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

R. Shawn Edmondson, Ph.D.
Spectrum Education Group
email: sedmondson@spectrumedu.com

Abstract

A mixed-methods research design was used 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 a telepresence-enabled model of teacher professional development has potential to be a highly effective method of training teachers.

Introduction

In 1981, United States Secretary of Education Terrel H. Bell announced that "…something is seriously remiss in our educational system" [29]. He subsequently appointed the bipartisan National Commission on Excellence in Education (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.

Unfortunately, since this assertion was made, the situation has not greatly improved. Despite an estimated $430 billion spent on education annually, the U.S. educational system is still performing abysmally [23]. 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 [15]. More recently, the 2000 National Assessment of Educational Progress (NAEP) found that 35% of 12th graders scored below the "basic" level and the 2003 NAEP found that 23% of 4th grade students and 32% of 8th grade students scored below the "basic" level. With so much that needs to be done to improve the 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* [30,17,7,31]. Teacher professional development is defined as ongoing, intentional, systemic educational and training opportunities available to educators in their schools and districts [17].

However, many current teacher professional development activities are criticized for having little impact on student outcomes [17,31,25]. This is partly because they fail to incorporate key components of effective adult learning such as modeling, observation, and feedback [8,13,36,28]. 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 [7,5,34,17]. 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 investigates such an approach.

Typically, teacher professional development presents abstract pedagogical concepts independent of an authentic context, ignoring the evidence that the ability to learn and use information is dependent upon context [16,33] to the degree that an individual integrates the context and the learning [12]. The *cognitive apprenticeship model of teacher professional* *development* presented in this research follows a three-stage learning process [6]. 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 his classroom with the 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: one, they must interact a great deal, and, two, 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. 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 and school districts rarely have the resources to locate, train, and evaluate these staff [24,37]. The U.S. Department of Education [34] states 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 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 gaze [27,28,35]. 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 [2,3,22,32,1,10,36,24]. If 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 with another". Essentially, what is required is a technology that achieves *telepresence* and *social presence* [4, 18].

Telepresence has been defined as "a psychological state or subjective perception in which, even though all or part of an individual's current experience is generated and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience" [18]. Similarly, social presence has been defined as occurring when "all or part of a person's perception fails to accurately acknowledge the role of technology that makes it appear that s/he is communicating with one or more other people or entities" [18].

In the context of enabling cognitive apprenticeship for this research, the degree to which an individual's perception failed to acknowledge the role of technology in their experience was relatively less important than degree to which the user was able to perceive and socially interact with people in a distant location. That is, the individual must be able to clearly see and hear and to be seen and heard at the distant location so that they may engage in communication with others. However, it was important that the technology not present an *obtrusion* (due to its inability to reduce the user's perception of its role) that impeded perceptual presence or social presence. The research described herein describes the evaluation of a cognitive apprenticeship model of teacher professional development enabled via technology specifically designed to enable this degree of telepresence.

Method

Purpose and Research Hypotheses

The primary objective of this research was to evaluate the effectiveness of Telepresence-Enabled Apprenticeship Model of Professional Development (TEAM-PD) by comparing it to a traditional, in-service workshop model of teacher professional development in terms of impact on teacher behavior and student outcomes. The experimental and comparison groups of 5^{th} and 6^{th} grade teachers participated in the same traditional, in-service 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 in-service 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. 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 [20]. Quantitative findings were be judged to be statistically significant if their associated *p*-values were less than .05.

The participants in the study consisted of two small groups 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 5th and 6th grade teachers at an elementary school located in northern Utah. The comparison group of teachers consisted of five self-contained 5th and 6th 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).

Telepresence equipment

The equipment used in this research differs from legacy videoconferencing in that it used 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 [39]. As discussed in the introduction, the specific technology used in this research was selected for it's ability to enable a remote individual to clearly see and hear and to be seen and heard at a distant classroom so that they may engage in communication with others. Although measures of social presence were not utilized in this research, the degree to which this level of telepresence was achieved was inferred by its ability to successfully enable cognitive apprenticeship and affect teacher and student outcomes (see the Conclusions section for discussion about social presence measurement).

Three pieces of telepresence equipment were used to enable TEAM-PD: the Telepresence Center, the Virtual Observer, and the Virtual Teacher. This equipment was custom built by Digital Video Enterprises, Inc. specifically for this research.

The purpose of the Telepresence Center (TC) was to enable teachers to conference with a remote consultant to discuss their implementation of her instructional strategies (see Figure 1). With the consultant sitting in front of a TC unit at her home in Denver, Colorado and a teacher sitting in front of a TC unit in northern Utah, teachers received corrective and directive feedback, suggestions, and instructional advice from the consultant as if they were in the same room sitting across a table from each other. Document cameras allowed those communicating to share paperwork or mathematical manipulatives.

***Figure 1*. The Telepresence Center.**

The Virtual Teacher (VT) allowed the remote consultant to model her instructional strategies for the experimental group teachers in their classrooms (see Figure 2). The consultant appeared as a holographic image displayed so that she appeared to be standing behind a podium at the front of the classroom. 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, the consultant was able to display manipulatives through the VT document camera.

The Virtual Observer (VO) allowed the consultant to capture video of teachers from the experimental group as they implemented the instructional strategies they had previously learned (see Figure 3). The VO is a wheeled locker containing an auto-tracking camera. As the camera automatically followed the teachers around the classroom it recorded the teaching session onto a DVD.

***Figure 2.* The Virtual Teacher**

Dependent Measures

The multi-methods 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 [18].

Together, these instruments provide an assessment of the degree to which and the fidelity with which teachers in the experimental and comparison were implementing the remote consultant's instructional strategies. The final quantitative instrument was a mathematics test designed to evaluate students' mastery of the content presented by the consultant. Qualitative data were collected primarily via video recordings of telepresence interactions between the consultant and teachers and students in the experimental group.

***Figure 3.* The Virtual Observer**

The students of the teachers in the experimental and comparison conditions were administered pre- and post-tests to assess their understanding of the mathematical concepts associated with the consultant's instructional strategies. This 5-item test was created by the consultant to assess understanding of a variety of mathematical concepts. The test required respondents to generate the answers—it was not multiple-choice.

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 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 [14]. The categories—consisting of code labels, code definitions, and code examples—was 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.

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 [14]. 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.

Procedures

The research began when both the experimental and comparison groups of teachers participated in a workshop administered by the consultant *in person*. This two-day workshop was held in a conference room at the school district's central office. The consultant, a renowned math expert, presented to approximately 80 teachers from throughout the school district an instructional strategy designed to teach students a 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 strategy in their classrooms.

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 the consultant. The teachers returned to their classrooms with the implicit understanding that they were to implement the instructional strategy into their mathematics lessons.

Teachers in the experimental condition then began implementing TEAM-PD by using the telepresence equipment to work with the consultant at their school in the cognitive apprenticeship model. Before the end of the school year, the consultant was able to model her instructional strategies in each of the 5th and 6th grade teachers' classrooms. On the first day of the subsequent school year, the consultant picked up where she had left off with TEAM-PD, continuing to work with the experimental teachers in individualized cognitive apprenticeships. Throughout the entire post-workshop phase of the research, the *only* contact that the consultant had with the experimental teachers was via telepresence. From September through November of the school year, the consultant 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 the consultant and the teachers. Shortly after the experimental group began implementing the TEAM-PD model, both the experimental and comparison groups were administered the Stages of Concern questionnaire. After several more weeks, both groups of teachers completed Levels of Use interviews.

To control for the additional amount of contact time that the experimental teachers spent with the consultant, the teachers in the comparison group participated in a follow-up workshop. Although the format of this workshop was essentially the same as the initial workshop (e.g., one-to-many, non-individualized instruction), the consultant 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 the consultant, approximately four more hours per teacher than the experimental group spent interacting with her.

The final data collection for the research occurred in November of the school year. Teachers in both groups were administered a second Stages of Concerns questionnaire, a second Levels of Use interviews, and a mathematics content post-test.

Results

This research utilized several dependent measures—including the Stages of Concern instrument, the Levels of Use instrument, video-recorded observations, and a student mathematics content test. The results are organized around each of these measures.

Stages of Concern

The Stages of Concern (SoC) instrument describes the feelings, thoughts, and information needs of the innovation "adopter" with Stages ranging from 0 (non-user) through 6 (experienced user)

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. It was expected that both the comparison and the experimental groups' SoC scores would resemble those of the *non-user* (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).

The first measurement of the SoC was administered in the early stages of the research (see Figure 4). 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 the consultant for each teacher in the experimental group.

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. The experimental group's averaged SoC score profile is generally consistent with that of the *non-user*, 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" [18]. This profile pattern indicates a substantial degree of doubt and resistance towards the innovation.

After the consultant'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 had alternative innovations in mind that they believed 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" (Figure 4). 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.

In sum, although both the experimental and comparison groups' profiles are indicative of *non-use*, the comparison group's profile is consistent with significantly more resistance to the adoption of the consultant's instructional strategies.

The second measurement of the SoC was administered at the end of the study (see Figure 5). A profile comparison was conducted to determine if a different analysis perspective would support or conflict with the peak analysis.

As with the SoC Measurement #1, p*rofile interpretation* was used to analyze the SoC Measurement #2 data. This analysis utilizes graphs of the SoC scores of teachers' group average scores. 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" [18, p. 40]. This indicates that these users were beginning to address issues related to the efficiency, organization, management, scheduling, and time demands of the consultant'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 the consultant's instructional strategies.

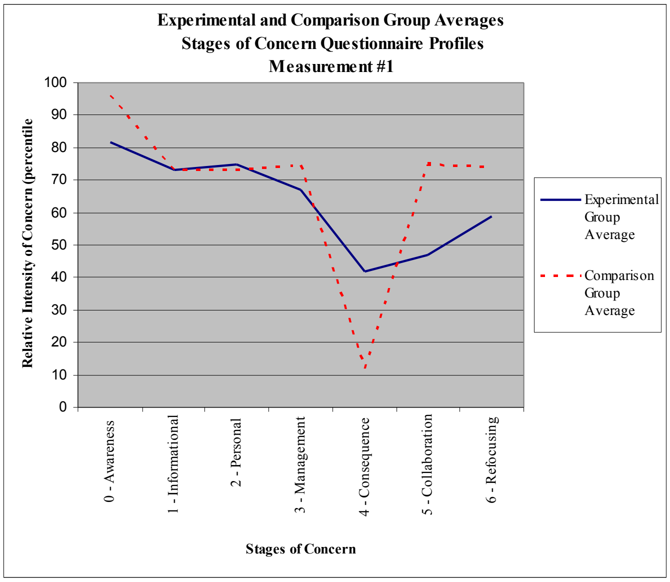

Figure 4. **Experimental and comparison group average SoC profiles, Measurement #1**

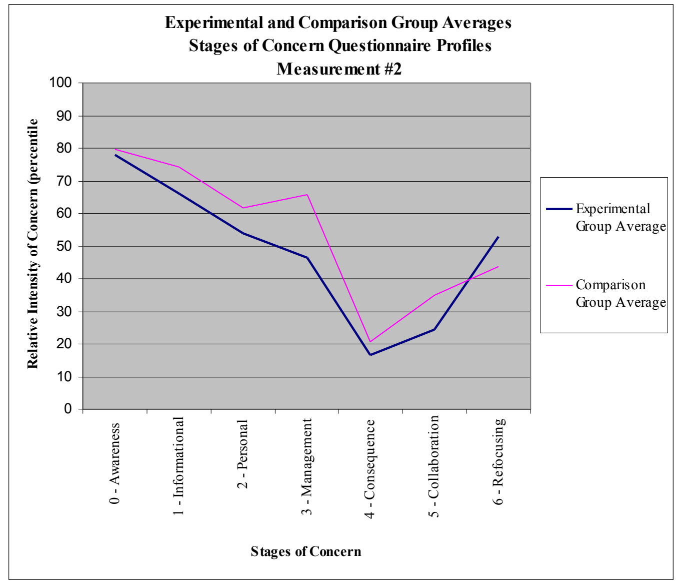

Figure 5. **Experimental and comparison group averaged SoC profiles, Measurement #2**

One difference is that the "negative one/two split" observed in both groups' Measurement #1 scores is no longer apparent. 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.

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 the consultant's instructional strategies may be progressing faster than those of the experimental group. However, making valid interpretations of between-group differences is difficult because the within-groups variability was 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, conclusions from these data are tentative.

Levels of Use

Recall that the Levels of Use (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 Levels of Use identified by this instrument focuses on behavior that is characteristic of the innovation user at a particular stage of development.

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 at the beginning of the school year.

Figure 6 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 the consultant'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. 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 the consultant's instructional strategies and exploring the demands it would place upon them.

At the end of the study, teachers in both groups were administered a second LoU interview (Figure 7). As predicted, the LoU scores of the comparison group teachers did show *some* development in their LoU of the instructional strategies but, as predicted, none of them moved beyond Level III. Four of the comparison group teachers received a Level III score and one teacher received a Level II score.

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.

Figure 6
Experimental and Comparison Groups' Overall LoU Ratings – Measurement #1

		Overall Level of Use							
	Teacher	**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						

One experimental group teacher reached Level IVb – refinement. This indicated that this teacher was varying the use of the consultant'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.

Overall, 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.

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) is "off", but it cleans up." This comment refers to a technical issue regarding the document camera used by the consultant. 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, " [the consultant] 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 consultant 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.

Figure 7
Experimental and Comparison Groups' Overall LoU Ratings – Measurement #2

Overall Level of Use

	Teacher	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				

As one teacher put it, "[the consultant's] instructional strategies require good classroom management... [she] modeled how to manage the classroom." This observation / feedback loop provided by TEAM-PD allowed teachers and students to attempt to implement what the consultant taught and then receive direct acknowledgement of their successes and failures so that they could be addressed. One of the teachers said, "The primary feedback the teacher and the students receive about their success is feedback from the consultant. [She] has said, yes, you have this, let's move on."

Coding of Video Data Content

After teachers in the experimental group had been working with the consultant for a several weeks, they each sat down and conferenced with via telepresence. These conferences were intended to be unstructured discussions between the consultant and the teachers in which each teacher could privately ask the consultant 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. These conferences were recorded and categorized to verify the implementation of the independent variable and to observe changes in the distribution of time.

Several characteristics of the distribution of time during the conferences are notable. First, 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 non-instructional content. Specifically, the largest category of discussion was instructional technique (61%).

It was also notable that the time spent delivering content knowledge to the teachers increased to 20%. This was because the consultant, 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 teachers 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, the consultant 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 spend 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 the consultant's initial workshop in January, students in both the experimental and comparison groups completed a mathematics concepts test developed by the consultant. Near the end of the study timeline, the students completed a second mathematics content test.

Figure 9
Students' Mathematics Content Pre and Post Test Performance.

		N	*M*	*SD*	*t*	*p*	*d*
PRE-TEST	Experimental Group	161	0.96	0.75	-1.06	0.29	-0.12
	Comparison Group	121	1.05	0.71			
POST-TEST	Experimental Group	123	3.2	1.35	13.56	<.001	1.72
	Comparison Group	125	1.25	0.86			

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

Because of the similarity of the groups' pre-test scores, they were not included as a covariate in the post-test 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 post-test 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 and 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 effect sizes show that that the comparison group's test score improvement was only ¼ 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 post-tests are presented in Figure 9.

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 [14]. 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 the consultant's instructional strategies.

Theme 1: The Evaluative Nature of Cognitive Apprenticeship. Throughout the conferences between the teachers and the consultant there were 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 the workshop was followed-up with face-to-face interactions with the consultant herself, teachers felt compelled to learn and enact the instructional strategy. As a review of the literature suggests, teachers participating in traditional workshops are rarely held accountable for their understanding or enactment of the learned content.

Statements provided by the teachers indicated that the 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 the consultant again, face-to-face, to discuss the workshop content created an expectancy effect.

Theme 2: The Power of Observation. The conversations between the consultant and the teachers also highlighted the important benefits of the observation component of cognitive apprenticeship. Prior to meeting with each teacher via telepresence, watched the teacher's most recent observation DVD recorded by the Virtual Observer. 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.

The consultant'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 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.

Although this concern about physical appearance was likely genuine to some degree, it seems likely that these concerns also indicate deeper concerns about being evaluated and judged as professionals. There was some indication, however, that the Virtual Observer was less obtrusive than a live observer would have been. Teachers indicated that they were more comfortable being observed by the Virtual Observer than they would have been being observed by a visitor in their classroom.

The importance of these observations is supported by the distribution of time spent during the conferences between and the teachers. In the first round of conferences, prior to first observing the teachers' DVDs, only 5% of the conversation was dedicated to providing mathematics instruction directly to the teachers. After watching these DVDs it became apparent to 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%.

Theme 3: The Power of Modeling. By using the Virtual Teacher, the consultant was able to model her instructional strategies to teachers with their students in their classrooms. The conversations between the consultant and the teachers illustrate several important aspects of the modeling component of cognitive apprenticeship. First, they illustrate the complex nature of teaching and the importance of an expert being able to model and explicate the necessary behaviors and cognitions. Secondly, although was directly teaching the students, she actively involved the teacher by providing instruction to her as well. Throughout the TEAM-PD process the consultant 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.

Theme 4: 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 the consultant to interact with each teacher individually and in private to address the needs specific to their background, their classroom, and their individual students. When the consultant began conferencing with the teachers individually, she often commented on the ability of this model to enable differentiated instruction.

In an interview with the consultant 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. 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:

> *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.*

Conclusions

This research clearly demonstrates that using telepresence to enable a model of cognitive apprenticeship is *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 the consultant, teachers, and students established that the equipment was successfully used for dozens of hours and that the overwhelming 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. 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 the consultant and the experimental group teachers and students revealed that principal components of cognitive apprenticeship were well-received and were perceived by the consultant 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.

Limitations

It is important to note several limitations associated with this research methodology and results. First, the quasi-experimental multi-methods 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 the consultant'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 the consultant and to what degree is was a result of the professional development delivered to the experimental group teachers.

Finally, this research did not employ a specific measure of social presence that would have established the degree to which the consultant experienced social presence in the remote classrooms. Rather, the success of the technology in enabling social presence was inferred based on teacher and student outcomes. Utilizing a valid and reliable measure of social presence would have allowed for the determination of the degree to which this variable impacted these outcomes. Future investigations of telepresence-enabled cognitive apprenticeship should include valid and reliable measurements of this important intervening variable [4].

References

1 Aguinis, H., Simonsen, M.M., & Pierce, C.A. (1998). Effects of nonverbal behavior on perceptions of power bases. *Journal of Social Psychology, 138,* 455-469.

2 Argyle, M. (1969). *Social interaction.* London: Methuen.

3 Argyle, M. & Dean, J. (1965). Eye contact, distance, and affiliation. *Sociometry, 28*, 289-304.

4 Biocca F., Harms C., & Burgoon, J. K. (2003). Toward a more robust theory and measure of social presence: Review and suggested criteria. Presence: Teleoperators and Virtual Environments, 12(5), 456-480.

5 Bull, B., Buechler, M., Didley, S., & Krehbiel, L. (1994). *Professional development and teacher time: Principles, guidelines, and policy options for Indiana*. Bloomington, IN: Indiana Education Policy Center, School of Education, Indiana University. ED384112

6 Collins, A., Brown, J. S., & Newman, S. E. (1987). *Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics* (Technical Report No. 403). BBN Laboratories, Cambridge, MA. Centre for the Study of Reading, University of Illinois. January, 1987.

7 Corcoran, T. C. (1995). Transforming professional development for teachers: A guide for state policymakers. Washington, DC: National Governor's Association. ED384600.

8 Consortium for Policy Research in Education (1996). *Public policy and school reform: A research summary*. Philadelphia: Author.

9 Darling-Hammond, L. (2000). “Teacher quality and student achievement: A review of state policy evidence.” Retrieved November 24, 2004 from http://epaa.asu.edu/epaa/v8n1/
10 Droney, J.M., & Brooks, C.I., (1993). Attributions of self-esteem as a function of duration of eye contact. *Journal of Social Psychology, 133,* 715-755.
11 Eich, E. (1985). Context, memory, and integrated item/context imagery. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 1l,* 764-770.
12 Frechtling, J.A., Sharp, L., Carey, N., & Baden-Kierman, N. (1995). *Teacher enhancement programs: A perspective on the last four decades.* Washington, DC: N ational Science Foundation Directorate for Education and Human Resources.
13 Fullan, M., & Stiegelbauer, S. (1991). *The new meaning of educational change.* Toronto: The Ontario Institute for Studies in Education.
14 Glaser, B.G., Strauss, S.L. (1967). *The discovery of grounded theory: Strategies of grounded research.* Wiedenfeld and Nicholson. London, UK.
15 Goals 2000: Educate America Act. U.S. Congress, 1994.
16 Godden, D. R., & Baddeley, A.D. (1975). Context-dependent memory in two natural environments: on land and under water. *British Journal of Psychology, 66,* 325-331.
17 Guskey, T.R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.
18 Hall, G.E., George, A.A., Rutherford, W.L. (1998). *Measuring stages of concern about the innovation: A manual for use if the SoC questionnaire.* Southwest Educational Development Laboratory. Austin, TX.
19 International Society for Presence Research. (2000). The Concept of Presence: Explication Statement. Retrieved August 17, 2007 from http://ispr.info/
20 Johnson, R.B., & Onwuegbuzie, A.J. (200). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33;* 14-26.
21 Joyce, B. & Showers, B. (1980). Improving inservice training: The messages of the research. *Educational Leadership, 37* (5), 390-392.
22 Kendon, A. (1967) Some Functions of Gaze-Direction in Social Interaction. *Acta Psychologica, 26*, 22-63.
23 Kirkpatric, D.W. (2003). A nation still at risk. *The Heartland Institute, April, 2003*. Retrieved from http://www.heartland.org/Article.cfm?artId=11776.
24 Kleinke, C.L., Staneski, R.A., & Berger, D.E. (1975). Evaluation of an interviewer as a function of interviewer gaze, reinforcement of subject gaze, and interviewer attractiveness. *Journal of Personality and Social Psychology, 13,* 218-223.
25 Lewis, L., Parsad, B., Carey, N., Bartfai, N., Farris, E., Smerdon, B., & Green, B. (1999). *Teacher quality: A report on the preparation and qualifications of public school teachers* (NCES 1999-080). Washington, DC: National Center for Education Statistics. Available online: http://nces.ed.gov/pubs99/1999080.pdf
26 Loucks-Horsely, S., Hewson, P.,Love, N.,Stiles, K.,(1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA Crown Press.
27 McNelley, S. H. (2000). The significance of eye contact while desktop videoconferencing (Doctoral Dissertation, United States International University, 2000). *Dissertation Abstracts International, UMI 9999473.*
28 Mullens, J., Leighton, M., Laguarda, K., and O’Brien, E. (1996). Student Learning, Teacher Quality, and Professional Development: Theoretical Linkages, Current Measurement, and Recommendations for Future Data Collection. (NCES 96–28). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.
29 National Committee on Excellence in Education, Department of Education (1983). A Nation at Risk: The Imperative for Educational Reform: A Report to the Nation and the Secretary of Education, United States Department of Education
30 No Child Left Behind Act of 2001, P.L. 107-110 (2002). Retrieved on September 17, 2002, from h http://www.ed.gov/legislation/ESEA02/107-110.pdf.
31 Rebora, A. (2004, March). Professional development. Retrieved November 24, 2004 from http://www.edweek.org/context/topics/issuespage.cfm?id=16
32 Rose, D. A., & Clarke, P. (1995). A review of eye-to-eye videoconferencing technique. *BT Technology Journal, 13*; 127-131.
33 Smith, S. M., Glenberg, a., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition, 6,* 342-353.
34 U.S. Department of Education. Does Professional Development Change Teaching Practice? Results from a Three-Year Study (2000). Retrieved online, November 24, 2004,at http://www.ed.gov/rschstat/eval/teaching/epdp/index.html.
35 Weinstein, I.M., Lichtman, H. S. (2005). *Emerging Technologies for Teleconferencing and Telepresence.* Wainhouse Research.
36 Wheeler, R.W., Baron, J.C., Michell, S., & Ginsburg, H.J., (1979). Eye contact and the perception of intelligence. *Bulletin of the Psychonomic Society, 13*; 101-102.
37 Wong, K., & Nicotera, A. (2003). *Enhancing Teacher Quality: Peer coaching as a professional Development Strategy. A preliminary Synthesis of the literature* (Publication Series No. 5): Vanderbilt University.