

Enhancing the practice of physics teachers: Mechanisms for the generation and sharing of knowledge and understanding in collaborative action research

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We are in an era of change and ferment in science education. Large scale reform efforts have been underway for several years on the national level (e.g. Scope, Sequence and Coordination and Project 2061), new standards for the teaching, learning and assessment of science are near completion (NRC, 1994), and many of the states are developing innovative curriculum frameworks for science (e.g., CADOE, 1989; MADOE, 1994). While these efforts could depend solely on a new cadre of science teachers educated according to new standards for teacher education, unless these reform efforts are willing to wait a biblical forty years for a new generation, they are dependent on the successful inservice education of experienced science teachers.

Most of the attempts to change the practice of experienced science teachers has consisted of outside experts "training" teachers in new practices (e.g., Joyce and Showers, 1983). More recently teachers have been trained to be the outside experts to train other teachers (e.g., the Physics Teacher Resource Agent project of the American Association of Physics Teachers). While these types of inservice education can be effective, they make little use of the expertise of the teachers being "inserviced." In this study I have looked at the use of action research as a form of science teacher inservice education that relies on the experiences and knowledge of the participating teachers. I have sought to better understand the ways in which science teachers use their own experiences and those of their colleagues to become better teachers as a way to answer the question, "How does teacher knowledge originate among practicing teachers?"

I have done this by encouraging a group of physics teachers to engage in collaborative action research on their own practice. In doing so, my research question became, more specifically, "What are the ways that teachers' knowledge about teaching and their educational situations grow when they are engaged collaboratively with other teachers in inquiry on their own practice?" Implicit in this question is the acknowledgment that science teachers are involved in professional practice, and are, therefore, interested in "getting smarter" about teaching to do it better.

In this paper I report on a three-year study of a group of physics teachers engaged in action research. It is important to note that while the physics teachers were engaged in action research, my study is not an example of action research. I describe my methodology and methods later in this paper. In the next section I begin with a review of action research and how it relates to the inservice education of teachers and the reform of science education. I follow that with a description of the project and the teachers involved to provide context for readers. I return to the questions that I have posed here and examine the ways that others have addressed the issues of teacher knowledge and how it is generated and shared. I then turn to the case study and the findings that arise from it of

the mechanisms used by teachers for the generating and sharing of knowledge about teaching. Finally, I turn to the implications that this has for practice, policy, and research.

Action Research and Educational Reform

In this section I review the history of action research in the US and its implications for the reform of science education. I begin by noting that many of the attempts to reform science education have used center-periphery or transmission models for development, dissemination, and implementation (Clandinin and Connelly, 1992; Snyder, Bolin, and Zumwalt, 1992). In these models, a group of university researchers, often in conjunction with science teachers, develop instructional materials and methods, which they then disseminate to teachers through publication and inservice education. While on paper these models appear to be highly efficient -- expertise is located centrally -- the models assume that the instructional materials and methods can be transmitted as if through a conduit (Reddy, 1979). As it turns out, the transmission lines are exceedingly noisy, and reform efforts that rely on center-periphery models have had little success on American schooling (Cuban, 1993).

In recent years, a different model of educational reform has begun to emerge in the US. It relies on teachers engaging in an activity known as action research or teacher research (Lytle and Cochran-Smith, 1990). In this model, teachers are assumed to have expertise at teaching their subjects in schools. Using a variety of methods, they inquire into their classrooms and schools to improve the educational experience of their students. This parallels the conception that Kurt Lewin had of action research as a way for social workers to use research to further social change (Noffke, 1990). While Lewin worked with social workers in the 1930s, action research had little influence on American schooling until the 1950s when it was taken up by Steven Corey of Teachers College, Columbia University (Corey, 1953). Corey saw action research as a way for teachers to engage in legitimate educational research, and as a way to bring the then new scientific study of education into the classroom (Noffke, 1990). Although under Corey's influence there was great interest in action research in the 1950s and into the 1960s, by the next decade it had nearly died out as a research methodology in the US.

Action research re-emerged in the US in the mid-1980s in two forms. One, which I call classroom action research (CAR), lays out a conception of action research as a problem solving process that relies on data collection and analyses to solve those problems (Feldman, 1994). [See Altrichter, Posch and Somekh (1993), Carr and Kemmis (1986), Elliott (1991), Sagor (1992), and Winter (1989) for examples of this form of action research.] CAR originated in Britain due to the influence of Lawrence Stenhouse (Elliott, 1991). His work with teachers in the Humanities Curriculum Project, and subsequent work by John Elliott and others at the University of East Anglia (Elliott, 1991) served as the basis for this model of action research that has spread to Europe, Australia, South Africa, and the US.

The second form of action research, which is more often referred to as teacher-research, arose from the work of the Writing Projects (BAWP, 1979) and Pat Carini of the Prospect School (1978). Teachers working with the Writing Projects, which originated at the University of California-Berkeley, began to do research as a way to improve their teaching, and their students' learning, of writing. They engage in teacher-research by paying close attention to their own work through journal keeping, and by paying close attention to children's work by collecting samples of their writing. Teachers in collaborative groups then share and critique each other's work by making public their journal entries and exhibiting their students' writing. They expand upon their ideas by writing self-reflective documents that rely on their journals, the student writing samples, and the comments and questions of their peers. These documents are shared again with the collaborative group in a peer review process. This latter process may be repeated several times until there is an acceptable finished product. Collections of teachers' writings have been published by Writing Projects (Alaska Teacher Researchers, 1991; Goodman, 1988; Page, 1992), and by university researchers (Cochran-Smith and Lytle, 1993).

What this amounts to is a method of doing research through writing. This is quite different from the model of research used by teachers who do classroom action research. Those teachers rely more on traditional research methodologies. There is usually some sort of recognition of a problem, dilemma, or dissonance in practice that they would like to resolve. Some attempt is made to do this by taking action within the system and by collecting data. The data is then analyzed in some way to learn more about the situation. This cycle of problem formation, action, data collection, and analysis may be repeated several times. There is then the assumption that some sort of research report will be written to be shared with other teachers.

The model of action research that I have used in this study has been influenced by both classroom action research and the work of the Writing Projects. When I talk with teachers about action research, I depend heavily on the CAR model. For example, I talk about Carr and Kemmis' four step cycle of planning, acting, observing, and reflecting (1986), and rely heavily on the methods suggested by Altrichter et. al. (1993). But my model is also dependent on the way that the Writing Projects encourage teachers to work together. The physics teachers kept research notebooks, shared their own lessons and their students' work with one another, and engaged in a narrative form of inquiry that I describe later in this paper.

The model of action research that I used is a form of collaborative action research. It consists of practitioners working together to take actions within their situations in order to improve their practice and to come to a better understanding of that practice. That is, by collaborative I mean groups of teachers working together in contrast to a relationship between university researchers and school teachers (Feldman, 1993a). In using the term research, I begin with Stenhouse's definition -- systematic, critical inquiry made public (1975). And by action, I mean that there is an assumption in action research that a good way, if not the best way, to come to a better understanding of a complex system --

teaching and learning, in particular -- is to take action within that system and pay close attention to the results of taking those actions.

I end this section by noting two particular aspects of the form of action research used in this study. First, the primary goal of this research is not the generation of new knowledge, whether local or more universal, but the improvement of practice. It is therefore a self-developmental process. A second aspect arises from its self-developmental nature. Teachers seek to develop their practice because they want to provide a better educational experience for their students. Therefore, action research is an ethical process which is deeply rooted in the moral aspects of teaching (Elliott, 1991). The moral nature of the process is reflected in teachers' choices of research to undertake - - research that improves their practice or their situations to better the educational situations for their students or peers. By amalgamating the processes of inquiry, improvement of practice and professional development within this moral framework, action research serves to integrate "...teaching and teacher development, curriculum development and evaluation, research and philosophical reflection, into a unified conception of reflective educational practice (Elliott, 1991, p. 54)."

Context: The Physics Teachers Action Research Group

*That seems to be the only way ... after you've reached a certain level
and you've gone to all the workshops and done all that, the only way
you can become a better teacher is to try to improve yourself*

-- Lettie Weinmann, physics teacher

Beginning in 1990, I worked with a group of eight physics teachers who were, and are, deeply concerned about improving their practice. For the most part they were not worried that they were not doing a good job; rather, they felt good about themselves as physics teachers but were aware that what they accomplished did not meet their own high expectations. Because of this, they agreed to join with me to engage in collaborative action research.

During the 1990-91 (Year 1), 1991-92 (Year 2) and 1992-93 (Year 3) academic years I looked closely at the ways the teachers learned from one another, and the ways that they generated knowledge and understanding from practice (Feldman, 1993c), as they engaged in collaborative action research to improve their practice. During Year 1 of the study I convened the Physics Teachers Action Research Group (PTARG). Year 2 was the primary data collection year. Most of the data analysis occurred in Year 3, during which I continued to meet with the teachers.

During Year 1, I sponsored a series of programs and presentations for physics teachers in the San Francisco Bay area. PTARG was established at the end of that year when I invited the regular attendees of Year 1 activities to participate in Lee Shulman's Spencer Foundation funded project, Toward a Pedagogy of Substance (TAPS). In this project, Shulman was looking at teachers use of representations: "visual images, analogies, metaphors, stories, and key cases (Shulman, 1989)" used to make sense of the world. For physics, the domain of teaching representations includes demonstrations, laboratory activities, graphs, and mathematical formulae. I convinced Shulman that it would be worthwhile to see what could be found if teachers were to investigate this aspect of their practice. As a result, PTARG was established with the use of TAPS' Spencer Foundation funds. These funds were used to provide each teacher with a \$500 honorarium, travel to professional meetings, and for meals at PTARG meetings.

During Year 2, PTARG met approximately once every three weeks. All of the meetings had a similar format: Each was at the home of a PTARG member, and I provided dinner. The meetings began with the teachers drifting in and beginning conversation about what was happening in their schools and classes, and about any questions that they had about physics. It was not until after dinner that the group turned from dinner to the agenda at hand, and I turned on my tape recorder. What went on for the next hour and one half varied over the course of the study. But for the most part it had two different forms. The first consisted of different members of the group holding the floor and making some sort of report to which the others first listened and then responded. The second form of meeting discourse was the discussion. Some of these discussions were pre-planned while others arose more spontaneously from remarks made by one or two of the teachers. There were other discussions that were more instrumental; those times when the teachers needed to decide on a research method or about a presentation.

I acted as the covener and facilitator of the group during Year 2. I established PTARG by inviting the teachers to join the TAPS project. I began the formal part of each meeting by reminding the teachers of what had happened during the previous gathering, what they had decided to do between meetings, and what the group had decided would be the agenda for the current meeting. I summarized points that were made, kept track of the time left in the meeting so that the agenda would be covered, and acted as an intermediary between the group and Shulman.

Between meetings the teachers taught their classes, tried out some of the ideas that they had got from each other in their classrooms, and kept a research notebook of their observations, reflections, and hypotheses. I transcribed the tapes, visited the teachers' classrooms, and interviewed them and their students. In addition, I acted as a research assistant for them when they needed help gathering data.

Year 3 went on in a similar fashion to Year 2. There were several differences. First, I no longer acted as facilitator. Instead, several of the teachers took turns facilitating. Second, I no longer taped the meetings. However, the PTARG teachers decided that they wanted to continue to tape them, and before the end of the academic

year, one of the teachers, Lettie Weinmann, analyzed the tapes to extract important ideas that had been discussed. And third, I no longer provided dinner because I did not have funds from TAPS project. Because having dinner together was an important part of the meetings, the teachers decided to take turns cooking for one another. At the time of this writing, six years after I first began to convene the group, and two years after I moved to Massachusetts, the PTARG teachers continue to meet on a regular basis, and have written a paper about their work that will soon appear in The Physics Teacher.

Conceptual Framework

I began this study with the assumption that to be a better teacher, one needs to possess more, or different, knowledge of teaching and educational situations. While in some ways this appears to be more of a truism than an assumption, it is only within the past twenty years that teachers' knowledge has become a serious subject of educational research. While some (Shavelson, Webb, and Burstein, 1986) say that it began as early as Shulman's call for an abandonment of behaviorist research (1974), it was not until the late 1980s that a literature emerged that focused on what it is that teachers must know to teach (e.g., Grossman, Wilson, and Shulman, 1989; Hashweh, 1987; Lampert and Clark, 1990; Leinhardt, 1990; McDiarmid, Ball, and Anderson, 1989; Shulman, 1986), and consequently, the development of a knowledge base on teaching for teacher education (Reynolds, 1989).

In this literature, several taxonomies of teacher knowledge have been developed (Carr and Kemmis, 1986; Elbaz, 1981; Grossman, 1990; Leinhardt, 1990; Shulman, 1986). For this study I have relied on Grossman's, which derives from Shulman's taxonomy. Grossman suggests that teachers possess four categories of knowledge that they rely on to teach: general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge, and knowledge of context (1990). In addition, Grossman has suggested some apparent sources for this knowledge: Lortie's "apprenticeship of observation (1975)," formal education in the subject area and in methods and theories of teaching, and for experienced teachers, knowledge gained through their experience in the classroom.

Shulman and his colleagues have suggested a "model of pedagogical reasoning" for the way that teachers' knowledge grows through their professional experience (Wilson, Shulman, and Richert, 1987). Pedagogical reasoning proceeds through a process which begins with comprehension and then transformation, instruction, evaluation, reflection, and then to new comprehension.

-----Insert Diagram 1 here -----

Teachers' comprehension is transformed through critical interpretation -- a review of curricular materials with respect to the teachers' understanding of the subject matter; representation -- the use of "metaphors, analogies, illustrations, activities, assignments,

and examples that teachers use to transform the content for instruction (Wilson et. al., 1987, p. 120);" adaptation -- the fitting of representations to students in general; and tailoring -- the adapting of representations to specific students.

According to this model, teachers comprehend and transform their own knowledge. They interact with students through instruction and then evaluate their instruction through the evaluation of their students. Using multiple forms of evaluation which can range from objective tests to observations of the looks on students faces, teachers can gauge how useful or effective their instruction has been by checking for students' understandings and misunderstandings. New comprehension then arises from teachers reflecting on their transformation of curricular material, their instruction, and their students' understandings (Wilson et. al., 1987).

Although this appears to be a reasonable model from which to begin an investigation into how teachers' pedagogical content knowledge is generated, there does not seem to be a place for the effect of teachers' colleagues and of the wider contexts of schooling. This model consists mainly of processes that lie within the teachers' minds -- it is a cognitive model -- and does not consider ways in which teachers' knowledge can be generated in their social milieu.

Design and methodology

To examine the ways that teacher knowledge is generated and shared in a social milieu, I needed to use a research methodology that would allow me to pay close attention to the ways that the teachers interacted with one another. Therefore, I decided to engage in naturalistic inquiry (Guba and Lincoln, 1982). Naturalistic inquiry uses methods similar to ethnography but relies on constructs in addition to culture to analyze the situations under study. For example, naturalistic inquirers may view teaching from the perspectives of anthropology, psychology, or sociology. I began this study from Shulman's psychological perspective, as I described above, and then generated a social constructivist perspective (Goodson, 1990) through the development of grounded theory (Strauss and Corbin, 1990).

My interest in encouraging teachers to engage in action research provided me with an opportunity to study the ways that the physics teachers generated and shared knowledge. By convening a collaborative action research group that I facilitated, I was able to be with the teachers during most of the times that they interacted with one another. In this way I acted as a participant and an observer by paying close attention to the ways that the PTARG teachers interacted with one another as they attempted to improve their practices and come to a better understanding of their educational situations. Therefore, the methods that I used were similar to ethnography, relying on tapes of the meetings, observations of classes, and interviews of the teachers and their students to write a set of case studies of the Physics Teachers Action Research Group. While I originally conceived it as a set of parallel and contrastive case studies of the individual

teachers using the methods of Eisner (1985; 1991), Wolcott (1990), and Yin (1984), the study co-evolved with the conceptual framework into a set of case studies that explore multiple aspects of the nature of knowledge and understanding, collaborative action research, and the ways that teachers go about understanding and changing their practice (Feldman, 1993c).

The teachers

The eight PTARG teachers are well educated and have had significant teaching experience. Six have more than fifteen years of experience, two hold Ph.D.'s in physics, and all but two have undergraduate physics majors. In addition, six have gone through teacher certification programs -- two at Stanford, two in campuses of the California State University, and two in other states. Most have maintained active professional careers with connections with the American Association of Physics Teachers (AAPT), the National Science Teachers Associations (NSTA), and through local alliances with universities, industry, and museums. As teachers who identify themselves as physics teachers, they teach in institutions that have relatively large enrollments in physics -- either large public institutions or schools with elite populations. These characteristics make them as a group special. Their involvement with professional activities outside of teaching, the schools that they teach in, and their level of education all add up to this being an exceptional group of teachers. And they are exceptional in another way -- three of these physics teachers are women.

What this amounts to is a group of individuals who chose to become a part of this action research group. They were not enrolled in a university course together and they have not joined a common reform effort. They were not fulfilling a requirement for employment of recertification by participating in the group. The common thread appears to be that they identify themselves as physics teachers, and that they are physics teachers who are interested in learning more about their own practice and improving it by interacting with other physics teachers. While the teachers gave me several reasons for agreeing to join the group, including the promise of an honorarium of \$500.00 for Year 2, all of the teachers agreed that their primary purpose of becoming part of the group was to work with other physics teachers (Feldman, 1993c).

Data collection and analysis

It is important for me to make clear that this is a report of a research study of people involved in research, and that there were multiple sets of data; the data that the teachers collected as part of their action research, and the data that I collected in my study of the teachers' engagement in research. Since this report is of my research, it followed my research agenda, and the data collection and analysis methods that I describe are the ones that I used.

The data that I collected includes classroom observations, interviews of the teachers and their students, audio tapes of PTARG meetings, and teachers' writing. The teachers' writing included journal entries, an interim report in Year 2, and the papers that they presented at professional meetings. The data provided me with information for

teaching biographies and pedagogical baselines for each of the teachers in addition to records of the discourse during the PTARG meetings about the teachers conceptions of research in general and action research specifically.

There were two primary methods that I used for data analysis: The first consisted of ongoing analysis that occurred during the data collection phase of Year 2. I wrote reflective notes and memos in my research notebook, added side comments to transcripts as I transcribed them, and engaged in extensive conversations with other university researchers. This led to both reformulation of my problem statement and significant modifications in the conceptual framework.

During Year 3 much of the analysis consisted of the grouping and coding of data with the software Hyperqual. Coding categories were developed using the principles of grounded theory (Strauss and Corbin, 1990). The transcripts of PTARG meetings, transcripts of interviews of the teachers, and pertinent field notes were entered into special files created by the software package. The use of this software allowed me to do an initial "chunking" of data into thematic categories similar to the sort of coding described by Miles and Huberman (1984). In addition, the coded data was organized into charts and tables to facilitate analysis. The chunked, coded and charted data then became the source for the writing of the case studies.

I shared much of my data with the teachers. I gave them copies of the notes that I took while observing their classes, the tapes and transcripts of student interviews, and all of the teachers were given the opportunity to read and respond to my analysis of the data.

In remainder of this paper I will show how I attempted to use Shulman's conception of teacher knowledge and the model of pedagogical reasoning to explore the question that framed this study: How do teachers generate and share knowledge when interacting with their colleagues? In doing so, I found that I needed to expand the model of pedagogical reasoning so that it could go beyond individual teachers, and to make two distinctions: the first between knowledge and understanding, and the second between context and situation. I return to this later.

The physics teachers action research group:

A case of enhancing normal practice

In the case study that follows, I have identified three activities in the PTARG teachers' collaborative action research through which knowledge and understanding were generated and shared. They are anecdote-telling, the trying out of ideas, and systematic inquiry. Before I turn to it, I must make clear what I am not doing: This is not a codification of what knowledge was generated and shared by these teachers. While it is possible to do so (Feldman, 1993b), what knowledge shared in this way is not as salient

for issues of teacher education, research on teaching, or educational policy as how the knowledge is generated and shared in collaborative settings.

I call the combination of anecdote-telling, the trying out of ideas, and systematic inquiry enhanced normal practice. This name came about in response to a common question that teachers have had when I talk with them about action research: "How is action research different from what I normally do?" What the teachers have meant by what they normally do is the monitor-and-adjust of good practice -- teachers pay attention to what is happening in their classrooms and make changes in what they are doing based on their perceptions as to whether their teaching is "working" or not. Enhanced normal practice begins there but goes further. The "paying attention to" is more systematic because it is part of a defined action research project, and the reflection-on-practice (Schön, 1983) that is part of normal practice becomes critical inquiry by extending it to the meta-level as reflection about practice in the setting of the collaborative group. As a result, enhanced normal practice is not only a form of systematic inquiry, but is systematic, critical inquiry made public, or research as defined by Stenhouse (1975).

In the next three sections of this paper I will describe these activities and show how each resulted in the increase of the teachers' knowledge and understanding about teaching and how to teach, and of their knowledge and understanding of physics. I will then show how they can be envisioned as a *mélange* of activities, enhanced normal practice, that can lead to a new conceptualization of action research.

Anecdote-telling: The sharing of knowledge and understanding

The first of these mechanisms for the sharing and generating of knowledge and understanding that I examine in detail is one that I have called anecdote-telling. An anecdote is "a narrative of a detached incident, or of a single event, told as being in itself interesting or striking (Oxford English Dictionary, 1971)." I use this term to distinguish it from storytelling and narrative for two reasons. The first is that the anecdote-teller is not necessarily telling a story: There need not be a crisis that is to be resolved, a plot, or a time sequencing of event in the anecdote (Bruner, 1990). And second, I do not call these verbal exchanges among teachers narratives because I do not mean to refer to all that Connelly and Clandinin (1990) and others mean by the term.

While I have labeled this activity anecdote-telling, it is obvious that more must be happening than telling. Because this was occurring in a group situation, others were hearing and listening to the anecdote-teller, and responded with their own anecdotes or with questions. In general, the teachers responded to anecdotes in one of three different ways. In some instances the response was another anecdote. At other times, anecdotes were responded to with questions about the details of what was described or explained in the anecdote. A third type of response also consisted of questions, but ones that were more critical in nature and asked "Why?" as well as "What, where, how, and when?" Therefore, by anecdote-telling, I mean the oral exchange and generation of knowledge

and understanding by the recounting and questioning of some teaching event or explanation of one's understanding to others.

Anecdote swapping would commence with a teacher either beginning with a phrase such as "That reminds me of ..." or by telling an anecdote of a practice or occurrence that was similar to that told by the first teacher. One example of this was when one of the teachers, Sean Fottrell, described a technique that he used to try to get his students to think through the solution of numerical problems before they begin to manipulate equations. As a way to illustrate the usefulness of this technique he told an anecdote about a student who had figured out how to solve a numerical problem on a test but did not have enough time to compute the answer:

Fottrell: I had one student who ran out of time at the end of the test and didn't have time to do all the computations. She said, "I wrote everything out" and it looked like everything that you would do to solve it (PTARG meeting 11/7/91).

A second teacher, John Hofland, responded with an anecdote about his own practice:

Hofland: When I ask questions I usually have an approach in mind. And they're usually multiple part questions -- not always part B depending on getting part A. The first one might be "What is the initial momentum?" and the next might be "What ..." They're kind of in the order in which you need to do a problem like that (PTARG meeting 11/7/91).

He continued

Hofland: I've always used that with hopes that the kids would pick up on what the approach is but [Fottrell's technique] sounds like it might be a more formal approach to getting them to do that (PTARG meeting 11/7/91).

While Hofland responded with his own anecdote, it appears to be part of the process that he used to come to a better understanding of what Fottrell was describing. When teachers respond to anecdotes with their own, there is a sharing of know-how and know-that about teaching -- the wisdom of practice (Shulman, 1987). The anecdotes add context and begin to indicate to others how this knowledge is related to the situations of the tellers, and there is a growing understanding of their educational situations.

Anecdotes were also followed with questions that fleshed out details of the anecdote. For example, Tom Woosnam described an activity that his students did that day in class:

Woosnam: We did a fun lab today, one suggested by Hewitt (1987), where you put a couple of pins through a horizontal candle and you light both

ends of the candle. It turns into a seesaw as the wax melts (PTARG meeting 11/7/91).

The other teachers in the group asked questions about how to do the demonstration. These included questions about the length of the candle, what sorts of pins were used, and how it was supported. There were also curricular and pedagogical questions asked, such as what concepts in physics it was demonstrating and how much information was provided to the students about what they should expect to see. All of these questions were being asked so that the teachers could duplicate this laboratory exercise with their students if they so wished.

When the teachers responded to anecdotes with questions that asked for details about pedagogy or about situations, they were seeking information that would help make the knowledge and understanding presented in the anecdotes more useful for them. As they struggled with trying to make meaning of the anecdotes they found that they needed information that would enable them to situate the anecdotes in their own experiences.

The second type of questioning that followed anecdote-telling took this a step further. In addition to asking for details, the listeners asked questions that would help them come to a better understanding of the situation described in the anecdote. These questions focused on the understanding that the anecdote-tellers had of their situations. When this sort of questioning occurred, the conversations shifted in form away from anecdote swapping and the seeking of additional details, to that of discussions. An example of this was when the PTARG teachers described the ways that they normally introduced the concept of electric charge (December 17, 1991 PTARG meeting).

As with many of the other conversations that occurred in the meetings, the PTARG teachers went around the room in turn to describe how they introduced the concept of charge. All the teachers introduced it empirically with some sort of demonstration or laboratory exercise that demonstrated the static electric force. Lettie Weinmann preferred to have her students play with strips of acetate and vinyl that they charge by rubbing with different materials. She then had them invent explanations for the various attractions and repulsions that they observed. Larry Hiebart surprised many of the others by describing how Scotch Magic® Transparent tape could be charged positively and negatively to give the same sorts of results that Weinmann got with her acetate and vinyl.

In each of these cases, the conversation consisted of each teacher describing his or her method through anecdote-telling and then the others asking questions about details. When Fottrell and Andria Erzberger told how they first introduced the electric force, the nature of the questioning changed. They told that they begin by referring to gravity and the other three fundamental forces, electromagnetic, strong nuclear, and weak nuclear. Fottrell continued by describing how he explains that the electric force is qualitatively different from the others and introduces charge as a rationale for the force. His approach led the group to discuss the nature of charge, whether the electron is a model or

something "real," and when in the physics curriculum it would be best to introduce the notion of four fundamental forces.

This discussion about how to introduce the concept of electric charge and force illustrates three ways that the teachers have responded to each others' anecdotes. It also illustrates how the responses were mixed together in ways that do not necessarily indicate a developmental process. That is, I am not suggesting that as a collaborative group like PTARG matures, the responses to anecdotes proceeds from anecdote-swapping to questioning about details to questioning about ideas. Rather, as the listeners try to make meaning of the anecdotes, they do so through sharing a similar anecdote, asking for more details about the educational situations of the tellers, and by asking questions about the tellers' own understanding of their educational situations.

Through anecdote-telling, these teachers have shared their knowledge and understanding about teaching and their educational situations as part of their participation in PTARG meetings. What this suggests is that for at least some of what they know and understand about teaching, other teachers have been an important source of this knowledge. This is not an unforeseen result. When teachers have the opportunity to get together and talk, they talk about what is of interest to them, their schools, their classes, and their students. The PTARG meetings provided the opportunity for teachers grouped by subject to talk about teaching and so subject matter specific conversation ensued: The teachers told anecdotes about physics and physics teaching as well as about more generic aspects of teaching. While this is not unexpected, my observations of these physics teachers engaged in this activity hints at the existence of a realm largely unexplored and ignored by policy makers: communities of teachers that transcend school borders.

Trying out ideas

Sharing and generating knowledge and understanding through the anecdotes of others is only one way that these physics teachers learned more about teaching. Their knowledge and understanding also increased by trying out for themselves what had been suggested by others. Many of these suggestions came from the other teachers in the group, but there was also much that came from the wider educational community including that of educational research.

In this section I present several examples of teachers trying out new ideas and learning from taking those actions. These examples are both of innovations arising from inside the group and from sources outside of the group. Although I am focusing on the trying out of the ideas as mechanism for the generation and sharing of knowledge and understanding, anecdote-telling played an important role in making that happen.

Ideas originating outside of PTARG

Through his work with the California Scope, Sequence and Coordination project Hiebart came upon the idea of giving his students a group examination based on a

problem that asked students how they would respond if an asteroid were on a collision course with the earth. He first told the PTARG teachers about his idea during the November 11, 1991 meeting. When he finished, they asked him about how he would put this exam into operation and what sorts of results he expected from it. In the meetings that followed, he reported on how his students responded to it and how useful it was as an evaluation tool. In a report that he made summarizing his activities during Year 2, he reported the following:

Hiebart: Just to review, in the first semester of our course, I finished the dynamics, kinematics unit with my asteroid problem. And the feeling that I got from it was that while it was not a comprehensive review of the unit it gave me a chance to see students actively involved in problem solving and using a variety of methods, some of them obviously from the course, many of them from outside information that the kids picked up. The research skills that my students showed, I felt were quite impressive. And they showed a lot of things that I was not fully aware of beforehand. One of the things that I was really surprised at was my ability to evaluate the students while they were working on the problems. And this I think for me was one of the biggest benefits; just the ability to wander around the room and watch the students in the process of problem solving. I think I learned a great deal more about my students watching them work than I would've ever learned from seeing what they did with paper and pencil. So in that respect I think that exam was very successful (PTARG meeting 6/2/92).

This has led to the work that the PTARG teachers were involved in from 1992-94; an inquiry into an aspect of this sort of assessment device that they find problematic. They were asking, "What is the connection, if any, between students' success with this sort of problem and their understanding of the formal knowledge of physics?"

Woosnam has radically changed the structure of his class to one based on the idea of mastery learning. Instead of using written quizzes and examinations, he has individual conferences with students to assess whether or not they have mastered the current material. He came upon this through his friendship with another physics teacher who has structured his classes on this model and has written about it in The Physics Teacher (Lucido, 1992). Woosnam was initially attracted to mastery learning because of his concern that his students were overly anxious in testing situations. Early on in the academic year he read a passage from his research notebook during the October 10, 1991 PTARG meeting describing how his students reacted to the mastery learning conferences:

This is the day of the conferences. I came home with a headache. The overwhelming impression is that of the stress that the kids feel in the conference situation. They turn white, they shake, [a student] said that she felt ill before taking it. Arghh. There is a certain amount of irony here given that I wanted to take the stress out of the teaching. ... Intense competition on the part of most of the students. They want to get mastery

as soon as they come in for a conference. The repeats will take a lot of my time ...

To his dismay, he had found that his new method of evaluation was causing even more stress among his students. As the year progressed, however, Woosnam and his students became more comfortable with this new way of doing things. Even so, he found that he was having problems with mastery learning. In his end of the year summary, Woosnam asked,

Woosnam: "What am I going to do next year?" is the question. Again something different as I always seem to, as we all do. Something different year to year, I'm not going to do it like this. For a practical reason when you do masteries with groups of kids, and I only have a few kids compared to public school teachers, it still takes me about 3 days to get through. While I'm doing the mastery the kids who aren't in conference are working on something and I'm keeping an eye on them, but it's an enormous amount of time. I'm not sure that it's worth it. And I am finding out now those things that I wish I had done this year that I sacrificed doing because of this time that was used ... (PTARG meeting 5/13/92).

He concluded with a statement of understanding of what it is to be an effective teacher:

Woosnam: ... We all have our own styles that work for us, and there isn't one Holy Grail of a method. I'm absolutely convinced of that. The closer you get to being yourself in the classroom, the more effective you will be as a teacher, well I should say, I will be as a teacher, by being myself (PTARG meeting 5/13/92).

Ideas that originated from within PTARG

The PTARG teachers also tried out new ideas that they heard from others in the group. For example, Fottrell had been concerned with a dissonance between his traditional physics class and his Conceptual Physics class. What he found was that while the students in the Conceptual Physics class spent the majority of their time attempting to arrive at conceptual understandings of physics, the traditional physics students spent the majority of their time engaged in learning to solve numerical problems in physics. He introduced an idea that he had gotten from Erzberger to shift the emphasis in the regular physics class towards more conceptual understanding. She had told of how she required her students to write down the "approach" that they used to arrive at a numerical solution. This idea, which she had gotten from a physics text, has the students writing down in words the way that they will go about solving a numerical problem. Fottrell began to have his students do the same on their homework so that they would be describing how they solve problems "... not just start writing down equations and trying to figure out what to do with them (PTARG meeting 11/7/91)." In early November he reported that

Fottrell: ... the biggest effect I've noticed is that when it comes time to go over problems in class, and I say, "What's your approach?" people are

starting to give me a lot of coherent approaches (PTARG meeting 11/7/91).

Later on in the academic year, Fottrell told the group of his experiences with having his students write out approaches and what he had learned from that:

Fottrell: What I found was that some students were comfortable with this idea of writing down an approach and others were not. And those who were not, generally did not do it very much. And those who were, I found, latched onto it and used it pretty much the year through, especially in test situations. Most of them used it when the problems were difficult and they were searching around for "How do I do this?" They would really sit down and write out their steps. I'm not sure how well it necessarily helped them. ... For those students who were really reaching and trying to figure out in writing their approach, it would make very clear [to me] that they had no idea of what they were doing. They would write out an approach and you could see, "This is what they're trying to do and it doesn't make sense. That's not the way it should be done." Very rarely would you find a problem where somebody wrote down an approach in full and then went through and did it all, and did it all right. ... And so their approach didn't describe how they would solve the rest of the problem. So sometimes it really helped them, other times, it just showed that they didn't understand what they were doing (PTARG meeting 5/13/92).

While Fottrell's adoption of Erzberger's technique did not necessarily give him his hoped-for results, as the year went on the other teachers became aware of a similar dissonance between their goals to teach conceptual understanding of physics and the students' concern with getting the right answer. Ultimately a concern for students' conceptual understanding led the group to the agreement that their goal would be to develop teaching methods and assessment techniques that would encourage conceptual as well as quantitative learning in all students.

Systematic inquiry

During the academic year, the teachers engaged in one collaborative piece of research that involved the entire group. This was an investigation into the teaching of the concept of electric charge as part of the Towards a Pedagogy of Substance (TAPS) project. The inquiry had three main components: discussions of the ways that the teachers introduced the notion of charge; the development of methods to investigate their own teaching; and an analysis of the data collected.

The method that the teachers created to investigate the students' perceptions of pedagogical representations evolved through anecdote-telling and the trying out of ideas from a technique for checking student understanding. Earlier in the year, Annette Rappleyea had begun to ask her students to write the answer to the question, "What did

you learn in class today?" on a file card at the end of the class period. She found it useful as a quick way to judge whether her lessons had been effective. This survey method was modified by the teachers to assess the utility of the teachers' representations for student learning.

The PTARG teachers agreed to introduce their unit on electrostatics in the same way. They would do a simple demonstration, and then ask their students to answer the same set of questions on file cards. The demonstration was to rub a balloon on their hair and then stick it to the classroom wall. The agreed-upon questions were:

1. After you have observed the demonstration, use what you know about electric charge to explain what has happened.
2. Use the back of this card to describe any additional details of what you already know about electric charge.

At the end of subsequent lessons, the following questions would be asked:

3. State one new thing that you learned today about electric charge.
4. What in class helped you learn it?
5. What happened in class that you found confusing? Why?

The first two questions were primarily designed as a pretest, to determine the students' knowledge prior to the start of formal instruction in electrostatics. Questions 3-5, which were asked at the end of subsequent lessons, had a dual function. While question #3 served to check on student comprehension and understanding, the latter two were specifically oriented towards identifying those representations that were exceptional in the students' view. During the 3-5 days of introductory lessons on electrostatics, the teachers followed the above procedure, some audio taped their classes, and I observed several and gave the teachers my notes of those lessons.

Narrative analysis

The PTARG teachers used two methods of analysis to look at the data that they collected: narrative and analytical. The narrative analysis consisted of the teachers reporting to the others what they had learned by reading through the cards. First the teachers had sorted through the cards to find examples that they thought were particularly telling. Then in the PTARG meetings the teachers read the responses to the group. This was followed by discussion of the significance of selected responses. That is, the narrative analysis consisted of the teachers treating the cards as anecdotes, and then responding to them in the same way that they responded to anecdotes -- with other anecdotes and with questions.

At an early February PTARG meeting, Rappleyea used narrative analysis to better understand how she explained physics concepts to her students:

Rappleyea: I think that these questions are really good questions, by the way. The one, "Write down something that you learned." helps them a lot but it also helps us to see what they're learning and whether they get it correct or not. Also if they have any misconception, that comes out too. In answer to this one a lot of students said the same thing, that the balloon was charged positively and that's why they stuck. So they had some idea that the opposite charges attract (PTARG meeting 2/6/92).

Rappleyea told the group that on the third or fourth day of the unit she did a dipole problem on the blackboard and then had the class do a mini-lecture exercise. She read the following responses to the question, "What in class helped you learn it?"

"Teaching another students helped me to learn it.

"I liked having to explain everything. It's more difficult to explain a problem than just do it.

"The diagram on the board and trying to explain the concept to my partner forced me to clarify the idea for myself before I could attempt to explain.

"Practicing out loud helped.

"I learned to try to organize the concept of the dipole in order to be able to explain it to a fellow student. I found it very valuable to have the opportunity to do this. From experience, I think I learn better if I try to explain things (PTARG meeting 2/6/92).

Several of the teachers asked Rappleyea about how she did the mini-lectures. They were interested in how much time she gave the students, whether the students actually talk about physics, and how she follows up the activity, that is, the first type of question asked in response to the telling of an anecdote. But then the questioning changed:

Erzberger: Did you find that people said things helped that you didn't expect to help?

Rappleyea: Yeah, I was surprised by the students about the mini-lectures. ... Well, these students are really oriented towards problem solving. That's why I was surprised I got any cards at all [about the mini-lectures]. And they're very, very shy and they have the hardest time talking to each other. It would be interesting to try it in other classes too. ... Another thing that happens with the cards is that you get validations, "Everything was perfectly clear." ... Or people who said, "I did not understand it when we first started but I understand it now." I take that as a validation. Also, there

were hints about what to do better. One person said that there were too many problems on the blackboard at once so I've been consciously trying to leave enough up there for people to copy but space it out a little bit more so there's not so much (PTARG 2/6/92).

As with the trying out of ideas, the group interaction during the narrative analysis closely followed the model of anecdote-telling. Rappleyea's description of her use of mini-lectures first engendered a "how do you do it" line of questions from the other teachers. But further questions led Rappleyea to critically reflect on their use in her practice.

It is important to remember that this sort of analysis does not seek to generate generalizations or to test theories. In the immediate sense, it provided the teachers with some information about that student. But by analyzing the response in the collaborative mode, the question "How does my understanding of this student's response help me to understand the ways that other students learn?" was also answered.

Analytical analysis

The second method of analysis that the teachers used as part of systematic inquiry is one that I have labeled analytic, and is one that would be more familiar to educational researchers. The student responses were coded and arranged in tabular form, and then some sort of generalization was looked for in the coding. This was done several times by the teachers. Hofland looked closely at his students' responses to the question, "What helped you understand it?" Fottrell coded a set of responses from his students during introductory lessons on the nature of light, and I coded a different set of data from Hofland's classes, the students' answers to question #3: "State one new thing that you learned today about electric charge." A fourth example was an analysis of students' responses to question #4, "What in class helped you learn it?" done by Rappleyea after she had her students do the mini-lecture exercise described previously. She brought a table of data (see Table 1) with her to the PTARG meeting (2/6/92):

-----Insert Table 1 here -----

This data led to the generation of the hypothesis that the students were separating representations into those that were useful and those that were not. And the key that they were using was whether or not those representations would help them to better solve numerical problems. Of the 46 students who responded to Rappleyea, equal numbers found the blackboard calculations and the mini-lecture helpful. A similar response was found when I taught a lesson for Erzberger's classes. Although I saw the lesson as an historical approach to the discovery of Coulomb's law, the students responded in a way that suggested that they saw the mathematical derivation of Coulomb's law as the most important part of the lesson.

There was at least one significant conclusion that arose from the analysis of the file card data -- that although the teachers had as their primary goal that students come away from their classes with a conceptual understanding of physics that could then be used in everyday life, the students saw the primary goal of the classes as learning how to

solve numerical problems in physics. This was a hypothesis that I suggested during the February 6, 1992 PTARG meeting:

Feldman: So, if we're using the students to probe our teaching ... and what they're really interested in is the most efficient way to learn problem solving, the metaphors, the analogies, what the graph means, is not important. What is important is ... the worked out problem on the black board.

This was picked up in the writing of a funding proposal, which was done primarily by Weinmann. This then led to the current PTARG focus on changing the ways that they assess student learning.

While the systematic inquiry that was done by the PTARG teachers did not produce the type of knowledge that was expected in the TAPS project, it did serve to generate knowledge that was of immediate use to the teachers about their students. It also resulted in the teachers being more knowledgeable about research methods and methodologies. By looking more closely at their own teaching and how their students responded to it, they came to a better understanding of their educational situations: the greater awareness of dissonances between their intentions and how they were perceived by their students. And, finally, the systematic inquiry resulted in the teachers beginning to change their practice by attempting to reduce those dissonances, and has led to PTARG's investigation into assessments.

It was the analytic process that was most problematic for the teachers (Feldman, 1993c). For the most part they were comfortable to accept what they could glean from the narrative inquiry. They did not see it as an attempt to theorize or generalize, but as a way to come to a better understanding of their teaching, their students, and other aspects of their educational situations. The analytic method was more suggestive of the scientific research that they were all familiar with, either through graduate studies or more vicariously as teachers of the "scientific method." As a result, they were suspicious of both the data and any claims made from that data. As teacher-researchers they found themselves in a situation that I have characterized as a dilemma -- they would accept what they learned through narrative processes that they did not label as research, but as their methods more closely approached that of the sciences, they grew more suspicious of it (Feldman, 1994).

Discussion

I have shown that the PTARG teachers have generated and shared knowledge about teaching through three mechanisms: the telling, listening, and questioning that makes up anecdote-telling; the trying out in their own classes of ideas that have come from others, both from inside and external to the group; and systematic inquiry into their own teaching. What I would like to do now is to show that these three mechanisms are all

different aspects of action research when it is engaged in collaboratively. I do this because what I have called enhanced normal practice looks different from the two common forms of action research practiced in the US: classroom action research and the teacher-research associated with the Writing Projects.

As I noted in my review of action research, classroom action research is organized around problem solving through the collection and analysis of data. While the systematic inquiry that the PTARG teachers engaged was similar to the methods of CAR, anecdote-telling and the trying out of ideas would seem to the practitioners of CAR a prelude to action research. The teacher-researchers of the Writing Projects would find the first two mechanisms similar to their own activities. In fact, anecdote-telling is quite similar to what Lytle and Cochran-Smith (1990) call oral inquiries. But the writing teachers who engage in teacher-research would notice the almost total lack of writing by the PTARG teachers. While much of their inquiry was done through narrative, very little was done through writing.

Knowledge and understanding

There are two keys to my construction of the three mechanisms of enhanced normal practice as different aspects of collaborative action research. The first is the distinction that I make between knowledge and understanding. I began to conceptualize this distinction as I went about coding and "chunking" my data. I began to realize that the conception of knowledge that I was using was problematic. In the teacher knowledge literature that I have reviewed, knowledge has the properties of a commodity -- it is categorical, codifiable, and can be traded or exchanged (Lyotard, 1979). However, much of what was important to the teachers seemed to be too nebulous or slippery to be put into an inventory and may be better thought of as understandings, rather than knowledge, where understanding is the result of meaning making in situations (Bruner, 1990; Heidegger, 1962).

This distinction can be seen in how the teachers talked about their activities. For example, there was Hiebert's claim that "one of the biggest benefits [for me was] ... the ability to wander around the room and watch the students in the process of problem solving. I think I learned a great deal more about my students watching them work than I would've ever learned from seeing what they did with paper and pencil." In this statement he did not say what it was that he learned about his students, but, if pressed, he could probably have made a list. He might have noticed how they interact with one another, whether they were posing and testing hypotheses, or whether they were skilled as researchers. Instead he was stating that he found that he could learn different things about his students than he could from paper and pencil assignments. This could be put into the form of a propositional statement: Teachers learn more about their students by watching them perform a task than through the use of paper and pencil assignments. But Hiebert claimed more than this, that when he is immersed in the situation, in the classroom with the students working with them in this way, he can use his expertise that has developed through his 20+ year career to better assess his students. A similar example is this statement by Woosnam: "The closer you get to being yourself in the classroom, the more effective you will be as a teacher." This is in the form of a maxim -- teachers' folklore in

propositional form (Shulman, 1986). As a maxim it is banal, but as a teacher's conclusion from a year-long experiment in pedagogy, it is profound. What makes it so is that it is a statement of a new understanding of his classroom, his students, and himself as a teacher. Woosnam has found that in order to improve his practice, to more effectively take advantage of his expertise, he needs to act more authentically.

And finally, Fottrell's summary of his use of written approaches in teaching problem solving transcends codifiable knowledge. In fact, Fottrell was aware of this. As he began his summary report, he referred back to the comments made by a visitor to a PTARG meeting:

Fottrell: It reminds me of what Peter Posch was talking about last time, he impressed on me the idea that it's often more useful, especially in this sort of stuff, to not give the conclusions but to tell the whole story because you can glean so much more from somebody else's experience hearing the whole tale than you can if you hear "I've found that this kind of student conversation is good and this is how you should implement." It's kind of empty, it loses something (PTARG meeting 5/13/92).

And so Fottrell told his story of using written approaches and described the advantages and disadvantages in narrative form in order to keep from "losing something" through an attempt to transform his understanding into knowledge claims.

What Hiebart, Woosnam, and Fottrell learned as part of trying out ideas in their classes, and sharing that with the other PTARG teachers through anecdote-telling, was a combination of knowledge and understanding. It is clear that they learned "chunks" of knowledge that they could exchange commodity-like with other teachers. But they have also gained a better understanding of themselves as teachers, an understanding that is dependent not only on their conscious awareness of their pedagogy, students, subject matter knowledge, and the other categories of teacher knowledge, but also on their accumulated and shared expertise.

Context and situation

The second key to the construction of enhanced normal practice as collaborative action research comes from the ways that the interactions between people and the world are conceived. If one thinks in terms of people acting in context, there is an implied separation that adds to the codifiability and categorizability of knowledge. The notion of the individual being a part of a situation, and the teacher a part of an educational situation, suggests a complex interaction among entities that is not only spatial but temporal (Dewey, 1938). The understanding that arises through the immersion in situations -- the meaning making that occurs -- is as much a part of the situation as the person coming to understand it (Dreyfus, 1991; Heidegger, 1962).

By thinking about teachers and their practice being immersed in an educational situation, it follows that teachers' knowledge and understanding is never completely divorced from their intentions or actions. That is, what teachers know and understand

affects both their goals and how they decide to act in order to reach those goals. Although there is not a one-to-one relationship between conscious thought and actions (Searle, 1992), it should be obvious that what a person knows and understands affects the way that person thinks and reasons about his or her practice. This suggests that when the teachers of PTARG would listen to another tell a teaching anecdote, the knowledge, or new understanding, gained by the listeners would affect their intentions and/or actions. As a result they might try something in their classes based on what they have learned from that other teacher in the group. This is what happened with Fottrell when he began to have his students write approaches to numerical problem solving after hearing Erzberger tell an anecdote of how she does the same. Similarly, Rappleyea began using the file cards to check on student understanding after she heard Woosnam tell an anecdote that reminded her of a workshop that she attended in which this technique was presented. She tried it out in her classes and reported on in to the group through anecdote-telling. Her tales of success with the technique prompted others to do the same. And, in addition, it became the principal probe in the group systematic inquiry.

What I am arguing is that both anecdote-telling and the trying out of ideas play a powerful role in generating and sharing knowledge and understanding. It is a role that goes further than serving as a prelude to research that would lead to other activities that generate knowledge. In accepting understanding as equivalent in import to knowledge, these two mechanisms -- anecdote-telling and the trying out of ideas -- can be seen as legitimate forms of research. And by recognizing the distinctions between knowledge and understanding, and context and situation, each of the aspects of enhanced normal practice -- anecdote-telling, the trying out of ideas, and systematic inquiry -- can be seen to result in the generation of knowledge and/or understanding, and are all legitimate parts of action research.

What this suggests is that a process is occurring that is more complex than simple story swapping. It is true that an anecdote told by one teacher was often responded to by another anecdote, but in doing so a complex mélange of the exchange, testing though action, and generation of knowledge and understanding was created. This mélange, what I call enhanced normal practice, is a way that teachers can improve their practice while coming to a better understanding of that practice.

-----Insert Diagram 2 here -----

Implications of the study

Enhanced normal practice and educational research

The PTARG teachers generated and shared their knowledge and understanding of teaching and being a teacher through the three mechanisms of enhanced normal practice. First, the telling, listening to, and questioning of the anecdotes of others supplied a context that made visible the educational situations in which the teachers were immersed, details about particular pedagogical techniques, and ways that they and their students

responded to them. Many of the anecdotes were technical in nature and focused on the know-how for teaching particular concepts in physics through explanations, demonstrations, experiments, and other representations of subject matter knowledge. Others were attempts by the teachers to come to a better understanding of how their work influenced their students' learning. At times the anecdotes and questioning were about theoretical issues such as learning theory, the psychology of groups, and the sociology of education. At other times they reflected a deep ethical concern for their students and others in the educational enterprise. In all cases, the telling, listening to, and questioning of anecdotes served a powerful role in enhanced normal practice in generating and sharing knowledge and understanding (Feldman, 1993c).

While this might be dismissed as just "teacher talk" it has important equivalents in more traditional research. There have been many times that I have sat in meetings of research groups when the participants shared anecdotes about their practice as researchers to illustrate an idea or to "prove a point." As the others listened to the anecdote and questioned the teller, a deeper understanding occurred for all involved. The same can be seen when people gather to discuss any sort of issue. Through the discourse that includes telling, listening, and questioning, the participants come to a different understanding and know something that they did not know before.

Many who have engaged in this sort of interaction recognize the importance it has as a part of research. It is typically seen as a prelude, as part of the process, that leads to other activities that generate knowledge. Instead, I am arguing that the understanding that arises in the discussions among the participants in the research group, whether school teachers or university researchers, is equivalent in import to the knowledge that arises through the more systematic research that may follow.

Second, all of the PTARG teachers tried things in their classroom that were new to their practice. Some of these ideas were self-generated, some came from others in the group, and some from outside sources including other teachers, publications, and educational research. While the claim "I never teach anything the same" is often made by teachers, and was made by several of the PTARG teachers, what makes the trying out of ideas a part of enhanced normal practice is that it is tied to anecdote-telling. In enhanced normal practice, teachers not only try out ideas but also tell anecdotes about them. Their experiences in their educational situations are shared in this way with others who respond with questions, and then often try out the ideas themselves. The sharing and critiquing of these experiences in a collaborative setting result in a growth in knowledge and understanding about the way those ideas work out in practice and goes beyond what normally occurs in practice.

This, too, plays an important part in traditional research. Just as in the collaborative action research of the PTARG teachers, educational researchers leave their research group meetings with ideas that they will use to further their research. They try out those ideas for modifying treatments, data collection and analysis, and theories, and return to the research group with anecdotes about how it went.

And third, the PTARG teachers engaged in systematic inquiry of their practice, a process that is most recognizable as research. Teachers who engage in systematic inquiry into their own practice use the methods of educational researchers to look carefully at some aspect of their practice. In doing so they may generate generalizable knowledge similar to that of other educational researchers or they may uncover discrepancies, dilemmas, or dissonances in their practice-- as did the PTARG teachers. And by focusing that inquiry on their own practice, it immerses it in their educational situations and allows for another way of experiencing that situation, an experience that leads to a different understanding in addition to any generation of knowledge through a personalization of the inquiry.

While it is this systematic inquiry that looks the most like Stenhouse's definition of research (1975) -- systematic, critical inquiry made public -- if the conception of knowledge is extended beyond the commodity form to include understanding, then all the mechanisms that I identified and described in this paper that make up enhanced normal practice can be appreciated as forms of research. Because they all can result in the generation and sharing of knowledge and understanding, they are research as Weinmann has defined it: "Anything that produces new knowledge is research (PTARG meeting 4/20/93)." In addition, by extending the conception of knowledge, action research can be seen to include both the problem solving through data collection and analysis that typifies classroom action research and the narrative practices associated with the teacher-research done in association with the Writing Projects. And, when action research is done in a collaborative mode, as in the PTARG meetings, understanding and knowledge can be shared and generated in a way that embeds it in the teachers' practice.

Collaboration and the importance of community

It should be clear from the way that I have described enhanced normal practice that it depends on teachers talking with one another about their practice, and that the conversations that occur go beyond a swapping of stories or anecdotes to critical listening and questioning. It is this sort of collaboration among the physics teachers that helped create new understanding and added to the legitimacy of all aspects of enhanced normal practice as research. What this suggests is that for enhanced normal practice to occur and for it to result in legitimate forms of knowledge and understanding, as well as the improvement of practice, it is important for it to occur among a group of practitioners who form a community of practice in which they both "talk about and within" their practice (Lave and Wegner, 1991, p. 109).

Enhanced normal practice, as a form of research, is a group activity, a process that occurs collaboratively within a community of practice. That community does not necessarily need to be constituted solely to engage in enhanced normal practice, but there are indications in my work with PTARG and other teachers, and from Lave and Wegner's work, that for knowledge and understanding to grow as a result of a collaborative effort, there needs to be a common culture or, as Searle might put it, a shared Background (1992).

There remains the question of how much that I have identified in the work of PTARG is dependent on the fact that all of the teachers were willing to be a part of a collaborative action research group. There is the possibility that what I have seen is dependent on volunteerism -- that these teachers generated and shared knowledge and understanding through enhanced normal practice because they are the sorts of people who can and will do this. I am currently investigating this question in my work with graduate students enrolled in an action research course, and with teachers taking part in a school district sponsored action research project.

Collaborative action research and the reform agenda

The success of the current reform agenda in science education is dependent on thousands of experienced teachers changing their practice. It is generally assumed that this will be accomplished through staff development activities. The prevailing models of staff development that pervade schooling are derived from a process-product perspective of educational research (Sparks and Loucks-Horsley, 1990). That is, some treatment is developed, science teachers are trained to implement it, and then students are tested for the results of that treatment. When applied to the in-service education of teachers, this model appears as the training of teachers to implement curricula and pedagogy to increase student learning (Joyce and Showers, 1983; 1988). When put into practice, this model is most often realized as outsider experts coming to schools to either train teachers in some new form of pedagogy or to instill them with knowledge derived from educational research. While this model is being challenged (Lieberman and Miller, 1991), there is still the suggestion that outside experts need to come into schools to tell teachers how to be professionals.

This has been a report of a study that looked at a different form of staff development -- collaborative action research -- that relies strongly on the expertise of teachers, and on their abilities to generate and share among themselves knowledge and understanding. This study suggests that for teachers' action research to be an effective part of the reform of science education; that is for science teachers to come to better understandings of their educational situations, for practice to improve, and for it to be self-sustaining, a different conception of what counts as action research must be accepted. It is a conception that fits into what science teachers normally do extended to include the collaborative activities of anecdote-telling, the trying out of ideas, and systematic inquiry. This conception of research is dependent on the acceptance of what I have called understanding as its product as well as categorizable knowledge. In addition, it should recognize that for many science teachers, other science teachers are an important source of the knowledge and understanding that they have about teaching and schooling.

The implications of this for in-service teacher education are significant. It suggests that action research operationalized as enhanced normal practice could serve as a model of staff development that will result in teachers both improving and gaining knowledge and understanding about their practice. That is, in-service teacher education for the reform of science teaching could be organized so that there is a combination of the sharing of knowledge about teaching through anecdote-telling, a trying out of ideas about teaching and learning, and the sharing of new anecdotes or other forms of narrative about

how it went. And, some sort of systematic inquiry could be a part of this process especially if the questions that are investigated arise from the dilemmas and dissonances of practice. What mix of these activities is best for teachers' professional development is not clear, but the indications are that the more it looks like teachers' practice as it is currently configured, and the less it looks like university research, as in the reliance on data collection and analysis of classroom action research, the more likely teachers will do it. This suggests that the mix should be tilted in favor of anecdote-telling and the trying out of ideas, with systematic inquiry coming into play when appropriate to the situation.

Enhanced normal practice and preservice teacher education

The success of the reform agenda is also dependent upon new teachers engaging in professional development activities once they are in the field. While this has been a study of action research done by practicing science teachers, it does have significant implications for pre-service teacher education. Some form of teacher research is becoming an integral part of certification and masters degree programs for teachers. In the former it takes the form of an assignment that is done either during student teaching or in a prior observational placement. Action research is presented as a set of steps that one follows to either solve a problem or to generate new knowledge. To the novice science teacher, it can become an algorithm to be followed to complete the assignment and to fulfill the requirements for the credential. The danger is that the action research could become just another "hoop to jump through," or even more troublesome, it could be seen as another one of those activities that is a part of teacher education that has no relation to the "real world" of practice. The same can be true of action research that is part of a masters degree program for teachers.

Conclusion

An acceptance of a variety of conceptions of what constitutes knowledge and understanding allows for a conception of action research that is inclusive of and goes beyond classroom action research and the teacher-research of the Writing Projects. This conception of action research, which remains self-developmental in nature, is of teachers engaging in enhanced normal practice in collaborative groups, and then making public to others not in their groups their new knowledge and understanding of their educational situations. Because anecdote-telling and the trying out of ideas are not far from the normal practice of teachers, collaborative action research envisioned as enhanced normal practice is a process that can be embedded in the practice of teachers and in the culture of schooling. It is a model of teachers engaging in collaborative action research by telling, listening to, and questioning anecdotes, by trying out ideas in their classrooms, and then telling anecdotes about that to other teachers, and by occasionally engaging in more systematic forms of inquiry. What this study suggests is that if action research is reconceptualized as an enhancement of normal practice by the encouragement of communities of practice in which anecdote-telling, the trying out of ideas, and systematic inquiry can occur, then action research as a form of professional development could be embedded in, and seen as a normal part of, teachers' practice.

	n=46 cards
	calculations helpful - 18
	mini-lecture was helpful - 18
	no response - 24

Table 1: Students' comments about class with mini-lectures.

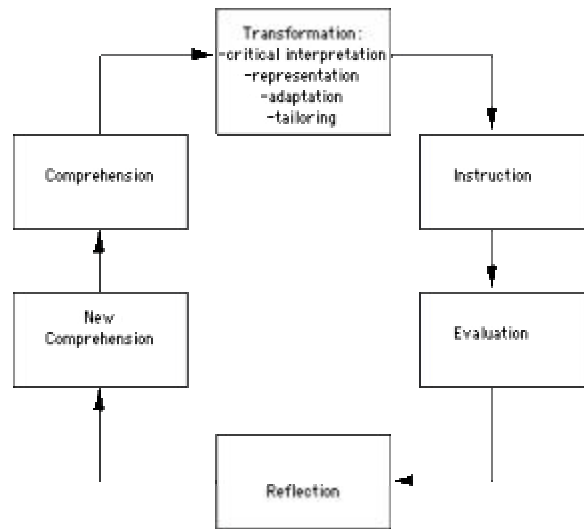


Diagram 1: A model of pedagogical reasoning (Wilson et. al., 1987)

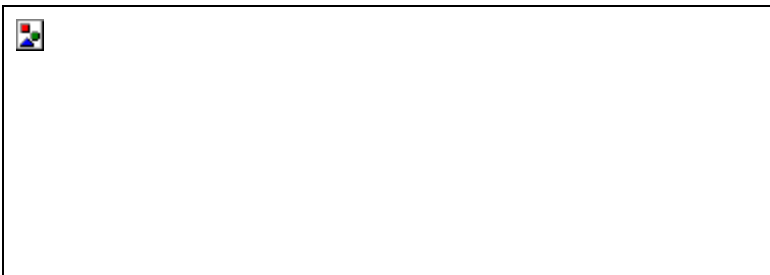


Diagram 2: Enhanced normal practice as a mélange of activities.

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