, telepresence, was deployed to establish the TEAM-PD. The research compared the effectiveness of TEAM-PD to that of the traditional workshop model of teacher professional development by measuring student achievement outcomes and teacher enactment outcomes.

Prior to the beginning of this research, five specific outcomes were hypothesized. This chapter is organized around these hypotheses. Data from each of the sources discussed in the Results chapter is triangulated in order to bring together all evidence bearing on each hypothesis. The discussion will conclude with a presentation of the limitations of the research and a discussion of possible directions for future research.

Stages of Concern Hypothesis

It was hypothesized that, as a result of their participation in TEAM-PD, teachers in the experimental group would advance to higher levels in the CBAM SoC with respect to McAnallen's mathematics instructional strategies than teachers in the comparison group. If supported, this would provide evidence that TEAM-PD leads teachers to advance more rapidly through a series of defined concerns regarding an innovation than traditional models of professional development.

Specifically, teachers in the comparison group were predicted to *not* progress past the Personal stage (Stage 2) by the end of the study. This would indicate that these teachers' concerns about implementing McAnallen's instructional strategies were focused on the demands of the strategies and their inadequacy to meet those demands. Because the traditional workshop model of professional development provides little or no follow-up support it is believed that teachers are often unable to overcome these Stage 2 concerns and, therefore, are unable to progress in their enactment of the instructional innovation. Teachers in the experimental group, however, were hypothesized to progress to the Refocusing stage (Stage 6) by the end of the study, indicating their exploration of the more universal benefits of the innovation. Because TEAM-PD provided individualized support, instruction, and coaching, distributed over time, these teachers were expected to overcome the self-direct concerns and to progress quickly with their enactment of the instructional strategies.

At the time of the *first* administration of the SoC instrument in August of 2005, both groups had participated in McAnallen's January 2005 traditional workshop. In addition, the experimental group had been introduced to TEAM-PD; McAnallan had just modeled her instructional strategies in each experimental group teacher's classroom for the first time. A peak score analysis of the experimental and control group teachers' SoC scores indicated that both groups had an awareness of McAnallen's instructional strategy, were interested in learning more about it, but were, for the most part, unconcerned about how the strategy impacted their classroom instruction. This was evidenced by both groups' overall averaged peak scores of Stage 0. This was supported by the video recordings of McAnallen and teachers conferencing. Teachers met individually with McAnallen and were able to have their individual concerns and needs personally addressed. As Rachel observed the teachers attempting to implement her instructional strategies, it was clear that the teachers had a mechanical understanding of the strategies, but that they had not developed a deep mastery of the content. These observations indicated that this was due, in part, to teachers' lack of understanding of the mathematical content.

As the review of the professional development literature indicated, this description is typical of the outcomes of traditional professional development workshops. Because TEAM-PD had been implemented for only a short time, it was not expected that the experimental group would exhibit higher SoC scores than the comparison group at this first measurement.

However, a profile analysis, in which the relative amount of concern at *each* of the Levels specified by the SoC instrument is considered rather than considering *only* the peak SoC scores, provided an indication that the experimental group's concerns had progressed slightly beyond those of the comparison group. A comparison of the two groups' scores at each level indicated substantive differences. This analysis suggested that the comparison teachers had less concern about or involvement with McAnallen's instructional strategies (high Level 0 concerns). It also indicated that they were less concerned about how the strategies would impact their students or how to evaluate such impacts (low Level 4 concerns). Video data analyses confirmed that teachers in the experimental group were beginning to think beyond the mechanical aspects of the instructional strategies (e.g., the process of using the manipulatives, behavior management) and were beginning to consider how to modify and adapt the strategies to meet the needs of their individual students. Finally, the comparative profile analysis indicated that the comparison group teachers were considering alternatives to McAnallen's instructional strategies to a substantially greater degree than the experimental group teachers.

In late October of 2005, both the experimental and comparison groups completed a second SoC questionnaire. A peak score analysis and profile analysis indicated that both the experimental and comparison groups' concerns had not developed past those of inexperienced users. Although this outcome was predicted for the comparison group, Hypothesis #1 predicted that the experimental group's concerns would have advanced to those of the experienced user. Both the experimental and comparison groups' Measurement #2 profiles correspond to that of an *inexperienced user,* indicating a development in concerns since Measurement #1. This development was modest but suggests that both groups of teachers concerns were shifting from self-focused to task-oriented. The comparison group's profile also indicated a growth pattern slightly more progressed than that of the experimental group. Given the substantial variability and the small number of teachers in each group all conclusions drawn from these data are very tentative. The video data were consistent with this finding—20% of the time spent during the conferences was spent by McAnallen delivering mathematics instruction directly to the experimental group teachers. This supports the fact that these teachers were still inexperienced users. Had the research allowed for a longer implementation, teachers might have been able to overcome this barrier through their instruction with Rachel and then progress onto the higher SoC stages. Video data, SoC data, and LoU interview data showed that these teachers were *beginning* to shift towards the behavioral and cognitive patterns of experienced users.

In sum, the hypothesis that experimental groups teachers' concerns related to the McAnallen's instructional strategies would develop substantially more than those of the comparison group teachers was not supported by the findings of the research.

Levels of Use Hypotheses

It was hypothesized that, as a result of participating in TEAM-PD, teachers in the experimental group would attain a higher LoU with respect to McAnallen's instructional strategies than teachers in the comparison group. Specifically, teachers in the comparison group were predicted to *not* progress past Preparation level (Level III) by the end of the study, whereas teachers in the experimental group were predicted to have progressed to the Renewal level (Level VI) by the end of the study.

At the time of the *first* administration of the LoU interviews in August of 2005, teachers in both the experimental and control groups had participated in McAnallen's January workshop. The experimental group teachers had also been introduced to TEAM-PD and were beginning to participate in the modeling, observation, and feedback process. Even though the implementation of the independent variable had only been in place for a limited time, the results of this first LoU assessment were consistent with Hypothesis #2. In the comparison group, four out of five teachers were at Level I—Orientation. This indicated that these teachers had received information about McAnallen's instructional strategies but were only exploring the demands it would put upon them and not really implementing the strategies in their classrooms on a regular basis. Five out the six teachers in the experimental group were scored as Level III—Mechanical Use on the LoU. This indicated that these teachers understood the day-to-day requirements of McAnallen's strategies and were implementing the strategies in their classroom, but in a superficial and disjointed manner.

The *second* LoU measurement occurred in October of 2005. The teachers in the comparison group did demonstrate some growth on this measurement of their LoU. However, none of them had progressed as far as Level III, supporting Hypothesis #2. This finding indicated that these teachers were using McAnallen's instructional strategies in their classrooms, albeit in a manner that was disjointed and superficial. Although the LoU scores of the experimental group were somewhat scattered, three of the six teachers in that group reached Level IVa or IVb—at lease partially supporting the hypothesis. This indicates that these teachers had obtained a mastery of McAnallen's instructional strategies that allowed them to move beyond dealing with the individual tasks associated with the strategies and instead focus their efforts on maximizing the benefits for the students. The findings of the LoU were supported by the analysis of the video data. These data showed that the experimental group teacher spent a considerable amount of time working directly with McAnallen on deepening their understanding of the instructional strategies. In addition, the video data provided many examples of how teachers worked with McAnallen to address their specific concerns, adapt the instructional strategies to suit their individual needs and those of their students. Teachers were able to discuss individual students, behavioral management issues, and procedural implementation issues that allowed them to overcome barriers that would have otherwise prevented them from continuing to progress with the strategies. For example, teachers that experienced behavioral management issues resulting from the use of manipulatives were able to get tips from Rachel about how to address these problems. A teacher unable to control her students' behavior while working with the manipulatives is likely to abandon the strategy for other, less problematic strategies.

To summarize, the findings of the second measurement of the experimental and comparison groups' LoU were partially supportive of the hypothesis. These data, along with the corroboration provided by the video data, are consistent with teachers in the experimental group beginning to develop an executive control of the instructional strategies.

Behavior and Artifacts Hypotheses

It was hypothesized that teachers in the experimental group would exhibit behaviors and create artifacts that would reflect a change in their instructional approach consistent with McAnallen's instructional strategies. The comparison group teachers, manipulatives with their students, they had not used them enough to have developed a system of deployment. These teachers were storing the manipulatives in the original box in which they were shipped, making it very difficult and time consuming for them to actually distribute the materials when needed. Teachers in the experimental group, however, all reported and were observed using the manipulatives numerous times. Their interview responses and the videos of them teaching clearly indicate that they had practiced and developed strategies and systems to allow them to efficiently deploy the manipulatives. For example, experimental group teachers had followed McAnallen's suggestion that they locate and use an egg-carton system to deploy the manipulatives. In this system, each student uses the 12 holes in an egg-carton to organize the manipulatives while they are participating the lesson and then to store the manipulatives afterwards. One experimental group teacher took this suggestion and modified it, as she described during a conference with McAnallen:

> *Teacher:* I bought *ice-cube trays* to put the digits in because I can put the ice cube trays in the dishwasher. They're pretty cheap at Wal-Mart. They have 14 holes instead of 12 (in the egg cartons) so I've got room for my pluses, my decimals, my equal signs and my greater and less (than signs). I really like that.
>
> *McAnallen:* Thank you! What a great idea. I call that a G.I.: a Great Idea.

Teachers in the experimental group not only were using and practicing with the manipulatives in their classrooms, they were subtlety modifying the strategies to better accommodate their needs. These slight modifications to McAnallen's instructional strategies are also consistent with the LoU scores of the experimental group teachers. According to definitions provided by the LoU instrument, when a teacher initiates "changes in the use of the innovation based on formal or informal evaluation in order to increase [student] outcomes" (p. 8), this is evidence that teacher has achieved Level IVa.

Teachers in the experimental group slightly modified McAnallen's instructional strategies in other ways. For example, while conferencing with Rachel, one teacher described an idea he had for grouping students during the lesson:

> *Teacher:* Do you put two lower kids together?
>
> *McAnallen:* Yes
>
> *Teacher:* How does that work—two kids that can't do it? Do you go by and help them…?
>
> *McAnallen:* Yes… if you put two brighter kids together, you can give kids choices. [excited look] Oh! I like this. I learn something new everyday... Oh wow, I love this [idea]. I just developed a new lesson here as a result of you. [Rachel explains the new strategy in detail.]
>
> *Teacher:* That's really good. That gives me some really good ideas…
>
> *McAnallen:* Don't be afraid to deviate from what I have written…because (I) just can't write everything down. You see, here you've given me this idea…. Next week I'm going to New York City…. I'm going to be teaching some 5th graders and some 7th graders. I'm going to be using these materials… I'm going to take what I just learned from you and have the kids do it.
>
> *Teacher:* Ok, we'll I'm going to go try it in my class.

Again, this level of thought and analysis indicates that, not only were the experimental group teachers routinely implementing the instructional strategies, they were adapting them and modifying them in new ways to maximize their effectiveness.

Together, these data support the hypothesis. They are consistent with the conclusion that teachers in the experimental group substantively modified their classroom behavior as a result of participating in the TEAM-PD model. Teachers in the comparison group, however, reported few, if any, substantive changes in their behavior and produced no notable artifacts indicating their implementation of the instructional strategies.

Mathematics Content Test Hypothesis

It was hypothesized that the teachers in the experimental group would perform significantly better than the teachers in the comparison group on a test of mathematics content as a result of their participation in TEAM-PD. Although the differences in the groups' posttest scores were not statistically significant, they did represent a moderate *ES*. Thus, although the difference between the groups is notable, they are not reliable, possible due to the small sample size.

The results of these teachers' students' performance on the mathematics content test were more conclusive. Although both groups of students performed poorly on the pretest, answering less than a quarter of the questions correctly, there was a large difference between their respective performances on the posttest. Sixty-seven percent more of the students in the experimental group passed the content test than students in the comparison group, representing 1.72 standard deviations of difference between the two groups' passing rates. This outcome is consistent with the conclusion that they had mastered more of the content presented than the students in the comparison group.

Although teachers and students were not randomly assigned, the pre-post comparison provides evidence that for the conclusion that the difference observed in groups' performance on the test was due to the manipulation of the independent variable. That is, it seems plausible that students in the experimental group performed better on this test because their teachers participated in TEAM-PD. Given this, some specific conclusions can be assumed regarding the relative contribution of the various aspects of TEAM-PD. First, it is important to recognize that Rachel McAnallen delivered instruction directly to the students of the teachers in the experimental group but not to students of the teachers in the comparison group. Therefore, it can be assumed that some of the differences in student mastery of the content are attributable to this direct expert instruction. This research does not indicate how much of the student gain can be attributed to the expert instruction and how much can be attributed to the instruction delivered by the teachers. On average, McAnallen only provided about three hours of direct instruction to student per class. Given this limited amount of expert-instruction it seems reasonable to assume that at least some of the observed effect was likely due to the improved instruction delivered by experimental group teachers themselves. The question that was not clearly addressed by this research was: will the cognitive apprenticeship model lead to teacher-delivered instruction that will sustain the educational growth initiated by the master teacher?

Conclusions

Despite some inconsistencies with hypothesized outcomes, this research provides initial evidence that using telepresence to enable a model of cognitive apprenticeship may be *possible* given recent advances in telecommunications technology. The technology employed to enable TEAM-PD in this research proved effective, efficient, and reliable. Observations of the interactions among McAnallen, teachers, and students established that the equipment was successfully used for dozens of hours and that the majority of that time was spent on professional development activities. However, comments from the teachers in the experimental group indicate that there are some limitations to telepresence technology. Much like any communications technology (e.g., telephones, email), there may be some essential elements of physical presence that are always missed by users of the technology. In addition, some technical details of the existing telepresence equipment would benefit from refinement. None of these proved to be substantial barriers, however, and these limitations should be considered in light of the efficacy of the model, especially as contrasted with existing models of professional development.

Technology issues aside, the primary purpose of this research was to begin to explore the evidence for the effectiveness of TEAM-PD in regard to teacher enactment of professional development content and subsequent student outcomes. Some of the resulting data failed to support the hypothesis that teachers receiving professional development in TEAM-PD would demonstrate substantially faster and more advanced levels of enactment. For example, the evidence did not indicate that the experimental group teachers' concerns about implementing the professional development content progressed beyond those of the comparison group teachers. Both groups' concerns were consistent with those of inexperienced users of the instructional strategies. Also, the experimental group did not demonstrate a substantially higher collective understanding of relevant mathematical content than the comparison group. However, these findings should be considered in light of the small group sizes and considerable variability within each group.

Other findings of the research were consistent with the conclusion that TEAM-PD has positive and significant effects on teacher classroom instruction and student outcomes. A qualitative analysis of the interactions between Rachel McAnallen and the experimental group teachers and students revealed that principal components of cognitive apprenticeship were well-received and were perceived by McAnallen and the teachers as powerful additions to the profession development process. These qualitative data were supported by the quantitative student outcome data indicating some significant differential growth in mastery of mathematical content knowledge. Students in the experimental group demonstrated significantly higher mastery gains than students in the comparison group.

Limitations

It is important to note several limitations associated with this research methodology and results. First, as noted in the Methods chapter, the descriptive multimethods research design does not allow for the attribution of causality of the outcomes to TEAM-PD. To the extent that was possible given logistical and practical limitations, data were triangulated to provide corroborating evidence for the validity of the conclusions. However, the effects of extraneous, uncontrolled variables (e.g., pre-existing group differences) are unknown. The conclusions drawn from the results of the research should be considered tenuous. More experimental research is required to provide further evidence that the observed results are, in fact, attributable to TEAM-PD and that they are generalizable.

A second important limitation was the limited time frame of this study. Although the magnitude of the effect of TEAM-PD is theoretically high relative to the effect of traditional professional development workshops, more implementation time is likely necessary for TEAM-PD to have full impact. Although teachers in the experimental group received only eight hours of cognitive apprenticeship each over a few months, evidence indicated that it had a substantial impact, especially on student learning. A more sustained and intensive implementation of TEAM-PD, distributed over the course of an entire school year, could result in more dramatic improvements in student learning.

Third, the requirements of the research design may have artificially limited the magnitude of the effect of TEAM-PD. Teachers were required to spend the majority of their time in TEAM-PD focused on Rachel McAnallen's instructional strategies so that hypothesized outcomes could be tested. Because the real power of TEAM-PD is derived from the individualized instruction, allowing teachers to freely choose the content of their professional development is likely to lead to even greater outcomes.

Fourth, the most dramatic finding of this research, the difference between the experimental and comparison groups' student outcomes, should be tempered with the limitations of the administered mathematics content test. Because the test consisted of only five items it represents a narrow slice of the domain of elementary mathematics. In addition, the research design does not make clear to what degree this effect was a result of direct instruction by McAnallen and to what degree is was a result of the professional development delivered to the experimental group teachers.

Future Directions

This research raises as many questions as it answers. There has long been a call for coaching in teacher professional development. However, in a report to the Aspen Institute Program on Education and the Annenberg Institute for School Reform, Neufeld and Roper (2003) stated, "No one, as yet, has proven that coaching contributes significantly to increased student achievement" (p. 1). Future research designs should contrast three experimental conditions: (a) traditional professional development workshops; (b) onsite, in-person, cognitive apprenticeship; and (c) telepresence-enabled cognitive apprenticeship. Further, the research should address the limitations of this dissertation research, described above.

Although not central to the research addressed here, many of these questions about TEAM-PD surround the nature of the telepresence equipment used, its practicality, and cost-effectiveness. Since the design and development of the equipment used in this research, new equipment has been developed and is currently being tested. One of these designs uses the least expensive, yet still sufficient, equipment available to make TEAM-PD as affordable and practical as possible (see Figure 18). A second design incorporates all of the functionality of the VO, VT, and TC into one piece of equipment (see Figure 19).

Future tests and research using this equipment will determine what technical

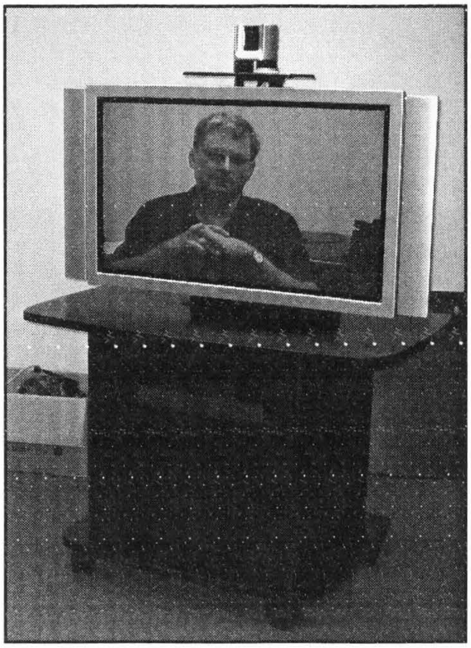

Figure 18. Inexpensive telepresence technology.

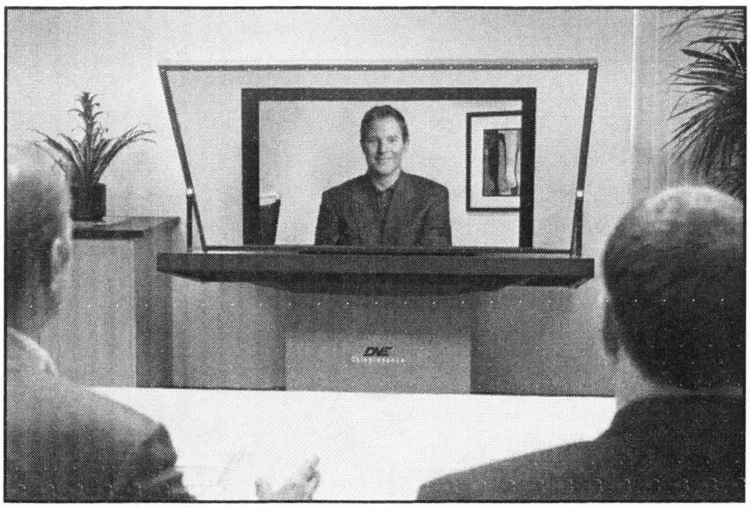

Figure 19. The future of telepresence technology (photo courtesy of Digital Video Enterprises, Inc.)

specifications are best suited for TEAM-PD. Once these specifications have been settled upon it will be important to conduct cost-benefit analyses. Such analyses could provide a cost per unit of gain on standardized test scores for both TEAM-PD and for the traditional workshop model. In conclusion, future research should provide strong empirical evidence for the effectiveness, practicality, and cost-benefit of a telepresence-enabled model of teacher professional development.

There are several ways in which future experimental investigations of the effects of a cognitive-apprenticeship model of professional development can be improved to better determine its effects relative to traditional professional development. Future experimental designs could utilize three groups: one that receives traditional professional development, one that receives in-person cognitive apprenticeship, and one that receives cognitive apprenticeship via telepresence. This would determine the effect due to cognitive apprenticeship compared to traditional professional development but would also allow for a comparison between in-person and telepresence-enabled cognitive apprenticeship. This information, combined with the cost-benefits analysis described above, will help to establish the practicality and sustainability of a TEAM-PD model. In addition, outcome measures should be improved to better measure teacher growth and student performance.

Future research would also benefit from longer, more carefully constructed implementations of cognitive apprenticeship. The existing literature and the results of this study show that teacher professional must be a sustained, long-term enterprise in order to be most effective. This exploratory study was much too short to achieve dramatic results in teacher practice and student outcomes. However, this dissertation provides encouraging evidence that a full school-year implementation of TEAM-PD may have substantial beneficial impacts. In addition, the nature of the time spent within the TEAM-PD model could be more carefully investigated and constructed to help ensure results. For example, as this dissertation showed, content knowledge is sometimes lacking and may be a substantial barrier to successful pedagogy. Perhaps teachers should participate in a more intensive instructional period prior to beginning TEAM-PD to ensure that they have the necessary breadth and depth of content knowledge to be effective instructors. Rather than spending time providing that instruction directly to teachers, the master might instead provide teachers with external resources (e.g., printed materials, DVDs, CD-ROMs).

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APPENDICES

Appendix A

Telepresence Equipment Specifications

Telepresence Equipment Specifications

Bandwidth: Quality of Service

Because one of the necessities of telepresence is a high-quality image, and because sending high-quality images over a network requires substantial bandwidth[1], a private "Quality of Service" broadband network was installed specifically for this research. This network was exclusively dedicated to this project. This meant that, unlike video and audio data typically sent over the public Internet, the quality of the data stream was 100% guaranteed. The resulting video and audio quality approximates that found on cable television: high resolution, widescreen, 30 frames per second, with little or no interruption in service, no frozen images, and no degradation in quality.[2]

The Telepresence Center

The TC consisted of a 37" Liquid Crystal Display (LCD) monitor, the image of which is reversed and then reflected on a half-silvered mirror[3] positioned at a 45° angle above the display. This arrangement allowed a camera to be mounted behind the eyes of the life-size image of the person presented on the display, enabling mutual eye gaze and accurate display of body language. The TC also contained a document camera, a personal computer (PC), a 17" LCD display, and a host of other audio-visual components.

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[1] Bandwidth is defined as the amount of data that can be transferred through a digital connection in a given time period.

[2] Several months after the beginning of this research, the experimental school received an Internet 2 connection, which far exceeds the network capacity used for the research in terms of bandwidth. Future implementations of the TEAM-PD model will likely utilize a small fraction of the bandwidth available to schools via Internet 2.

[3] This mirror was a "beamsplitter," a sheet of safety glass with a thin coating of silver on one side, designed specifically for this application.

The document camera and 17" monitor allowed the teachers and Ms. McAnallen to exchange documents, PC documents lesson plans, and other information. For example, because Rachel's instructional strategies rely heavily on manipulatives, she was able to place manipulatives under her document camera. The resulting image of the manipulatives was then viewable by the audience at the receiving end on the 17" monitor.

The Virtual Teacher

The Virtual Teacher (VT) consisted of a wheeled podium with a Plexiglas screen mounted vertically above it. Imbedded in the Plexiglas screen was a sheet of holographic film onto which the live image of Rachel McAnallen was projected (see Figure A-1).

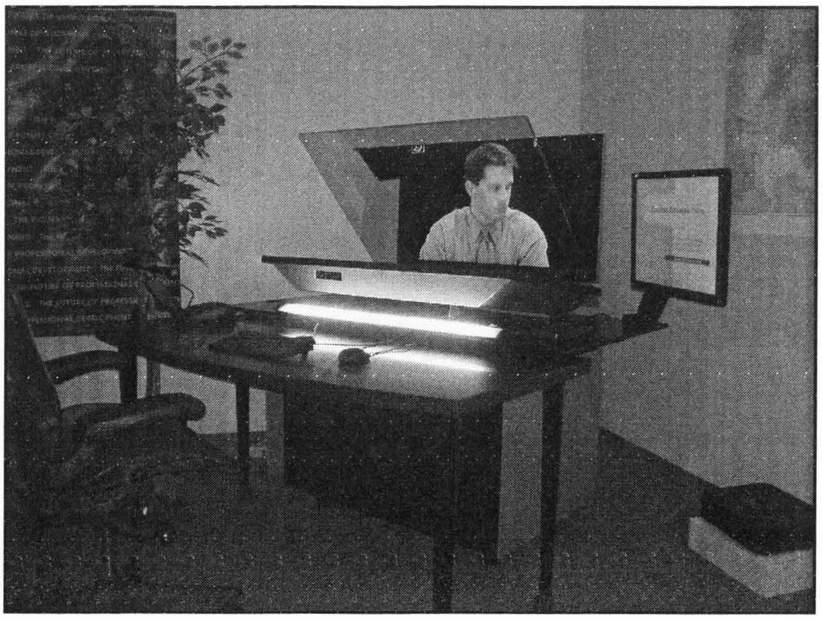

Figure A-1. A document camera allows users to display information on a 17" secondary monitor.

Behind a one-way piece of glass built into the podium was a camera, through which Ms. McAnallen was able to see the classroom. Rachel controlled the camera at Pioneer Elementary with a remote control and could pan, tilt, and zoom the camera to observe virtually any aspect of the room.[4] Figure A-2 shows an image captured from a spontaneous interaction between Rachel and students in a 5th grade class. The large image of Rachel is what students saw on the Virtual Teacher and the small, inset image is what Rachel saw on her Telepresence Center (except that image filled the 37" display on her TC).

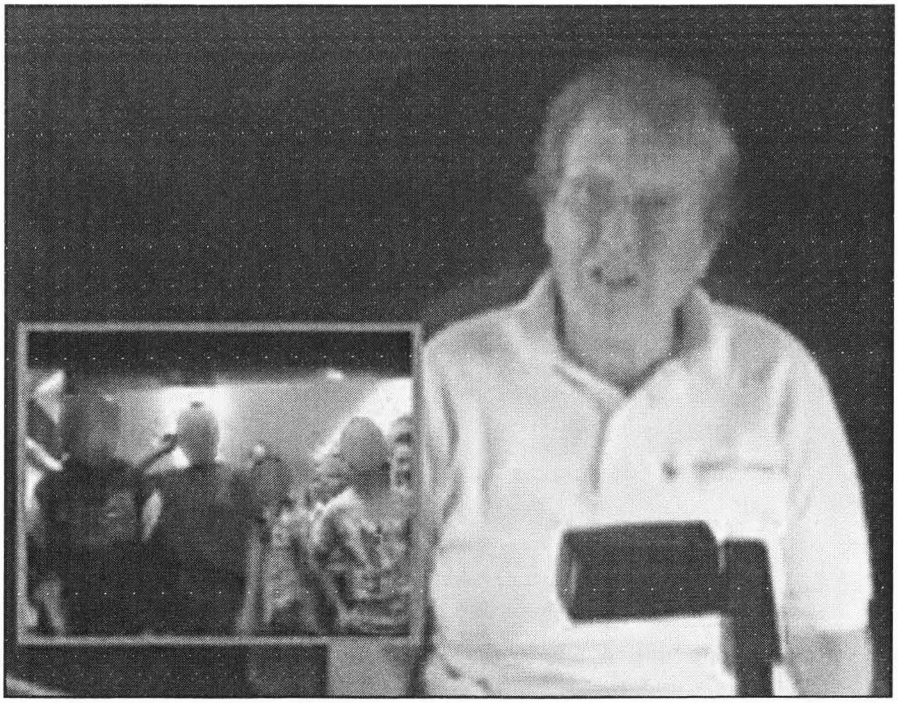

Figure A-2. Rachel talks with a group of students via the Virtual Teacher.

---

[4] The quality of the image produced by this camera was excellent; McAnallen was able to easily observe the ticking second-hand on a wristwatch that was more than 30 feet away from the camera she was controlling.

Speakers built into the podium projected Rachel's voice into the remote location and a wireless microphone on a tripod delivered audio from the classroom to Rachel. Sitting in front of her Telepresence Center in Denver, she was able to appear on the VT and model instructional strategies to teachers at Pioneer elementary.

As with the TC, Rachel was able to display manipulatives using the document camera. However, because the VT did not have a secondary display, the document camera image would temporarily replace Rachel's image on the holographic screen (see Figure A-3). When the document camera image was present on the screen, Rachel could still be heard at the receiving end and was still able to see the classroom.

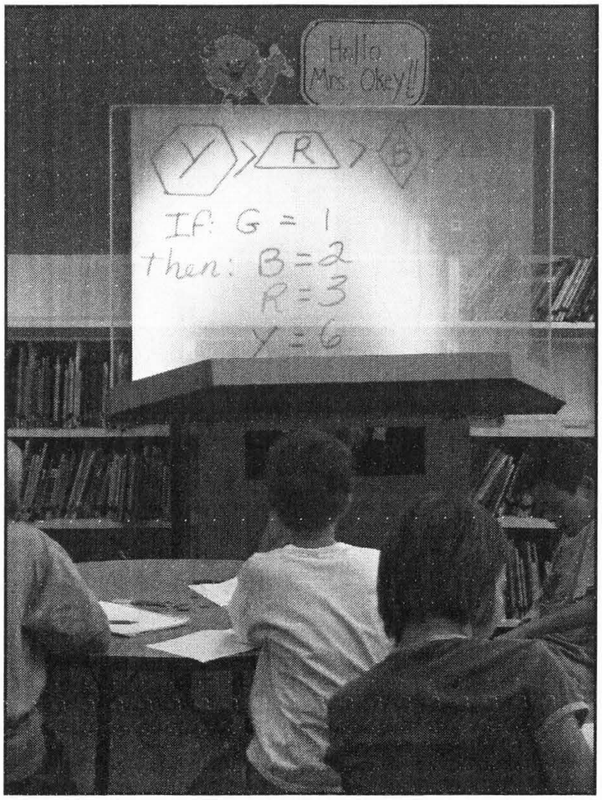

Figure A-3. Rachel uses her document camera like a chalkboard, to guide students through a lesson.

The Virtual Observer

The VO is a wheeled locker (see Figure A-4) containing an auto-tracking digital camera, a small video monitor, and a Digital Video Disk recorder (DVD-R). Operating silently behind a sheet of curved, reflective plastic, the auto-tracking camera located a signal sent by a microphone worn by the teacher being observed. As the camera automatically followed this signal around the classroom it recorded the teaching session onto a DVD. These DVDs were later watched by Ms. McAnallen.

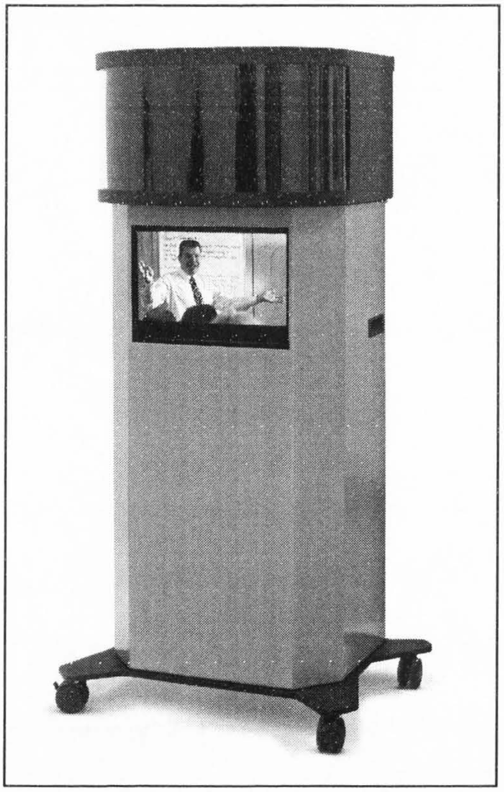

Figure A-4. The virtual observer records a teacher in the classroom. Photo courtesy of Digital Video Enterprises, Inc.

Appendix B

The Stages of Concern about an Innovation Questionnaire

Stages of Concern Questionnaire

0	1	2	3	4	5	6	7
Irrelevant		Not true of me now		Somewhat true of me now		Very true of me now	

1.	I am concerned about students' attitudes toward this innovation.	0	1	2	3	4	5	6	7
2.	I now know of some other approaches that might work better.	0	1	2	3	4	5	6	7
3.	I don't even know what the innovation is.	0	1	2	3	4	5	6	7
4.	I am concerned about not having enough time to organize myself each day.	0	1	2	3	4	5	6	7
5.	I would like to help other faculty in their use of the innovation.	0	1	2	3	4	5	6	7
6.	I have a very limited knowledge about the innovation.	0	1	2	3	4	5	6	7
7.	I would like to know the effect of reorganization on my professional status.	0	1	2	3	4	5	6	7
8.	I am concerned about conflict between my interests and my responsibilities.	0	1	2	3	4	5	6	7
9.	I am concerned about revising my use of the innovation.	0	1	2	3	4	5	6	7
10.	I would like to develop working relationships with both our faculty and outside faculty using this innovation.	0	1	2	3	4	5	6	7
11.	I am concerned about how the innovation affects students.	0	1	2	3	4	5	6	7
12.	I am concerned about this innovation.	0	1	2	3	4	5	6	7
13.	I would like to know who will make the decisions in the new system.	0	1	2	3	4	5	6	7
14.	I would like to discuss the possibility of using the innovation.	0	1	2	3	4	5	6	7
15.	I would like to know what resources are available if we decide to adopt this innovation.	0	1	2	3	4	5	6	7
16.	I am concerned about my inability to manage all the innovation requires.	0	1	2	3	4	5	6	7
17.	I would like to know how my teaching or administration is supposed to change.	0	1	2	3	4	5	6	7
18.	I would like to familiarize other departments or persons with the progress of this new approach.	0	1	2	3	4	5	6	7
19.	I am concerned about evaluating my impact on students.	0	1	2	3	4	5	6	7
20.	I would like to revise the innovation's instructional approach.	0	1	2	3	4	5	6	7
21.	I am completely occupied with other things.	0	1	2	3	4	5	6	7
22.	I would like to modify our use of the innovation based on the experiences of our students.	0	1	2	3	4	5	6	7
23.	Although I don't know about this innovation, I am concerned about things in the area.	0	1	2	3	4	5	6	7
24.	I would like to excite my students about their part in this approach.	0	1	2	3	4	5	6	7
25.	I am concerned about time spent working with nonacademic problems related to this innovation.	0	1	2	3	4	5	6	7
26.	I would like to know what the use of the innovation will require in the immediate future.	0	1	2	3	4	5	6	7
27.	I would like to coordinate my effort with others to maximize the innovation's effects.	0	1	2	3	4	5	6	7
28.	I would like to have more information on time and energy commitments required by this innovation.	0	1	2	3	4	5	6	7
29.	I would like to know what other faculty are doing in this area.	0	1	2	3	4	5	6	7

30.	At this time, I am not interested in learning about this innovation.	0	1	2	3	4	5	6	7
31.	I would like to determine how to supplement, enhance, or replace the innovation.	0	1	2	3	4	5	6	7
32.	I would like to use feedback from students to change the program.	0	1	2	3	4	5	6	7
33.	I would like to know how my role will change when I am using the innovation.	0	1	2	3	4	5	6	7
34.	Coordination of tasks and people is taking too much of my time.	0	1	2	3	4	5	6	7
35.	I would like to know how this innovation is better than what we have now.	0	1	2	3	4	5	6	7

Appendix C

Definitions of the Stages of Concern about the Innovation

Stages of Concern Definitions

Level	Label	Description
0	AWARENESS	Little concern about or involvement with the innovation is indicated.
1	INFORMATIONAL	A general awareness of the innovation and interest in learning more detail about it is indicated. The person seems to be unworried about himself/herself in relation to the innovation. She/he is interested in substantive aspects of the innovation in a selfless manner such as
2	PERSONAL	Individual is uncertain about the demands of the innovation, his/her inadequacy to meet those demands, and his/her role in the innovation. This includes analysis of his/her role in relation to the reward structure of the organization, decision-making and consideration of potential conflicts with existing structures or personal commitment. Financial or status implication of the program for self and colleagues may also be reflected.
3	MANAGEMENT	Attention is focused on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, scheduling, and time demands are utmost.
4	CONSEQUENCE	Attention focuses on impact of the innovation on students in his/her immediate sphere of influence. The focus is on relevance of the innovation for students, evaluation of student outcomes, including performance and competencies, and changes needed to increase student outcomes.
5	COLLABORATION	The focus is coordination and cooperation with other regarding the use of the innovation.
6	REFOCUSING	The focus is exploration of more universal benefits from the innovation, including the possibility of major changes or replacement with a more powerful alternative. Individual has definite ideas about alternatives to the proposed or existing form of the innovation.

Appendix D

The Levels of Use About an Innovation Questionnaire

Levels of Use Questionnaire

1. Are you using the innovation?
   - If yes, then proceed to 2
   - If no, then proceed to 10

2. What do you see as the strengths and weaknesses of the innovation in your situation? Have you made any attempt to do anything about the weaknesses?

3. Are you currently looking for any information about the innovation? What kind? For what purpose?

4. Do you ever talk with others about the innovation? What do you tell them?

5. What do see as being the effects of the innovation? In what way have you determined this? Are you doing any evaluating, either formally or informally, of your use of the innovation? Have you received any feedback from the students? What have you done with the information you get?

6. Have you made any changes recently in how you use the innovation? What? Why? How recently? Are you considering making any changes?

7. As you look ahead to later this year, what plans do you have in relation to your use of the innovation?

8. Are you working with others (outside of anyone you may have worked with from the beginning) in your use of the innovation? Have you made any changes in your use of the innovation based on this coordination?

9. Are you considering or planning to make major modifications or to replace the innovation at this time?

10. Have you made a decision to use the innovation in the future? If so, when?

11. Can you describe the innovation for me as you see it?

12. Are you currently looking for any information about the innovation? What kinds? For what purposes?

13. What do you see as the strengths and weaknesses of the innovation for your situation?

14. At this point in time, what kinds of questions are you asking about the innovation? What do you share?

15. What are you planning with respect to the innovation? Can you tell me about any preparation or plans you have been making for the use of the innovation?

16. Can you summarize for me where you see yourself right now in relation to the use of the innovation?

Appendix E

Levels of Use Rating Sheet

LEVEL OF USE RATING SHEET

Tape #: Site: Interviewer:

Date: / / 75 I.D. #: Rater:

Level	Knowledge	Acquiring Information	Sharing	Assessing	Planning	Status Reporting	Performing	Overall LoU
Non-Use	0	0	0	0	0	0	0	0
D.P. A								
Orientation	I	I	I	I	I	I	I	I
D.P. B								
Preparation	II	II	II	II	II	II	II	II
D.P. C								
Mechanical Use	III	III	III	III	III	III	III	III
D.P. D-1								
Routine	IVA	IVA	IVA	IVA	IVA	IVA	IVA	IVA
D.P. D-2								
Refinement	IVB	IVB	IVB	IVB	IVB	IVB	IVB	IVB
D.P. E								
Integration	V	V	V	V	V	V	V	V
D.P. F								
Renewal	VI	VI	VI	VI	VI	VI	VI	VI
User is not doing:	ND	ND	ND	ND	ND	ND	ND	
No information in interview:	NI	NI	NI	NI	NI	NI	NI	

Is the individual a past user? Yes No

How much difficulty did you have in assigning this person to a specific LoU? None 1 2 3 4 5 6 7 Very much

Comments about interviewer --

General Comments --

Appendix F

Definitions of the Levels of Use and Categories of Use

Level of Use Definitions

The Seven Levels of Use of the Innovation

Level	Description
Level 0:	Non-use: State in which the user has little or no knowledge of the innovation, no involvement with the innovation, and is doing nothing toward become involved.
Level I:	Orientation: State in which the user has acquired or is acquiring information about the innovation and/or has explored or is exploring its value orientation and its demands upon user and user system.
Level II:	Preparation: State in which the user is preparing for first use of innovation.
Level III:	Mechanical Use: State in which the user focuses most effort on the short-term, day-to-day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than client needs. The user is primarily engaged in a stepwise attempt to master tasks required to use the innovation, often resulting in disjointed and superficial use.
Level IVa:	Routine: Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving innovation use or its consequences.
Level IVb:	Refinement: State in which the user varies the use of the innovation to increase the impact on clients within immediate sphere of influence. Variations are based on b oth short- and long-term consequences for clients.
Level V:	Integration: State in which the user is combining own efforts to use the innovation with related activities of colleagues to achieve a collective impact on clients within their common sphere of influence.
Level VI:	Renewal: State in which the user re-evaluates the quality of use of the innovation, seeks major modifications of or alternative to present innovation to achieve increased impact on clients, examines new development in the field, and explored new goals for self and the system.

The Eight Categories of Levels of Use

Category	Description
KNOWLEDGE	That which the user knows about the characteristics of the innovation, how to use it, and consequences of its use. This is cognitive knowledge related to using the innovation, not feeling or attitudes.
ACQUIRING INFORMATION	Solicits information about the innovation in a variety of ways, including questioning resource persons, corresponding with resource agencies, reviewing printed materials, and making visits
SHARING	Discusses the innovation with other. Shares plans, ideas, resources, outcomes, and problems related to use of the innovation.
ASSESSING	Examines the potential or actual use of the innovation or some aspect of it. This can be a mental assessment or can actual collection and analyses of data.
PLANNING	Designs and outlines short- and/or long-range steps to be taken during process of innovation adoption (i.e., aligns resources, schedules activities, meets with others to organize and/or coordinate use of the innovation).
STATUS REPORTING	Describes personal stand at the present time in relation to use of the innovation
PERFORMING	Carries out the actions and activities entailed in operationalizing the innovation.

Appendix G

Mathematics Content Test

Mathematics Content Test

Instructions: Please answer all of the questions to the best of your ability. You may not know the answer to *any* of these questions -- that's ok! Just do your best. Please use the additional paper provided to show all of your work and clearly number your calculations to show which question number they go with. Your results are anonymous and confidential. Please don't write your name on the papers that you turn in so we cannot identify you individually. The results of this test will only be reported as a group – we will not be reporting the score of individuals.

---

1. Write 349 in expanded form.

ANSWER: 300 + 40 + 9

2. Write 74.85 in expanded form.

ANSWER: 70 + 4 + .8 + .05 **or**

70 + 4 + 8/10 + 5/100

3. Write 564 in distributive form.

ANSWER: 5(100) + 6 (10) + 4(1)

4. Write 12.592 in distributive form.

ANSWER: 1(10) + 2(1) + 5(1/10) + 9 (1/100) + 2(1/1000) **or**

1(10) + 2(1) + 5(.1) + 9 (.01) + 2(.001)

5. Write 4.285 in exponential form.

ANSWER: $4(10^0) + 2(10^{-1}) + 8(10^{-2}) + 5(10^{-3})$

Appendix H

Rachel McAnallen's Curriculum Vitae

CURRICULUM VITAE

RACHEL R. McANALLEN

Rachel R. McAnallen
701 Cottage Grove Road
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rmathmania@aol.com
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Earned degrees and additional work:

BS — Slippery Rock State Teacher's College, 1958
Majors: Mathematics and Social Studies

MS — Adelphi University, 1968

University of Vermont, Lesley College, Johnson State College

Fifty-two credits in mathematics, education, curriculum and administration 1969 – 1982

University of Vermont

Enrolled in Administrative Leadership Program leading to Ed.D. degree, 1983

Professional Experiences:

2000-Present Partner of Aeon Knowledge, Inc.

1990-2000 Founder and President of the McAnallen Consulting Services Corp.

1984-2002 Founder and President of the Institute for Math Mania

1984-present Model teaching / In service trainer for the following:

State of Vermont – Thirty districts – over 100 schools

State of Maine – Fourteen districts

State of New Hampshire – Eight districts

State of New York – Ten districts

State of Massachusetts – Seven districts

State of Connecticut – Six districts

State of Delaware – Seven districts

States of Arizona, California, Colorado, Florida, Georgia, Hawaii, Indiana, Illinois, Idaho, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Pennsylvania, Rhode Island, Texas, Tennessee, Utah, Virginia, Washington, West Virginia, Territory of Virgin Islands - St Croix, St Thomas

1983-84 Leave of absence to pursue ED.D degree

1983/Dec Interim Principal, Alberg Elementary School, Alberg, VT

1979-83 Associate Principal, Harwood Union High School, Moretown, VT

1979-83 School Board Member, U-32 school district, East Montpelier, VT

1958-79 Teacher of math courses grades 7-12 in states of Pennsylvania, New York and Vermont

1972-1979 Mathematics Department Head, Vermont

Related professional experiences:

1997-1998 Staff development presenter, Durham School Board, Ontario, Canada

1996-1999 Staff development presenter. Government of the Virgin Islands, St. Croix, St. Thomas

1995-1997 Visiting lecturer, Schmerenbeck RAU Educational Centre, Craighall Primary School, St Peter's Preparatory School, Johannesburg, South Africa

Visiting teacher, Weiler Farm School, Orange Farm School, Makhoarane Primary, Soweto, South Africa

1994-1998 Instructor and coordinator of "Math Problem Solving Institute" between Norwich University and IMM

1986-1993	Instructor of "Math Problem Solving Institute" EDSS 200, University of Vermont
1984-present	Instructor of "Math Strands for Gifted and Talented" Confratute, University of Connecticut
1986	Instructor of "Math Without Fear" PSTG 10, University of Vermont
1980	Instructor "Women and Math Anxiety," Goddard College, Plainfield, VT
1976-1992	Instructor: "Professional Problems in Education: Improving Basic Math Instruction" EDSS 380, University of Vermont
1975-1994	Staff development trainer for programs sponsored by Adult Basic Education, Resource Agent Program, Early Elementary Education Institute, Vermont Department of Education
	Bilingual/Multicultural Education Program, New Hampshire Department of Education
	Department of Educational and Cultural Services, Maine
	Department of Education Tri-State Bilingual Parent Training Program, St Michael's College, VT
	Northeast Equal/Northeast Regional Exchange Inc., Chelmsford, MA
	Delaware Summer Math Institute, Delaware Dept. of Education.
1980-1993	Trainer for parents and teachers in "Family Math" program

Publications, presentations, keynotes:

2004	Keynote speaker/presenter Lagniappe, Louisiana
2004	Keynote speaker CMCSS CA Math Conference
2004	Math workshop presenter Nebraska Gifted Conference
2004	Keynote speaker Montana Math Conference

2004	Keynote speaker Iowa Gifted Conference
2004	Presenter at CEESA conference Budapest, Hungary
2004	Keynote speaker/presenter AGATE conference, Arkansas
2004	Keynote speaker/presenter Winter EduFest, Coeur d'Alene
2003	Workshop presenter national convention NAGC, Indianapolis
2003	Keynote speaker/presenter, Montana Gifted Conference
2003-04	Presenter EduFest, Boise
2002	Keynote speaker/presenter EduFest, Boise
2002	Keynote speaker/presenter national convention NAGC,Denver
2001	Keynote speaker, Georgia gifted conference
2001	Major presenter national convention NAGC, Cincinnati
2001/2002	Workshop presenter at Illinois gifted convention
2001	Keynote speaker at Louisiana gifted conference
2000	Major presenter NAGC, Atlanta
1999-present	Creator of math publication – Wonderful Ideas
1999	Keynote speaker national convention NAGC, Albuquerque
1997	Workshop presenter at national convention NCTM, Minneapolis,
1996	Workshop presenter at national convention NCTM, San Diego
1995	Workshop presenter at national convention NCTM, Indianapolis
1995	Published math book "Action Fractions"
1995	Workshop presenter national convention NAGC, Salt Lake City
1996	Workshop presenter at national convention for NAGC, Miami

1994	Workshop presenter at national convention NCTM, Seattle
1985-present	Workshop presenter at many regional NCTM conferences
1994-present	Keynote speaker Confratute at University of Connecticut

VITA

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PROFESSIONAL ASSOCIATIONS

American Psychological Association
American Evaluation Association

EDUCATIONAL EXPERIENCE

2006 Ph.D. Psychology, Utah State University, Logan, Utah

2003 M.S., Psychology, Utah State University, Logan, Utah

1998 B.A., Psychology, University of South Alabama, Mobile, Alabama

TEACHING EXPERIENCE

2002-2005 Co-instructor for Psychology 1010, Introduction to Psychology, Distance Education

2000 Psychology 3500, Research Methods and Scientific Thinking

1998-2000 Psychology 1210, Human Adjustment

PRESENTATIONS

Randolph, J. J., & Edmondson, R. S. (2003, November). *Using the Binary Effect Size Display: A Method of Presenting the Magnitude of Effect Sizes to the Evaluation Audience.* Poster presented at the American Evaluation Association, Reno, Nevada.

Edmondson, R. S., (2000, November). *Performance Measurement for Accountability of Undergraduate Psychology Programs: Moving from Promise to Meaningful Implementation.* Multipaper, American Evaluation Association, Waikiki, Hawaii.

Ferguson, T. J., Edmondson, R. S., & Gerity, D. S. (2000, October). *Pain with a purpose: Anticipatory shame and guilt in daily dilemmas.* Invited paper, Society for Experimental Social Psychology. Atlanta, GA.

Ferguson, T. J., Barrett, K. C., Edmondson, R. S., Eyre, H. L., Ashbaker, M., Grotepas-Sanders, D., Van Wagoner, R., & Hawkins, S. (2000, February). *Adaptive and maladaptive features of shame.* Society for Personality and Social Psychology, Nashville TN.

ARTICLES

Randolph, J.R., Edmondson, R.S. (2005). *Using the Binomial Effect Size Display (BESD) to Present the Magnitude of Effect Sizes to the Evaluation Audience.* Practical Assessment Research and Evaluation, 10(14).

PROFESSIONAL EXPERIENCE

2005-present	Senior Research Associate, Spectrum Consulting
2001-2004	Evaluator Worldwide Institute for Research and Evaluation
2003-present	Director of Information Technology, PMGEAR
2002-present	Instructor, Psychology 1010, Utah State University
Fall 2000	Instructor, Psychology 3500, Utah State University
1998-2000	Instructor, Psychology 1210, Utah State University