Third Misconceptions Seminar Proceedings (1993)

Paper Title: THE CLASSROOM TEACHER AS RESEARCHER OF CHILDREN'S SCIENCE LEARNING

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Keywords:
General School Subject:
Specific School Subject:
Students:

Macintosh File Name: Kerr - Classroom Teacher
Release Date: 12-16-1993 C, 11-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

in bringing you this proceedings, on the part of the many authors and conference organizers. The original publication of this proceedings was supported by a grant from the National Science Foundation, and the transformation of this collection into a modern format was supported by the Novak-Golton Fund, which is administered by the Department of Education at Cornell University. If you have found this collection to be of value in your work, consider supporting our ability to support you by purchasing a subscription to the collection or joining the Meaningful Learning Research Group.

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THE CLASSROOM TEACHER AS RESEARCHER OF CHILDREN'S SCIENCE LEARNING

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The "endless variations" of how teachers use what they have learned in their own teaching is one of the most intriguing features of teachers' research (Duckworth 1987). This paper reports on the experiences of elementary teachers who acted as researchers in their own classrooms after attending a summer workshop designed to encourage them to assume that role. Their inquiry involved them in reflection on their own practice.

> The art of teaching ...exemplifies the use of what John Dewey referred to as qualitative thought. The fine-grained adjustments that good teachers make in speaking to individual children, their vision of options that can be pursued in a classroom, their assessment of levels of student interest and motivation, and their appraisal of student comportment as well as their written and verbal expression--all require the use of qualitative thought. Eisner & Peshkin (1990, p. 366)

Duckworth (1987) argues for including research as part of a teacher job description.

> . . . one is in a position through teaching to pursue questions about the development of understanding that one could not pursue in any other way. If as a researcher one is interested in how people build their understanding, then the way to gain insight is to watch them do it, and try to make sense of it as it happens. (p. 134)

Teachers are in an enviable position to generate knowledge about teaching. They are rarely afforded the opportunity to do that, nor do teachers perceive themselves in that role. This paper reports on knowledge about teaching science, constructed and used by teachers for themselves and their immediate communities. My interpretation of their records rests on the validity of their role as researchers; a role increasingly supported by many educators. However, while I can represent teachers' texts , I do not speak for them.

These principles formed the basis for the second summer workshop that I directed at the Center for Teaching and Learning, University of North Dakota. Forty-seven North Dakota teachers from grades K-9 attended two three-day workshops funded by the Dwight D. Eisenhower Mathematics and Science Education Act. Eighteen teachers chose to participate in a research project in their classrooms in the fall. The focus of this paper is how the teachers responded to this role, and what experiences counted as meaningful in their research on students' science learning.

THE WORKSHOP

The title of the workshop was "Classroom Action Research: Opportunities for Science Teaching." The purpose of the workshop was to enhance the integration of method and content by introducing teachers to the learning tools of concept mapping and vee-diagramming, to alternative assessment by portfolio and concept mapping, to clinical interviewing as a process for finding out childrens' prior knowledge, and to support their roles as classroom researchers into teaching and learning in science.

The workshop had two major components. Teachers learned how to use the heuristics of concept mapping and Vee diagramming, applying them to their favorite science activity. This included learning C-Map in the computer lab. They went on to use the the heuristics to create their research plans for the fall. Teachers were encouraged to think about their planning for curriculum and instruction by envisioning students' science learning as constructivist activities.

Discussion in science education about constructivist learning and teaching includes how (or whether) constructivism serves as a theory or a world view or an epistemology. I would refer the reader to the extensive literature on this subject, suggesting as a starting point an interpretation by Wheatley, 1991. The principles that govern my understanding of meaningful learning in science, and the use of the heuristics of concept mapping and Vee diagramming are represented by Ausubel, Novak and Hanesian (1978), Novak and Gowin (1984) and Gowin (1981).

The second component of the workshop was facilitated by two university professors and two classroom teachers. Dr. Sara Hanhan, whose research in early childhood education involves the nature and use of portfolios, taught a section of the workshop devoted to the nature of childrens' portfolios, and particularly how portfolios might afford a more appropriate assessment for constructivist science learning than pencil and paper tests. Dr. Jean Thomas shared with the teachers some of the concerns about classroom research including ethical issues. The emphasis was on how research can be regarded as an extension of the normal teaching process, especially as inquiry into ones' teaching and childrens' learning. Two classroom teachers, Ms. Deborah Stahlberg and Ms. Rosemary Hoberg had conducted research in their classrooms on integrative approaches to learning language and science in primary classrooms and about science learning and cooperative learning activities, had kept portfolios and were familiar with the processes, and had written their master's theses about this research.

They shared their experiences with the teachers, showing how new strategies for teaching science and science curriculum developed from their research. Throughout these three days, teachers were encouraged to share ideas about science activities that they had found successful.

Directions were given to the teachers only in the form of suggestions for completing the projects and requirements for finalizing their written work. They were to resubmit a copy of their research plan which included a concept map and a Vee diagram, and a three to five page paper describing what took place in their classrooms. They were asked to write their paper as a descriptive essay in the first person from their notes and other materials, to include reflections about their teaching as their students worked with concept maps or other schema during their science classes, to evaluate any differences they noted in their learning or involvement, and to note any negative factors that surfaced. They could include student work and comments (anonymously), summarize what they might have learned from this exploration, and how their teaching might reflect (or not reflect) this new knowledge. In short, act as researchers in their classroom, hopefully far beyond this summer project.

The research plan submitted before leaving the summer workshp was necessarily structured, but the teachers had considerable freedom in how or when they would use concept mapping (including not using it at all), and Vee diagramming was also optional in their research project. The directional emphasis was on the reflecting and systematic and intentional inquiry into student learning and their teaching.

One of the strengths of teachers' research is that multiple resources become available. Records for this study included teachers' initial essays, journals during the workshop, lesson plans and ideas for the use of the heuristics, both concept mapping and Vee diagramming, the resulting essay by the teacher describing her work, as well as (in most cases) samples of student work. Finally, five of the teachers involved in this research project were interviewed and three of these five teachers made it possible for us to be classroom observers.

LITERATURE REVIEW

Lytle and Cochran-Smith (1992) claim that teachers rarely participate in the generation of discipline-based or "official" knowledge, yet "research by teachers is a significant way to knowing about teaching." (p.450) They offer a comprehensive view and rationale for teacher research as a way of knowing, as well as a substantive literature base that explores the nature of research and teachers' work. They propose teacher research as a way of knowing about teacher's work rather than only the knowledge generated by the university researcher. Teacher knowledge requires the

> . . .development of a different theory of knowledge for teaching, a different epistemology that regards inquiry by teachers themselves as a distinctive and important way of knowing about teaching. ...Teachers are among those who have the authority to know--that is, to construct "capital K" knowledge about teaching, learning, and schooling. And what is worth knowing about teaching includes what teachers, who are researchers in their own classrooms, can know through their own systematic inquiry. (pp. 447-448)

If, as Lytle and Cochran-Smith argue, teachers in schools are a "primary source of generating knowledge about teaching and learning about themselves and others" (p. 447) then those sources should not be marginalized. While firmly supporting and confirming the importance and validity of knowledge generated by university researchers, they argue that the existing work would be enriched and enlarged by teacher research.

Teacher classroom research is systematic, intentional inquiry by teachers about their own school and classroom work (Cochran-Smith & Lytle, 1990). It is systematic in the sense that they gather and record information and document experiences by leaving a written record.[1] It is intentional, in that it is planned, rather than spontaneous. Finally, it is inquiry because it "stems from or generates questions and reflects teachers' desires to make sense of their experiences". . . (Lytle & Cochran-Smith, 1992, p. 450). They propose four categories for teacher research that is based on a wide range of teacher writing. This present study comes under the category of “brief and book-length essays in which teachers analyze their own classrooms or schools and consider issues related to learners, curricula and school organization.”(p. 450)

Science education research reporting on teacher attitudes, behaviors and pedagogical content knowledge often includes references to teachers who are empowered to act as researchers in their classrooms. However, there is little teacher initiated research unless it is incorporated into a collaborative project where university personnel are also involved.

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[1]. For this, Cochran-Smith and Lytle refer to the work of Stenhouse (1985). See reference list for complete annotation.

Carol Briscoe (1991), in her case study of a high school science teacher suggests that changes advocated for teachers through pre-service and in-service education must occur under a constructivist framework; that teachers "need time to experiment in their classrooms and construct knowledge about teaching without fear of administrators evaluating them on the basis of traditional images." (p. 198) Brickhouse and Bodner (1992) in their case study of a beginning science teacher observe that teachers need the opportunity to learn how to "assess students' interpretations of lessons and how to rethink those lessons so that they provide students with the optimal conditions for learning." (p. 482) They refer to conditions where a teacher can learn how to engage in classroom research without penalty, and with support from the school organization and colleagues. Shymansky and Kyle (1992), reviewing the need for a research agenda in science education, note how teachers see themselves in classrooms in ways that fit the context of their environment. (p. 759) These contexts acts as restraints as teachers construct their pedagogical knowledge to fit their environment. Richardson (1990) and Hollingsworth (1989) both note the importance of considering teachers' preconceptions about teaching in order to implement change that derives from the teachers' own beliefs and understandings.

Starr and Krajcik (1990), observing teachers using concept maps as a heuristic for science curriculum development, describe these teachers as classroom researchers. The teachers gained control by participating in a development process, and this involvement is critical for change. Shymansky (1992) describes a pre-service education practice at the University of Iowa that casts students in the role of researchers in their science classrooms. By researching science concepts, students go through a systematic study. They create questions, collect data and record experiences for analysis. This process encourages students to examine theoretical frameworks that support their beliefs about teaching and learning science. The three year study by Baird, Fensham, Gunstone and White (1991) showed the importance of reflection on teachers' practice and on the nature of science teaching and learning. While these teachers were in close collaboration with colleagues and the research group, they referred to the ability to be able to carry out systematic procedures as constructive.

PRIOR KNOWLEDGE

From teacher journals at the beginning of the workshop, thoughts about participating in a research project or even considering themselves as researchers were tentative and framed in terms of student learning. The most consistent response to the challenge was in terms of its usefulness in improving their teaching, to evaluate their teaching, to help them in their classrooms, and to answer questions about teaching methods

> If we become researchers in our classrooms , we will become better teachers. The more research we do, the more we will notice important things about our students. I like this research idea. It makes me feel like I am part of the learning process. It takes me out of the all-authoritative position--keeps me openminded. Made a promise to myself when I graduated from college--I will be open minded. I will change my teaching style to meet the needs of students. My ultimate goal. . . is the kids. This gets very hard in a society who wants visible results or doesn't want change. I am willing, I will push for it. (BK)

The second major response was in terms of how they thought they already participated in a research process because they constantly changed their lessons, evaluated them, searched for new materials and methods.

> I think elementary teachers inadvertently are researchers although we don't view ourselves as such. I write notes to myself about what activities work well, which need more time to develop, which need to be changed. I keep records of areas that need attention, students that need help, checklists of all kinds of things. I use these to adjust my methods, take shortcuts, make plans for next year. All this helps me improve myself as a teacher. (EK)

The teachers' prior concepts about what constituted research affected what and how they began their lesson and inquiry. For most of them, it simply meant taking the two tools learned about in a summer workshop and applying it to a lesson they had already planned, observing the students and their own reactions, and writing it up as an essay, thus meeting the requirements for workshop credit. They reflected on the process to the degree that it met their ideas of improving their teaching of science and their students' learning.

ON TEACHING SCIENCE

To the teachers, good teaching in science is good teaching in general: covering the units; integrating as much as possible across the curriculum especially into reading and language arts; having lots of hands-on activities (doing experiments); going on field trips and having guest speakers; "doing research" which meant being able to find information about science topics in texts, trade books, encyclopedias and computer programs. The teachers use a variety of teaching models--lecture, discussion, demonstration--and a variety of student groupings; whole group, seat-work (individual) and cooperative learning in small groups. What teachers liked about science teaching always included how much students were excited and motivated, how they participated interactively and shared, and how intense they became in the pursuit of science activities. They portray the discipline of science as all-encompassing, interdisciplinary, never-ending, constantly changing, informal, and "about nature."

On the negative side, even those teachers who loved to teach science stressed their need for space, time and equipment. Time was related to the pressure of the rest of the curriculum, which is why many said that it was essential that they teach science as part of language arts or social studies. They didn't like some of the implications of teaching science that they got from text materials that involved lots of vocabulary and reading with few activities. To a lesser extent they commented on their lack of self-confidence as science "knowers", but there was an element of acceptance of this, that they would be learners with the students, and that they were, indeed, getting better. Two teachers told of experiences that seemed ideal as research questions: why students seemed reluctant to investigate experiements that failed, and why students didn't seem to understand science concepts even after a good "hands-on" activity. Neither of these teachers chose to investigate these problems. There was little or no discussion of science content or science concepts and what they mean.

All of the teachers (but one) made concept maps for the science lessons they planned to teach, and fourteeen of the teachers constructed a Vee diagram (some made several) indicating the event, the concepts, records and focus question for their research plans. As reported elsewhere, (Kerr 1992) these teachers, after initial exposure, found concept maps and Vee diagrams helpful for organization and planning purposes.

RESULTS

When reports of the fall activities were returned and transcriptions were made from classroom observations and teacher interviews, of the many categories available for analysis, I chose to collect those actions or thoughts that seemed to occur as a result of a systematic, intentional and self-critical inquiry that included record keeping. I am including some characterization of the teachers' work along with the categories of analysis because they are almost impossible to separate. I am impressed anew by what Connelly and Clandinin (1985) refer to as personal practical knowledge and modes of knowing revealed in "narrative unities." It is evident in teacher interviews, in class observations and their writing about teaching, that an experiental way of knowing directs their choices and their decisions for instruction.

REACTIONS TO STUDENTS USE OF CONCEPT MAPS

The major response to student reaction to concept maps was in terms of the students' excitement. The following comments are typical:

> The first day we made a concept map on the board on plants. The students were amazed that they already knew so much about the subject. I was also amazed. It really helped to know what they already knew. . . . the reason the students enjoy this is that they always take such satisfaction in knowing how much they really know. . . . there is so much excitement in seeing how everything fits together continuously. (LVB)

There are several aspects to these comments. First, both the teacher and the students found out and were amazed at how much they knew. The value of the visual representation is evident here. This fourth grade teacher also is aware of children's developmental needs as well as the constraints that prevent teachers from fulfilling those needs.

> We know all kids need visuals, but in upper grades get away from them and into text. This (concept mapping) organizes everything for them, and for me. So that I know that we've covered the things ahead of it, prior knowledge. And then it takes it beyond what we need to learn, as far as the objectives go in the textbooks. Because the kids get interested, and they want to find out what comes after that. (Interview JL)

Concept mapping provides opportunities for expansion of the topic. A teacher found this to be true when she looked at student concept maps after a unit on aerodynamics.

> A surprise factor showed up. I found they had developed an appreciation for airplanes and their history. They appreciated how long and frustrating a process discovery can be, how far air travel has come and how much we take for granted. . . . What wonderful discoveries! I know every teacher wants these things to happen but rarely are we lucky enough to have the students share reflections like that. (CM)

Second, the meaning of the concept labels became clear when the students were able to make sense out of their connections. A teacher describes how students initiated putting individual animal food chains into a concept map. They had not been taught about concept maps yet, but they already saw how the food chains of individual animals fit with other animals to create a much more complex set of relationships. The teacher then introduced concept mapping (not by name) and the students excitedly fit everything together. She says, "They did not want to go to lunch, because they had a need to fit it all together." (JL)

> The next day I handed the students our post-it notes. We then put the whole web together on the chalkboard. This was a c-map, but I chose not to use this label. The students were unable to sit still as each child brought up their various animals. The students quickly realized the complexity of the web. They saw how every animal is important to the entire web. It may look a mess to you, but these students know exactly what was going on. . . . they need the concepts broken down into pieces that connect with one another so things make sense to them. . . . if they don't see how it fits together, they don't remember it. (Interview, JL)

Her intentional teaching behavior is evident here as she decided not to tell the students the name of the tool. She had also decided to let them see how the relationships were evident before introducing them more formally to the linking. (Which in this case was accomplished by adding the links that tied one animal to another.)

Finally, this teacher was aware that the request came from the class, "Can we put all these together?" She did not initiate that step of making meaning, it came from the students. The meaning was freeing and created the excitement for learning; it was not filling in the blank, but actually understanding the connection. It was that real, but not material triadic relationship that Percy calls "the coupler."[2]

CHANGES IN STUDENT DISCOURSE

Within the context of the science lessons, most often related to concept mapping, but in some cases in completing another part of a lesson, the teachers reported on the ways students were reacting with each other. Many of the teachers use cooperative learning in their classrooms and prepare the students to be aware of the social skills they are practicing. These teachers emphasized the responsibilities of each member of the group and occasionally stopped lessons in order to remind students of these responsibilities. The teachers found that students were discussing science topics differently; that there was non-agreement, but with discussion; that they felt comfortable with some ambiguity; sensing that there was more than one way to know;

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[2]. "The Divided Creature", by Walker Percy. This reference is from an essay adapted from the 18th Jefferson Lecture in the Humanities, delivered on May 3, 1989, in Washington, D.C. Copyright c 1989 by Walker Percy, and printed in *Teaching & Learning: The Journal of Natural Inquiry*, *4* , 3, 1990, 9-19. It was first published in *The Wilson Quarterly,* Summer 1989.

and an occasional student being able to explain a relationship (with great pride) that no one else had observed (even the teacher). The awareness of more than one way to know comes partly from the teachers' efforts with cooperative learning groups. One of the social skills stressed was respect for classmates' other ways of knowing.

An awareness of how a community of learners might resolve a scientific dilemma from the data available comes from this teacher's observation of student discussion.

> . . . we discussed our concept maps and how the activity related to directing space probes. A long discussion took place with a final consensus that distance definitely does affect accuracy. The students also concluded that there are other variables in accuracy other than distance. This was so fun for me! The students were talking scientifically without even knowing it. (BK)

A fifth grade teacher began a unit by asking her students what questions they would like to ask about cells. After they had made a list and started finding information to answer their questions, they gathered in a group to share answers, and make a concept map of their findings. She discovered that questions that could be answered by a yes or no required very little research and provided very little information. "Questions need to be reworded to get more comprehensive answers." (SL) She then found the students correcting each other, "See here it says. . . " The students individually made cell models, because she wanted to allow them the freedom of creativity rather than making a group model.

> Each student was then given a chance to tell about his/her model including how it was made. Students began spontaneously to ask questions of each other such as ,'What kind of a cell is it? Where is the cell wall? ...cell membrane?' (SL)

In a discussion of categories for communities (an integrated science and social studies unit), CN's third grade students came up with the concepts of people, places and things, and proceeded to discuss and in some cases disagree about how to sort these concepts.

> Some students determined that birdhouses and doghouses should be things; others listed them under places. I told them that as long as they could reasonably defend their decision, they could list them wherever they thought best. (CN)

This unit proceeded through a fairly complex series of lessons, each one building on one proceeding, tying together the concepts the children decided on and eventually creating a concept map. Throughout this entire process there was much discussion, and defense of choice for each concept. CN concludes that the discussions, controversy, and cooperation which developed from the CMAP creation was a beneficial experience for third graders.

TEACHER CHANGE

The teachers said it was important to give students more independence. They made decisions about the uses of the heuristics on the basis of student responses rather than where it fit into their plan. They were taking more risks because they found that they didn't have to know a topic a well in order to facilitate student learning. They made a greater effort to find out childrens' prior knowledge. They reorganized units by taking a second look at content and process in response to their students' learning. They were more anxious for collegial support, and they also were more proactive in reporting what they were doing: to their peers, administrators and the parents of students.

One teacher identified her teaching as research:

> For the third unit, I decided to use the research approach for learning. I made a Vee diagram and a concept map as a guide for teaching the properties of a water drop. When I used these tools to conduct a clinical interview, I discovered that students' knowledge about a water drop was quite limited. They knew that water is wet and that it can be found in three different states. (Interview EK)

In addition, EK reported that she was in the process of reorganizing her science program so she can use the "research approach" for all units. She customarily writes teaching objectives with activities, but found that the Vee diagram "just added another dimension."

> I guess I'm not teaching to the objective like I used to do. I mean there are certain things that I want the children to learn, but I'm holding off on telling them. Like, today, at the end of the actvity we did, if I were teaching to the objective, I probably would have told them why they were able to stretch a water drop. But, I'm just going to hold off from that a while. (Interview EK)

Not knowing the answers was another admission of change, especially as it related to how a teacher felt about understanding the teaching of science.

> Well, its made me willing to risk, I think. It takes a lot to say to kids 'What do you think?' . . and we explore it together, and figure it out together, and . . . I'm comfortable doing it, and that surprises me. I don't have the answers going in. And there was a time I would have. I would have needed concrete answers. I would have had to know what the result was going to be. (CM)

For skeptics at the workshop who thought that concept mapping was not going to make any difference and would probably be a lot more work, the evidence of children's reactions was convincing to them.

> I feel that I will use this more in the future because the students showed me that it truly is worthwhile. As I noted in my statements this summer, I was not convinced that this was the answer for any new teaching techniques in my science. the students have shown me, however. . . (Later) I guess what has changed is how I view lessons, as parts versus whole, and putting those together, instead of teaching lesson 1, 2, and 3. . . I'm teaching the whole thing. (Interview JL)

> I learned a lot about my students. I learned who could work well in a group. I began to understand better their thinking process on a broad range of subject. I could more easily determine students' knowledge and understanding of vocabulary words and concepts. (CN)

Teachers looked at evaluation differently:

> At the end of each activity, we had a large group discussion about what each small group had discovered. Then students wrote a paragraph about the activity and what they had learned. . . . Instead of a test, I collected the paragraphs and concept maps and evaluated them instead. I was pleased at their understanding of the properties of water. (Interview EK)

One teacher found that a different atmosphere was created in her classroom, expecially among less able students.

> The hardest part was getting students to understand the idea of "no grades." Learning still takes place, you are still held accountable. All relaxed, especially low ability; they took chances to answer in class and on their activity, where other times, with grades, they cannot afford to take chances. A whole new atmosphere was created in my classroom.

Teachers expressed a need for colleagues with whom to share new ideas and the results of their research. One mentioned that she recently talked with colleagues about how much they did and how little they talked. However, others planned ways in which to share these ideas.

> The next goal is to keep portfolios, with concept maps, for one quarter of school, for science class. At the end of the quarter are parent/teacher conferences, where I will share the portfolios. I am very excited.

> I spread the news right away. I told every teacher I saw, even my administrators who have totally supported my effort. I've had four teachers come and ask questions, and are very interested in concept maps and portfolios. I now have two colleagues joining me! (BK)

Finally, a modest report from a teacher who had a corn-popping party with her first-graders, then had them relate all the senses they were using and make a concept map about it.

> We had an inservice at our school this week with area schools. We had ten first-grade teachers and shared ideas. (Bringing up). . .the popcorn party wasn't my idea, but we got onto the subject after they looked at my displays. They all just loved it and were impressed with the mapping ability and the colorful collages. I was a big hit. (CMK)

DISCUSSION

Three sets of information about the workshop were available to the teachers: the brochure that included the application form, the acceptance letter, and the program of activities sent to them prior to their arrival on campus. There was some evidence that the teachers were reluctant to abandon the idea that summer workshops exist to "give" them science activities for their children. In follow-up evaluations as well as in comments from interviews, a few teachers maintained that the workshop was not what they expected, that they thought they would get "hands on" activities. Graciously, they admitted that they had learned new ideas, but it was clear that their work as classroom teachers did not include Duckworth's idealistic description of teacher-researcher. Teachers are not often asked to be reflective, to inquire into their own practice for the purposes of improving instructional skills, or to learn how to respond constructively to students' science experiences.

Ditchburn, Jardine and Prasow (1992) make a distinction about reflection that is important to the conception of this study. They suggest that reflection as a "corrective measure" or as a "technical instrument" is atheoretical and acts as a set of practices brought into play only in problemmatic situations. A research project where teachers are asked to be observant or critical or reflective about their practice might evoke that vision of reflection as an instrument. Efforts were made to insure that teacher voices emerged from their practice, remaining central to their pedagogical activity, rather than being imposed from outside as an instrument of research. The essays and interviews and classroom observations together helped serve as evidence that the reflection was, for the most part, coming from the particular context of those teachers' experiences.

The teachers' response to the challenge of this activity was limited not only by beliefs about themselves as classroom teachers, but also by the restraints imposed by the structure of elementary schooling. For the most part, these teachers were supported (in attending the workshop) by their regional teacher centers, districts, administrators and peers. The restraints become evident when their activities as teachers move beyond traditional practice. Signs of these constraints occur as teachers talk about the units they are supposed to teach, availability of materials, time allowed for science teaching, and accountability in terms of student evaluation. Two-thirds of these teachers came from small rural districts where community life revolves around the school. What counts as learning and appropriate pedagogy is confirmed by the community and parents as well as the schools. Concept mapping meets with approval because it is another visual manifestation of children's learning that can be shared with others.

Evidence that teachers were reluctant to give up the "old paradigm" of teaching science occured when a teacher commented on his students' success as . . ."this showed students have ability to learn from me." Another contradicted herself by saying that "it is important to be ready to 'go with the flow' when you see what the students want to pursue, and also to guide them to get complete and correct information." It is understandable if one thinks of teachers as responsible for learning, but the conflict between allowing students to pursue their own understandings and the need to direct that pursuit is very strong. The teacher who is now calling her teaching a "research approach," who is no longer teaching to objectives, and using Vee diagrams for planning, still refers to students finding out things on their own as "looking it up" (instead of asking her.) There remains the appeal to an outside authority for confirmation of truth and knowledge.

Other signs of the conflict between the need for affirmation of teaching science "right" was found in teachers who did one marvelous activity after another, but the science concepts in those activities were not explicit and not clarified in ways so that students could connect them for meaning. The activities were "fun" but made little sense conceptually, and the students did little exploring of ideas on their own. Another teacher found concept maps, while enjoyed by the students, disrupted his classroom because they were messy and his students became noisy. The chaos of learning did not fit his notion of the orderly classrooms.

Is this research, because teachers were asked to use concept mapping and Vee diagramming just another example of what Lytle and Cochran-Smith (1992) call "field-testing?" Citing Calkins (1985), they claim that the goal of teacher research is not product testing, but "a way of knowing for the larger communities of teachers and researchers because it contributes both conceptual frameworks and important information about some of the central domains of the knowledge base" (p. 467). This group of eighteen teachers is a very small sample of teachers who agreed to explore and ask questions about their science teaching. To deny them the authenticity of their findings simply because they used concept mapping and Vee diagramming in their research, refutes the principles on which this study rests: that teachers, from their own practice, constantly evaluate, revise and create conceptual frameworks about teaching. The teachers were asked in the interviews to respond to Duckworth's (1987) statement "that teachers have endless variations on how they use what they learn in their own teaching." CG responded by saying that "we all went back changed. Each thing that you do in life puts a different weave. . . in your blanket. I don't believe that you can take something, and use it verbatim the way someone tells you to. . . if you don't make it yours, then its not a real experience."

Finally, what did these teachers find out about their teaching of science? and what does that mean? The categories that emerged from the voices of their essays, interviews and observations were those of perceptions about student meaning-making, capabilities, and discourse; about the social and cognitive skills of learning science, and about pedagogical decisions they made based on this inquiry. Their reflection was tempered by perceptions and beliefs about themselves as knowing how to change their practice , and about themselves as disseminators of that knowledge. For many, this meant moving away from a "received knowledge" model to one that honors students' construction of meaning. This was not a complete transformation, but, depending on the individual experiences, was hedged about by the constraints of their schools and their beliefs about what ultimately counts as evidence of science knowing. This is not <u>new</u> knowledge about teaching science, except that it was generated by the teachers themselves.

What did not emerge was a discussion of science knowledge, of what science content entails, of the conceptual frameworks of science. This is not surprising considering the backgrounds of most of these elementary teachers. It is believed that one must know science content in order to teach it. Yet, these teachers reported on the involvement of students finding out about rocks, or cells, or plants; enthusiastic and motivated. The teachers moved toward constructivist teaching as much as they understood and accepted it within the contexts of their classrooms. However, when we measure science content knowledge nationally, and come up lacking, we perceive one of the problems to be that of teachers not having appropriate science content knowledge.

Perhaps teacher research that places the teacher in a different relationship to scientific knowledge may bridge this gap.

CONCLUSION

Gowin (1981) says that "an end of educating is self-educating; an aim of educating is to change the meaning of an experience (p. 201). This simple (but profound) statement might well represent the fairly elaborate justification made for this study. Teachers "teaching" requires that they be engaged in educative events, events that change as soon as they are engaged. These eighteen teachers were engaged in an educative event of their own teaching that involved their perceptions, concepts, questions and subsequent records of these events.

The ultimate goal for a teacher educator is for these teachers (and future teachers) to construct meanings about their practice so that they no longer rely exclusively on "outsiders" to generate knowledge about their practice; to enter classrooms as active inquirers. As Lather (1991) and Lyons (1990) and others engaged in feminist pedagogy have observed, this process creates a different relationship between the teacher, learner, and subject matter. This change is emancipatory and legitimate as a way of coming to know ones' own knowledge about teaching and about how knowledge is constructed.

This study is about elementary teachers becoming researchers in their science classrooms, asking questions about their practices and about their students' learning of science concepts. Not all those questions were answered, but an awareness of <u>being able</u> to ask those questions and carry out an intentional and systematic inquiry is an essential first step. The call for science education reform, an area of great concern in our country and in our educational institutions has created a tremendous number of research projects and strategies designed to help us reach national goals of scientific literacy. We would do well to affirm and centralize the knowledge of teachers as we go about this effort.

ACKNOWLEDGMENTS

The summer workshops that served as a resource for this research were made possible by funding provided by the Dwight D. Eisenhower Mathematics and Science Education Act of 1988 (Title II, Part A), Grant # 91.3 (1991) and Grant # 92.31 (1992), administered by the University of North Dakota, Grand Forks, ND. I wish to

express my appreciation to Ms. Rachel Schweigert, Ph.D. candidate and Dr. Perry Cook, Assistant Professor, Center for Teaching and Learning, University of North Dakota who conducted the followup interviews and observed classrooms. I owe a great debt to the teachers who participated in the workshops, who willingly and cheerfully carried out their projects and shared the results with me, and who, above all, shared their ideas about teaching and learning with such enthusiasm.

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