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ABSTRACT

Recent research has focused on the use of reflection to examine teaching practices of preservice and inservice teachers. Limited research, however, has been done by university science educators on their own practice. This study involved two university science educators collaboratively participating in such an activity with an inservice teacher. It used narrative inquiry to examine the practice of the three science educators. Specifically, it used one form of narrative inquiry, namely autobiographical analysis. Autobiographical analysis is a useful methodology for self-reflection. In this study, two science educators (a university science educator and a K-12 science teacher) reflected on the influence of constructivism on their practice while the third (a university science educator) reflected on her practice from a feminist perspective. The shared outcome is the recognition of conflicting dilemmas that each experienced in his/her practice. (Author/LZ)

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WORKING DRAFT

THE ART OF REFLECTING IN A TWO-WAY MIRROR: A COLLABORATIVE AUTOBIOGRAPHICAL STUDY BY THREE SCIENCE EDUCATORS

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ABSTRACT

Recent research has focused on the use of reflection to examine teaching practice of presevice and inservice teachers. Limited research however has been done by university science educators on their own practice. This study involved two university science educators collaboratively participating in such an activity with an inservice teacher. It utilized narrative inquiry to examine the practice of the three science educators. Specifically it used one form of narrative inquiry, namely autobiographical analysis. Autobiographical analysis is a useful methodology for self-reflection. In this study two science educators (a university science educator and a K-12 science teacher) reflected on the influence of constructivism on their practice while the third (a university science educator) reflected on her practice from a feminist perspective. The shared outcome is the recognition of conflicting dilemmas that each experience in their practice.

RESEARCH FOCUS

The influence of an individual's beliefs on their actions has been a focus of research in the area of student's understanding of science concepts since the early 1980's (e.g. Driver, 1981; Osborne & Freyberg, 1985). Similarly, some researchers have noted that as with preconceptions of science, preconceptions of teaching and learning may conflict with more pedagogically appropriate notions in a student teacher's propensity to personally construct an intended view of teaching (Hewson & Hewson, 1985; Aguirre, Gurney, Linder & Haggerty, 1989; Parsons, 1981). This conflict has been noted even when a specific view is the focus of instruction in preservice science education. While such studies have focused on identifying the beliefs which science students, and more recently preservice and inservice teachers bring to science teaching (Parsons, 1991; Martens & Crosier, 1994), little attention has been paid to university science educators also engaging in reflective inquiry (Taylor, 1991; Parsons & Matson, 1995). When science educators engage in research with teachers the focus is on the teacher's practice rather than their own (Martens & Crosier, 1994; Tobin et al, 1992a, 1992b). This approach seems at odds with the overall intent of reflective inquiry. By reflection we mean reflection-in-action and reflection-on-action (Schon 1983, 1987) as it relates to one's own practice. Therefore rather than analyze the teaching of others the particular form of research used is an autobiographical case study.

This paper will share a collaborative autobiographical account of three science educators' narrative inquiry into their practice. Two science educators will reflect on their practice from a constructivist perspective. The other will take a social construction of knowledge perspective by examining her practice from a feminist perspective.

A Constructivist Perspective

The overall epistemological position which has influenced the interpretation of the data in the three case studies is constructivism. The constructivist perspective is one which acknowledges that individuals, through their own mental activity, experience the environment and social interactions through their own interpretive framework (Driver & Erickson, 1983; Driver & Oldham, 1986; Erickson, 1987; and von Glasersfeld, 1989). Within the constructivist framework the social construction of scientific knowledge is a particularly useful analytical framework. This position is that knowledge is socially constructed rather than that there is an objective reality to be discovered (von Glasersfeld, 1989).

The position that knowledge is socially constructed can also be interpreted from a feminist epistemology. Beyond the claim that science is a social construction, feminist theory extends the argument further to entertain the idea of the social construction of science education. Given that the feminist movement is not a unitary movement within feminist theory there is a wide range of positions. Feminist theory however is characterized by some commitment both to critique and to a project for change (Noddings, 1990). The specific feminist position taken in the second case is postmodern feminism (Nicholson, 1990). The arguments presented in the case will bring, not only a postmodern feminist perspective but, also offer support for the social construction of scientific knowledge.

Overview of Methodology

Our research assumption is that through our collaborative case studies we can better understand some aspects of our teaching and at the same time empower ourselves to take action. In undertaking the case studies we have employed a narrative inquiry methodology (Connelly & Clandinin, 1993). The specific technique employed is autobiographical reflection on our own teaching agenda. We will present and analyze three autobiographical cases wherein:

Case #1: A university science educator will reflect on his changing perceptions of science and science teaching along the career journey from scientist to high school science teacher, to university science educator/scientist.

Case #2: A k-12 science teacher will reflect on the last two years of his teaching. He will focus on his attempt to construct a constructivist practice.

Case #3: A science educator will reflect on her teaching/research agenda. In doing so she will employ a feminist methodology.

All three cases will illustrate how we have attempted to transform our practice, and some of the dilemmas associated with transforming a practice.

JOHN'S STORY: HIGH SCHOOL SCIENCE TEACHER/SCIENCE EDUCATOR/SCIENTIST

High School Science Teacher: Context for Change

I came to teaching with a doctorate in zoology assuming that a trained scientist could easily teach science. I began by using what I believed to be standard teaching methods. Traditionally, teachers used the "lecture" or "lecture/demonstration" method in science classrooms. This approach is consistent with an objectivist epistemology (Tobin et al, 1991; Tobin et al, 1992A & B; Parsons 1991; and others). However, a broader concept of how students learn suggests that a multisensory (multimodality) approach is more effective (Howard and Orlansky, 1988). In a discussion of how students learn, Novak and Gowin (1984) also advocate using multiple approaches to learning. In addition, we need to consider building upon the existing knowledge and skills that students bring with them into the classroom if we wish to greatly enhance their learning. This would be more in line with a constructivist view of learning (von Glasersfeld, 1989; Nussbaum, 1989; and Tobin et al, 1992 A & B). In constructivist epistemology, knowledge is not considered an absolute. Knowledge is the result of the social, cultural, and historical milieu of an individual. In this sense, then, knowledge is constructed individually based upon a person's socio-cultural background.

In order for teachers to be able to bring about positive changes in their basic approach to teaching, it is necessary for them to reflect upon their practice (Schon, 1987 and Parsons, 1991). Reflection is necessary because teachers often have preconceived ideas about teaching and learning and about the students with whom they interact. Teachers need to take time to analyze their teaching practices on a regular basis. This analysis, or reflection, must occur before any significant change can take place in learning. Since current classrooms have a cultural mixture of students, at various developmental stages, it is not realistic to believe that they will all learn in the same way or by the same technique. It is therefore necessary that teachers bring about change in their teaching methods.

Lincoln (1987) believes that teachers must use as many of the student's senses as possible in order to facilitate learning. A holistic approach (child centered) is believed to be the most effective by Cartwright, et al (1984). They believe it enhances learning because it includes the specific learning modalities of the students concerned. Goodman and Mann (1976) summarized several different multisensory projects which were effectively used by different schools for various subjects, including science. They were able to show that there was a definite increase in the number of students who "passed" their academic subjects. In addition, these students tended to improve their self-concept, their attitudes toward school improved, and they seemed to be more motivated.

High School Science Teacher: The Reality

It was reading the literature, such as discussed above, that has allowed me to analyze data that I collected during a school year. I taught Life Science at a medium sized (1600 students) high school in southern California for seven years. When I first started (and in previous years in General Science classes in a Junior High School), I used primarily lecture/demonstration teaching techniques. This seemed justified since it was the method used by other science teachers (most used lecture only). Intellectually and philosophically I knew that knowledge was culturally and socially biased. I also believed that there was no absolute truth, knowledge constantly changes. Yet, the way I taught was from an objectivist or logical positivist perspective. Essentially, trying to transfer knowledge to the students.

My teaching methods were in line with other teachers. My students performed with essentially equivalent results. However, I was not satisfied with these results. Each of my Life Science classes had at least 32 students. My grading showed 30% failed or received unsatisfactory grades. This was consistent with the results of other teachers but it did not seem right to me. I decided to research the academic history of each of my Life Science students, two classes with a total of 64 pupils. I discovered that more than one-third were in special education categories. Most of these students were classified as learning disabled, two students had physical disabilities. The 23 learning disabled students had a wide array of learning problems, such as inability to concentrate, various emotional problems, communication disorders, etc. While not all of the learning disabled students did poorly in my classes, few received grades above "C" (only two "B"'s). In addition, the class was racially and ethnically mixed (Hispanic, Black, White, and Asian). I knew there were different ways that students learned, I simply had not taken the time to prepare different lessons to reach students who learned by other than traditional auditory or visual means.

In addition, students often come to classes with preconceived ideas about the topics. These preconceived ideas directly affect the student's learning. It was necessary for me to think about the way I had been teaching and to make decisions about what was important and how to effect change in my classroom.

High School Science Teacher: Initiating Change

During the school year I developed teaching units that included multisensory approaches. For example, in teaching a unit on the "Cell Theory", I lectured, showed slides, had the students feel and observe the cell models and structures inside the cell. The students drew pictures of different cells. They acted out the roles of different cells in the body and of different structures within the cell. Students were involved in several laboratory sessions that allowed them to prepare microscope slides of living cells from their own body and from a variety of different organisms. Students were given the opportunity to identify cells or cell products based upon how the cells felt, tasted, or smelled (e.g. yogurt, meat, liver, onion, orange, etc.).

In preparing lessons, I chose to capitalize on the students own knowledge and skills which is more of a constructivist approach (Driver and Erickson, 1983; Tobin et al., 1992A and B). For example, when students were to act-out the roles of cells and cell parts, I asked two students who were particularly interested in drama to help. They were eager to write the scripts for the different roles. One of the sequences went like this:

NERVE CELL---"Hey, RBC, you ain't like really very smart are ya." RED BLOOD CELL---"Hey! Like, just because I don't have a brain doesn't mean I can't do nothing. I like happen to be the only way the rest of you cells can get any oxygen." SKELETAL MUSCLE CELL (to Nerve Cell)---"YEA, well like you always try to get me to work bending joints, holding bones together, always contracting and relaxing. You make little RBC work hard too. Lay off him. I can take it because I'm strong." NERVE CELL---"Look you guys you can't do nothing if I don't tell ya what to do. My gang and I, the Nervous System, control the body."

While this was a fairly simplistic script, it did show a great deal of imagination and conceptual understanding by the two students. Their ability to compare the RBC's lack of a nucleus to a body's brain, while not scientifically correct, does show that they understood that a nucleus controls cell activity and the brain controls body activity. Previously, these two students had said they did not like science, "It wasn't their thing". Their major interest in school was in drama and acting in school plays. After they completed this unit they were eager to do other science plays.

High School Science Teacher: Feedback for Change

When the two classes (a total of 64 students) were assessed for their conceptual comprehension of this unit 54 passed with a grade of "C" or better, three received a grade of D, only three failed, and four did not take the test. In the two years preceding the use of this technique only 104 of 160 students received a grade of "C" of better. Thirty-one received a grade of "D" and 25 failed. Actually more failed because the classes had a total enrollment of 190, some 30 students did not take the test.

Several aspects of this approach need comment. First, the time necessary to teach concepts using a constructivist approach is greatly increased. In previous years I spent only two to three weeks teaching the unit on "Cell Theory". This change in approach increased the instructional time to over five weeks. Similar time increases occurred in the other units as well. However, I believe the success of this approach outweighs the problem of covering all the content material. I simply had to choose what needed to be cut from the curriculum and what needed to stay. One of the problems with today's science curricula is that they are too content oriented. Increasing comprehension of science should be our goal.

A second important result was the noticeable change in students' self concepts. The results were similar to those reported by Goodman and Mann (1976). The students' image of themselves as learners seemed to improve. Students were more apt to come to class on time and seemed eager to participate in classroom activities. Fewer students were absent for exams. Students told me that they really enjoyed science "NOW". Many indicated that they would go on to take additional science classes. In fact, the demand for Biology (college preparatory) classes increased over the next few years.

Reflections on High School Teaching

My reflections on past teaching experiences, from a constructivist perspective, has provided a framework for the interpretation of changes I attempted to make in my instruction. When I was making changes, I had not been introduced to the "reflective" tool. I could have benefited greatly from this knowledge and technique. It was from reading the two papers by Tobin, Tippins, and Hook (1992A & B), and recognizing that "Karl" had undergone a similar journey, that helped me make sense of my teaching. I am continuing my reflection on a regular basis via discussions with students, other teachers, and self-analysis in the hope that I will continue to grow pedagogically. More science teachers need to share in order to break down the barriers of isolation that is so prevalent is schools today.

Science Educator

I came to a university science education program with a 'normal' science (*sensu* Kuhn, 1970) view of science and nine years experience teaching in Junior and Senior High schools. It was during my first year as a teacher of teachers that I was introduced, in full, to the constructivist epistemological perspective in education. I had been superficially familiar with the term 'constructivism' and assumed that that was my view of education. How wrong I was! Reading, in order, Nussbaum (1989), Schon (1987), Tobin et al. (1992 A and B), Tobin et al. (1991), and von Glasersfeld (1989) gave me the insights to analyze my previous teaching experiences. These papers (and others) and interaction with other science educators has initiated a new and different perspective on my teaching and the way I view teacher education.

While constructivism would appear to be a powerful epistemology to bring about conceptual change in the classroom (Nussbaum 1989, von Glasersfeld 1989), few teachers appear to use this approach (Tobin et al. 1991). Essentially, in constructivism, knowledge is not considered an absolute. Knowledge is the result of the social, cultural, and historical milieu of an individual. In this sense, then, knowledge is constructed individually based upon a person's socio-cultural background. I have noticed that while many science faculty profess a constructivist philosophy of knowledge, in reality they act as logical positivists or objectivists in their teaching. In essence, they teach a set of "truths". There seems to be a vestigial transcendentalism among logical positivist scientists who wish to maintain an idealized concept of "truth" in nature rather than to embrace the notion of multiple interpretations dependent upon a multi-cultural/social background of the learner.

As educators we need to understand and appreciate the backgrounds of our students in order to effect conceptual learning. As a trained scientist prior to entering the teaching profession, I believed the most important aspect of science teaching was the ability of the teacher to be able to do the process of science. This would make teaching 'easy'. Again, I was wrong. The ability to carry-on science, while important, cannot substitute for an understanding and appreciation of students' backgrounds.

In addition, it appears to me that few science teachers have been introduced to the process of reflection (Schon, 1987). Reflection on one's teaching can empower a teacher to initiate changes in their teaching. In my own experience, I find it difficult to be consistent using a constructivist approach to teaching. Because it is easy to fall back into old habits, I must constantly reflect upon and re-evaluate my methods and techniques.

Scientist

As a university scientist I conduct research primarily in biogeography and teach introductory biology courses for both majors and non-majors. While my experience with constructivism and reflection has had a major impact on my teaching, I am not sure how it has affected my research. In my training, I was introduced to both Popper (1968) and Kuhn (1970). I would consider myself as doing 'normal science' as described by Kuhn (1970). However, I had not thought in the context or terms of constructivism (Nussbaum, 1989). I am currently attempting to evaluate my research within this new paradigm.

Concerning my university teaching in biology (Animal Biology and Vertebrate Biology), I do bring a different perspective to the classroom. As noted above, while many faculty in science profess a constructivist view, few actually practice one. This has caused a struggle on my part in attempting to break the mold of entrenched teaching practices. However, major revisions have and are taking place in our three semester introductory core courses for biology majors. These changes have included the addition of more guided and open inquiry based laboratory activities. More emphasis has been placed on concepts rather than the traditional content orientation that is so prevalent in introductory courses. These are modest changes but, I feel, in the right direction. In addition, faculty in my department have initiated a teaching workshop to examine and evaluate current practices in an attempt to improve teaching. It is voluntary with over half the faculty involved (15-20 at any one meeting).

JIM'S STORY: A K-12 SCIENCE TEACHER

Context For Change

I have been a K-12 science teacher for this past 13 years. During that time I have kept a journal on my practice. Recently, I have stared to analyze that journal for my master's thesis. In this paper I will focus on some of the events of this last two years.

My experience as a high school science teacher about one-third of the way into 1993-1994 school year caused me to look at my teaching in a way that I hadn't experienced before. Based on what I perceived to be a lack of student responsibility for their own learning and student dependence on me as "knower", I began to question my teaching practices and beliefs.

I was teaching a mixed ability group of twenty-four 9-10 grade students, in a biology class with a laboratory. The students were about equally divided by grade and gender and were relying (passively accepting) on me to provide the content of the course through lecture and demonstrations, the style of teaching which has characterized high school science classes based on a positivist paradigm. When given the opportunity to discover knowledge, or generate their own ideas, and test their own hypotheses, in the laboratory, class, or other-wise, they (about two-thirds) seemed unwilling, unmotivated, uninterested, and/or bored.

It was particularly noticeable whenever they had required reading, be it preparing for a lab by reading and writing-up the procedure or just doing content reading in the text. Many complained about not being able to understand what they were reading. Upon questioning them, many admitted giving up after trying for only a few minutes, many did not even try, and only one said she read the material but did not understand it completely. With so few prepared to engage in a meaningful discussion of important issues and concepts, it became a situation of me, "the knower", filling up the cup of the "wanting (needing?) to know".

I began to question myself (Am I part of the problem?), the curriculum (Whose curriculum is it?), my students (Is their behavior just the product of the '90's?), the school's role in society (Teach social responsibility, content, or what?), et al. It's not that this is an inherently bad thing, but, what I was finding was disconcerting. I felt I was not reaching them, that they were "surviving" rather than being interested, motivated, responsible, and excited learners.

At this time I was doing coursework for a clear California credential leading ultimately to a master's degree in secondary education. I had came upon the epistemology of "constructivism" the year before in a course on health education from a guest lecturer, Sharon Parsons. The health course was offered via "distance learning" which meant that while I was in Santa Cruz in a class of seven, the professor was in San Jose with a class of about 20. After Sharon and her topic were introduced, I remember being struck by Sharon's opening statement as regards the problematic nature of communicating through lecture (without even being able to physically see all the students in the class) on a topic that (1) ideally puts teacher and student in a more equal power relationship; (2) that embraces students' prior knowledge; and (3) that sees the role of the teacher as coach/facilitator (Schön, 1987) rather "knower". The more I looked into constructivism and reflected on my teaching both past and present, the more I felt that this is what I was doing or trying to do in my own classroom. I felt as though someone had peeked into my own classroom and had seen what I was seeing. I felt I needed to learn more about it. I signed up the following semester to take a course entitled "the role of constructivism in the elementary science classroom" from Sharon at the beginning of the 1993-1994 school year. My class and the biology class in question began concurrently in the fall of that year.

Initiating Change

What I became aware of from the course was that constructivism was a way of understanding learning that demanded students to take responsibility for their learning by acknowledging that they are the only ones who can change (decide to change) their understandings, building upon and making connections to previous notions in science as well as other areas of learning. It seemed important then, as now, that students be given opportunities to reflect often on their own learning, especially during class time. Part of the learning was having an awareness of how one learns (Novak and Gowin, 1984) which means structuring time for reflection. In addition, being that I have always felt that students be informed about issues that affect them, I felt it important for students to have an understanding of constructivism itself, as this was how I was now perceiving theirs and my own learning in terms of classroom management, assessment, planning lessons, teacher's role in the classroom, etc.

This new found understanding and perception on my part was not enough however. I felt in a bind. On the one hand the students were counting on me for information and were unwilling to take responsibility for their own learning. If I decided to teach in a way that was more in line with a constructivist epistemology, then students would have to take responsibility for their own learning and I might loose them completely if they didn't.

I felt I needed some concrete, well documented means of allaying my fears while approaching teaching in a way that engendered meaningful learning. I found two such means in **concept mapping and metaphoric thinking activities**. In addition, we adopted a **"real life" research** focus as a project for the whole class during the later half of the semester.

I was unfamiliar with **concept mapping**, although I had had some exposure to "mind mapping" and "bubble mapping" in language arts. In my graduate classes I had learned only very recently about concept mapping as a way of integrating newly learned concepts into prior frameworks, as a tool for assessment of content knowledge in a unit or chapter, and as an exploratory tool for bringing to a conscious level previous knowledge on a topic or theme. In addition, the introduction to the teacher's edition of the biology text we were using had a section on concept mapping as it related to biological themes.

After much hesitation on my part, I decided to try it in the class. I initially questioned my belief that it could help students' comprehension. I doubted it could help students make connections to their previous notions in their science learning and, as a fallback to a previous mind set, whether making connections to prior notions was even important. I also doubted that students would go for it. I feared they would probably see it as just another assignment to do "the minimum". I decided to try it myself first. I made up two maps on my own and found, to my surprise, that I thoroughly enjoyed it. It seemed to open me up to my inner world in much the same way that writing does. In my other classes in middle and high school mathematics, I have always incorporated an element of journal writing or explanatory writing and found it to be extremely valuable as a learning tool. It seemed as though it could enhance student learning.

I went ahead and spent class time teaching how to construct the maps and why we were doing it. After a practice concept map was created with the whole class, I asked the students to do one on "science". I explained there were no "correct" answers and I was not looking for textbook definitions. I gave them class time to work on them and asked them to rewrite them as a homework assignment, explaining to them that, as in any writing, revision and editing were essential.

All 24 students turned in a concept map. Some of them went beyond paper and pencil, displaying them in a variety of colors on large sheets of paper. All students responded positively upon my questioning them on its usefulness. I decided, as research suggested, to not only use them for exploration of prior knowledge on a subject, but to use them for assessment at the end of a unit, and at any time during the unit to help enhance their learning and connections. Concept mapping continued to be a useful and much accepted tool that year in biology. I saved many of the maps and copied others before returning them to the students.

Another means employed to develop meaningful learning was the use of **metaphoric thinking activities** to bring prior knowledge to the conscious level and to make connections with prior notions in science. The idea and material for these activities was synthesized from a doctoral thesis by Gloria Snively and from my reading of *Metaphors We Live By* by Lakoff and Johnson (1980). In the book the authors suggest that all thought is rooted in metaphor. To get students in touch with their own particular frameworks for interpreting life experience, metaphors can be used. By asking students to choose from among several competing concepts and then have them explain their choice, students can tap into their own understandings and belief systems. For example, to begin our study of ecology, I used the metaphor: the environment is a __________

a) a gift,
b) town,
c) legend,
d) factory,
e) family.

Students responded to the question by first selecting one or more choices and then reflecting on and explaining their reasoning. All students responded and the overall rating for the activity was very positive. Students said they enjoyed the activity and learned about their own thinking as well. It became one of their favorite activities throughout the year. It took some time to put together in that the categories had to have some coherency and yet be broad enough to encompass their possibly diverse orientations. In reflections recorded in my journals I documented the process I went through in creating them as well as my responses to the work of the students. I saved many of the student responses and copied others before returning them to the students.

Lastly, I employed a **real life research agenda** in the classroom in order to bring science to life and to make the connection between science learning in the classroom and science as it is practiced in the work world. I felt is necessary to enlist support for such a project by asking students if they would like to do a field experience as part of their biology curriculum. I explained the idea of doing "real" science and of the possibility of us doing it on the school grounds. The consensus response was a resounding "yes". We would do plant and tree surveys to help determine the effects of logging in the Santa Cruz mountains. The project involved training half the students as leaders and engaging the services of the forest manager, a civil engineer, of the schools 355 acres. She agreed to help and we began the project the following week. Students were told of an assessment that would include their journal entries in the field and their own self evaluation. I also kept an ongoing journal of my observations and reflections in the field with the students.

The project lasted eight weeks, during which time we spent two hours once a week in the forest conducting our surveys. The students were divided into two large groups of 12 students each. Each of these groups was further divided into four groups of three. Each small group of three was responsible for gathering data on one quadrant of a large 100-foot diameter circle in a particular area of the forest. The work included making some simple calculations as to percent canopy cover in each quadrant. Each week a new site was chosen in which to conduct the surveys. Often we walked to each site; taking, on the average, about 20 minutes to get to each site.

Reflections on My Teaching

Throughout the time that I was engaged in conscious constructivist practice in my biology classroom, I kept an ongoing journal on my reflections about my experiences in the classroom. Reflection was "in-action" (Schön, 1987); that is, it happened on the spot, in the classroom. It was often and continuous. In fact, it constituted a thread that I would use to gauge the progress and the path of the evolution of this class. Reflection was also "on-action" (Schön, 1987), that is, reflection at a later time based on my actions with students. These reflections happened especially at night when I would get out my journal and write about my experiences, musings, impressions, and plans for the following day and the future.

This thread of thought, with its accompanying and ongoing interplay of action and reflection, provided the impetus for continued change. It ultimately strengthened the learning that took place in the classroom both for my students and for myself. Classrooms offer, by their very nature, limitless possibilities of expression of the human spirit and concurrently limitless and varied interpretations of that experience. Without reflection, change would no doubt have taken place. By being able to reflect in my journals, I was able to bring a greater awareness to my teaching and to use that knowledge to make decisions in the classroom as regards the structure of the learning environment I desired. My goals for the class were continually being re-evaluated and I was able to construct for myself an understanding of constructivism as it related to my own self-knowledge and of its import in my teaching in the classroom.

SHARON'S STORY: SEARCH FOR FEMINIST MODELS FOR SCIENCE EDUCATION

Since 1992 I have engaged in an autobiographical analysis of my practice (teaching and research). This analysis has been informed by feminist theory. The feminist movement however is not a unitary movement. Within feminist theory there is a wide range of positions. Feminist theory is characterized by some commitment to both critiquing and changing the status quo (Noddings, 1990). Within feminist theory there are three analytical frameworks which I find useful to analyze my practice:

1. historical feminism,
2. radical feminism, and
3. postmodern feminism.

Historical Feminism

The history of feminist theory provides a basis for the analysis of my work in science education. In particular, I find the categories constructed by Kristeva (1982) to describe feminist history to be useful. She describes feminism as being first, second and third generation. First generation - women seek equality with men, the typical liberal position. Liberal feminism is mainly concerned with unfair employment practices. This a political criticism in favor of equal opportunity for the sexes in science careers; it does not attempt to question the androcentric biases within science or science careers. Second generation - women embrace their own special qualities and reject uncritical assimilation into the male world; the emphasis here is on moving the best female qualities into the public world. Third generation - women critique what they sought and accomplished in the first two phases and seek solutions that arise out of a careful synthesis of old and new questions.

Offen (1988) uses another classification of feminist theory. She talks of individual and relational feminism. Individualistic feminism is often associated with liberal feminism which aims mainly at securing women rights and privileges equal to those of men. Whereas relational feminism advocates gender sensitivity and emphasizes experience, needs, and responsibility. In conclusion one striking difference we note is that, unlike Kristeva's historical analysis of feminist theory, Offen's classification is primarily descriptive. Such a view of feminism, as presented by Kristeva is not only descriptive but one of continuous evolution. Based on such a pattern one would conjecture that feminism will continue to evolve and move beyond a third generation. Like-wise we would hope that research on science teacher development and gender issues will also evolve.

Radical Feminism

Another label which has been used to describe one area of feminist theory is radical feminism. Radical feminism argues that scientific ideologies and philosophies are based on androcentric[1] foundations. These androcentric foundations permeate the social structure of science, its applications and its methodologies. This critique questions the nature of scientific ideology (Keller, 1985). Throughout history, science has prided itself on being an objective body of knowledge pursued by rational and unbiased individuals. The scientific method is based on hypothesizing, testing and retesting to ensure the validity of the results. Through the use of these apparently rigorous rules, the scientist is led to believe the result is objective knowledge. Objectivity in science is

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1 Eurocentric science which is prodominately a white Anglo-Saxon male perspective.

supposedly maintained by separating the knower and the knowable. However in scientific inquiry objectivity has strong masculine links and in particular, is linked to a history of seeking dominance and control over nature. Metaphors often portray the scientist as masculine and nature as feminine. What is ignored is the social context in which the method is developed and used. Radical feminism suggests that science educators challenge the androcentric foundation upon which scientific ideologies and philosophies are based.

Postmodern Feminism

Postmodern feminists (Nicholson, 1990) pose a significant question about gender and science. They ask who are the women we are talking about? Women are not homogeneous. Women differ by such factors as class, race, culture, and sexual orientation. This suggests that multiple feminists voices be heard not a dominant feminist voice (white, western, academic). Giroux (1992) notes that two of the most important challenges to modernism have come from postmodernism and feminism. Specifically he states:

> I invoke the feminist critique of modernism to make visible some of the ideological territory it shares with certain versions of postmodern feminism and to suggest the wider implications that postmodern feminism has for developing and broadening the terrain of political struggle and transformation. It is important to note that this encounter between feminism and postmodernism should not be seen as a gesture to displace a feminist politics with a politics and pedagogy of postmodernism. On the contrary, I think feminism provides postmodernism with a politics, and a great deal more. What is at stake using feminism, in the words of Meaghan Morris, as "a social context in which debates about postmodernism might be further considered, developed, transformed (or abandoned)." Critical to such a project is the need to analyze the ways in which feminist theorists have used postmodernism to fashion a form of social criticism whose value lies in its critical approach to gender issues and in the theoretical insights it provides for developing broader democratic and pedagogical struggles. p.63

Given the critique of modernism that has been on going in science education this last decade, postmodern feminism provides further insight into what a transformed science education might look like (Harding, 1986; 1987).

Establishing A Link Between Feminist Theory and Methodology

Given the feminist theoretical positions above, historical feminist theory provides an initial reflective tool, with radical and postmodernist feminist frameworks providing the primary basis of the methodology utilized in my research. There has been much talk about feminist methods, and some feminist question as to whether or not a feminist method exists (Roberts, 1981). Harding (1987) distinguishes between method, methodology and epistemology. She defines method as techniques for gathering evidence, methodology as the theory and analysis behind the method, and epistemology as theory of knowledge. She claims that the three are related but what is distinctive about feminist research is not the use of feminist methods but the use of feminist methodology and epistemology. It is the latter which I choose to employ. The assumption is that through such efforts we can better understand some aspects of how to present an alternate image of science to elementary teachers and at the same time empower them to take action in their own teaching. A feminist methodology suits the undertaking of such actions in teacher research (Harding, 1985; Hollingsworth & Miller, 1994).

The employment of a radical and postmodern feminist methodology also carries with it a responsibility for transformative action. A part of what transformative research is about is empowerment by gaining an understanding about the forces acting to shape our lives. Empowerment is viewed as being achieved when the actors are able to change their situation. Certainly within science education such issues need to be addressed. In particular, what influence feminism has had on professional development in science education is indeed a significant question. I think it is a question that those of us who claim to be "feminist researchers" need to ponder. Feminist research should present something different not fix the system such that females can succeed in science as it is. Recognizing the challenges of dealing with the dilemmas within the context of my practice, I now embark upon an autobiographical reflection.

An Historical Feminist Perspective

Autobiographical Sketches from my Practice

Some of the sketches which I shall present will be from published works covering a period of 1987 to 1994. These sketches can be interpreted as representative of first, second, and third generations of feminism as described by Kristeva (1982). In analyzing my work I have noted that some of the thoughts and ideas that I communicated at any one time could be described as representing various descriptions of feminism. It is therefore the dominant focus that I have used as the basis for my analysis.

First generation feminism. The first sketch that I would like to present is an abstract from my contribution to the Fourth GASAT (Girls and Science and Technology) Conference, 1987.

> One of the factors affecting students' success in science is their existing knowledge prior to instruction. One theoretical position which can be taken is that such knowledge is constructed through prior experience. This study focused on one type of prior experience, namely tinkering. It examined the role of tinkering in students' approaches to the study of electricity. The appearance of tinkering in the science education literature centers around the gender issue of females and science. Specifically research has focused on specific topics within physics such as electricity, where the claim has been made that the greatest gender difference occurs. However, before one can investigate such a claim tinkering needs to be defined within the context of physical science. This study utilized a case study approach which consisted of multiple cases designed to explore tinkering and how it interacts with instruction in one area of physical science; with a focus on how gender gets played out in this context. (p. 97)

The focus here can be described as individualistic feminism or first generation. While my reason for exploring tinkering was primarily to understand how to improve instruction for females in the physical sciences, I was directing all my energy to understand an activity in which males have typically excelled. The main argument presented focused on having females acquire actional knowledge in the physical sciences such that they could equal the males in achievement and participation. Such an argument does not look at broader issues such as, the nature of science but indirectly lays the fault with the females for not having acquired such knowledge.

Second generation feminism. Based on a review of science education literature I noted that most of the discussion of the gender issue had centered around achievement on large scale achievement tests. Given that achievement had received so much attention when I was presented with the opportunity to examine such data I was happy to re-analyze it from a feminist perspective. The result was the appearance of a co-authored article (Bateson & Parsons, 1989). My major role in writing that paper was that of providing a theoretical framework to analyze the data. The following abstract summarizes the outcome:

> In large-scale testing programs it has been consistently noted that males tend to out-score females in science and mathematics, particularly in the areas of physical and earth/space sciences. The third provincial assessment of science in British Columbia, Canada, which tested over 100,000 students in grades 4, 7 and 10 has again shown strong gender-related differences in various domains of science achievement. Explanations for these differences have, in the past, centered on either biological or sociological considerations with explanations concerned with the gender orientation or 'realm of experience' of items receiving a great deal of support in the academic community. It was found, however, that there was considerable disagreement among a panel of judges regarding the gender orientation of many items that calls into question some of the previous work in this area. It is also possible that observed differences in achievement in domains higher than the knowledge level may be an artifact of item construction. Many items in higher level domains are dependent on knowledge that has been shown to have strong gender-related differences. As such, gender-related differences in achievement in domains such as application, critical and rational thinking, technology and the nature of science, and safety may be predetermined through item selection for the instruments. (p. 371)

The abstract illustrates that I had moved beyond liberal feminism to question the androcentric knowledge base of standardized achievement tests. Such radical feminist argument suggests a movement beyond first generation feminism.

While feminist theory was introduced in the paper to question the knowledge base of standardize tests, I still resorted to putting forward differential experience rather than focusing on the nature of scientific knowledge. I avoided the question of examining the nature of science, of dealing with the double science dilemma. I relied instead on the mainstream viewpoint presented in the science education literature. Beyond raising the issue as a question I did nothing to advance the argument. In fact later in the paper when we reviewed some of the arguments for gender differences the dominant focus was on using the argument of differential experiences[2] to explain gender differences. Extensive efforts were made to explain studies which suggested that differential experiences are important in explaining gender differences in science. While we used the argument for changing test construction, we only paid token attention to the idea of a new knowledge base for science. It was at best a token effort.

Movement towards third generation feminism. Another illustration of second generation feminism thinking is reflected in a paper which I presented at the Sixth International GASAT Conference, 1991.

> I would like to share the findings of a qualitative study of female and male participation in physical science activities. Specifically I will report on a case study of female and male students engaged in a hands-on study of electricity. Based on a qualitative analysis of survey data, interviews, and classroom observations the experiential, social and personal factors influencing female and male participation in physical science activities will be metamorphically described as an apprenticeship. That is, males will be described as engaging in an informal

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2 The dominant argument is that better male performance in the physical science areas of science (such as electricity) can be explained by males engaging in more out-of-school activity related to the physical sciences.

> apprenticeship. For a discussion of gender differences in the apprenticeship factors I will draw upon the work of Belenky, Clinchy, Golberger and Tarule (1986). Their work provides an interpretive framework for the viewing of areas of physical science, such as electricity as "connected knowing" for males and "disconnected knowing" for females. (p. 286)

This abstract was written before the conference and appeared in the conference contributions. At the conference however I felt the need to critique my contribution which had been written six months earlier. The basis of my critique was that by focusing on activities in physical sciences which males are good at was *an illustration of blaming the victim.* Why had I not focused on an area of science where females typically excel and use that as a model? Another issue that I raised was why not examine the nature of science itself. This suggests that while I was sensitive to the need to improve science instruction for females I still laid the blame with the victim. This was despite the fact that feminist literature enabled me to describe such activities as disconnected knowing (Belenky, Clinchy, Golberger, & Tarule, 1986). This signaled that I was ready to entertain the thinking of what has been described as third generation feminism. This position was further outlined in my first autobiographical paper at the National Association of Research in Science Teaching (Parsons, 1992) where I critically examined my past work. Such papers set the stage for future work which allowed me to bring radical and postmodern feminist perspectives to my practice as a science educator. A discussion of such work now follows.

A Radical Feminist Perspective: Search For A New Vision For Elementary Teachers

My work moved to focus on the understanding of the needs of one special group, elementary teachers (Parsons, 1992, 1993, 1994). I have chosen to explore this area because whenever the issue of inadequate instruction in science is discussed elementary teachers receive a major portion of the criticism. Such criticism has added to elementary teachers viewing themselves as deficient in science. Since the majority of elementary teachers are female, I believe we need to reconsider this issue from a feminist perspective. A radical feminist vision would be the viewing of the science education of women as being deficient rather than blaming the victim (Parsons, 1992). If you accept the argument that the science education of women is deficient rather than blaming the victim then this calls for a different approach in science education (Bearlin 1990; Parsons 1992, 1993; Parsons, Delauter, & De La Torre, 1993). One approach might be to offer teachers a different view of scientific knowledge which involves understanding the nature of the construction of scientific knowledge, and the envisioning of themselves in such roles as teacher as researcher, and teacher as experienced learner. Such roles give teachers the opportunity to view the construction of scientific knowledge differently.

Traditionally, elementary teachers perceive themselves as being deficient in science and have been taught to assume the fault is theirs. The result is they are reticent to look externally for the cause of the problem. From a radical feminist perspective the social construction of scientific knowledge is a particularly useful analytical framework. Beyond the claim that science is a social construction, feminist theory extends the argument further to entertain the idea of the social construction of science and gender. In particular, Keller (1985) argues that not only are science and gender socially constructed but that science has socially been constructed in a masculine image.

A Postmodern Perspective: The Search for Routes to Self-Empowerment

Examining The Voices In Preservice Science Education. The question is what strategies can we employ in the science education of adult women in preservice programs? We need to examine the profiles of elementary teachers who become interested in science because their voices need to be heard. Postmodern feminists (Nicholson, 1990) recognize the need to listen to multiple voices if we are truly interested in bringing in the outsider (female elementary teacher) to science. Brickhouse (1994) uses the word, outsider to describe underrepresented groups in science. In 1992 I undertook collaborative research with two preservice elementary teachers, Cathy and Blanca, in an attempt to share their stories (voices) with others who were interested in the empowerment of elementary teachers in science (Parsons, DeLauter, & De La Torre, 1993). Fortunately, the undertaking of such collaborative research has allowed me for the first time to seriously listen to voices other than those of established science educators.

While there are a number of scenarios that are worth sharing I will focus on the dominant outcome of the research. While both Cathy's and Blanca's stories were different, the common element is that both needed a sense of self empowerment before they developed a strong commitment to a professional development agenda. Cathy, a non-traditional education student enrolled in the elementary teacher education program, can be described as an emerging elementary science teacher. It was both her maturity and her experience as a mother that gave her confidence to try science. Cathy had developed a sense of self-confidence that she did not have earlier in her education. Blanca's story is different in that there was an extra struggle. She was an immigrant who did not initially speak English; and had to cope with racial discrimination. Her story can also be described as one of self empowerment. It was experiences, such as the multicultural elementary education program which had the greatest impact on her view of science teaching. She developed a strong commitment to bilingual education, and came to view science as a valuable tool in this process.

Our research recognized that some elementary teachers need to feel empowered as individuals before they sense a need for professional growth in science education. Some support for this claim comes from Roth and Abel's (1994) examination of the narrative of a science enthusiastic teacher where self-empowerment appears to be a key issue in the student teacher's success. Such research suggests that science educators may need to aid in facilitating the empowerment of the preservice teacher if they want professional development in science education to occur. Unfortunately, most research in science education which centers around gender and science had yet to challenge the nature of science education itself. I suspect that this is mainly due to the fact that researchers work only within the accepted paradigms within science education. While alternate research paradigms do exist it appears that science education has yet to explore such paradigms. Feminist scholarship appears to have had limited influence on preservice science education.

Preservice/Inservice Teachers Transforming Science Education. Recently I have begun to work with preservice/inservice elementary teachers who are attempting to bring a science emphasis to their teaching (Parsons, 1994). Examining this issue from a postmodern feminist perspective allows teachers to become active participants in bringing about changes in elementary science teaching. It allows them an opportunity for a voice. This is an action research project[3] where student teachers are matched with master teachers who are interested in improving their practice, by

[3] This work has been supported in part by NSF funded California State University Science Teacher Development Project, and San Jose State University in Teaching/Learning Fellowship.

focusing on science. This creates a vision for elementary education where we can link preservice and inservice science education by establishing elementary science focused school sites. The Holmes Group promotes the idea of a professional practice school where teachers are actively engaged in the improvement of practice (Holmes Group, 1990). The improvement of professional practice and the self empowerment of teachers where science is a focus provides a framework for the establishment of **elementary science emphasis sites** (Parsons, 1994). These would be sites where we not only work towards improving practice but elementary teachers transforming science education. The intent is to empower teachers in effecting change in science education at their local school sites. Since we want to maximize the potential for empowerment the elementary teachers participating at the science emphasis sites act as facilitators at their school sites. They assume a leadership role in elementary science by recruiting teachers at their site to participate in the improvement of elementary science, conduct action research in their own classroom, plus work with student teachers.

We need to move beyond just providing sites for preservice teachers. It is also hoped that this can lead to inservice teachers to taking charge of an agenda for elementary science enhancement. If we allow the primary focus of professional development to be on teacher preparation within academia it will do little to create an emancipatory action research climate for teacher practitioners. We can not achieve a new model for science teacher preparation routed in practice without inservice teachers becoming empowered. To achieve emancipatory action research at the classroom level is a developmental process which needs to evolve over time. It also calls for a shift in research goals, from research activity which is theory driven to research which is theory generating in its orientation. If we can move towards theory generating research routed in practice this will allow for a greater voice of teachers. It will also allow for feminism theory to be a part of that agenda.

New Vision of Science Education. My research suggests that, with regards to professional development in science education, I need to challenge the models for science education which are available. The need is critical, especially in the education of elementary teachers who have already been victimized by a poor education in science. My research has led me to question the future direction of science education. We certainly need to examine the nature of science education with a focus on how can we develop new rhetorics of science education for prospective teachers. My work to date suggests it is possible to bring new interpretations to elementary science education. If science education is serious about professional development, we must not only assume an agenda of what is good for science education, but an agenda of what is good for women in science. These stories need to be explored. We need to developed models of what a good science education for women might look like. To do this we need to go beyond the fix-it level. Like Lather (1993) I recognize that such efforts are 'inquiry as lived' which focuses on anticipating a generative methodology to define a new vision for science education amid the complexities of a postmodern era.

Discussion of the Dilemmas in Science Education

Through our collaborative autobiographical case studies we have come to better understand some aspects of the various factors influencing our agendas. The use of collaborative narrative inquiry presents the possibility for transformative action. One outcome of our collaboration is the potential to empower ourselves, and others by reflecting upon our experiences to understand the factors influencing our agenda. A part of what transformative research is about is empowerment by gaining an understanding about the forces acting to shape our lives. The next step would be to take action. Critical theory similarly talks of becoming critical by taking action (Carr, & Kemmis, 1986).

Empowerment is viewed as being achieved when the actors are able to change their situation. It is hoped that the theories generated through our case studies will be useful to other science educators interested in improving their practice.

John's and Sharon's cases illustrate the double science dilemma. John's dilemma is illustrated during his interpretation of his dual roles of being high school science teacher/scientist, and university science educator/scientist. Sharon's dilemma is illustrated by her interpretation of her evolving dual roles of science educator/feminist scholar. Working within the double science dilemma (Lather, 1994), her research assumption is that through an autobiographical case study from multiple feminist perspectives she can better understand some aspects of her practice. In Parsons & Matson (1995) she notes that:

> While I am particularly interested in an analysis of the factors which may have influenced my agenda I recognize the relationship of my position to the dominant paradigms in science education. In particular I need to examine how I can contribute to a feminist critique of science education.
>
> As a feminist science educator I have no choice but to explore the double science issue of working within, and against the normalizing borders of science/science education and working towards a feminist imaginary of science education. A similar position is described by Lather (1994) in the context of her project on women living with HIV/AIDS. p. 22

The case studies also illustrate the need for university science educators to reflect on their practice. If we ask others (preservice/inservice teachers) to change we need to model such change ourselves. While alternate research paradigms for exploring preservice and inservice teachers practice do exists, it appears that science educators have yet to adopt such paradigms when examining their own practice. Failure to do so does not challenge the traditional hierarchical power structure in science education. Science educators seem to work within the paradigm of 'normal science education' to play on Kuhn's (1970) words. We need to step outside our paradigm if we are asking teachers to do so. The following section written by Jim on the dilemmas in his practice is a good argument for our doing so:

> While it is true that students were getting a chance to experience real science, (in fact, the engineer who assisted us initially said that this was very much like what she did for a living in her job, as a partner in an environmental engineering company in San Jose) it was not all rosy. At one point in the surveys, I felt that I should end the experiment due to what I perceived again to be student lack of responsibility for their learning. It seemed to become a mindless activity. They were going through the motions of engaging work, but when I observed and questioned them, they seemed to really enjoy being "out of class". The students became careless in their recording of data, were not willing to double check their work, and acted irresponsibly to one another in the form of practical jokes and fooling around. In short, they did not take it seriously enough for me. The data for one-third of the surveys had to be throw out while the other data, although usable, needed much of my time to rewrite to make presentable. From a constructivist paradigm where students participate fully in the curriculum, it became an untenable situation. How does one create a learning environment that meets the needs of all the students? Indeed, some students had done fine work throughout.
>
> As a teacher who was now practicing with a constructivist approach, I brought the situation up after we ended the project, feeling again that there be no secrets. We discussed it openly yet briefly. Some students admitted the lack of responsibility on their part and we then moved on.

Probably the greatest dilemma for me is deciding what aspects of science teaching is to be given priority; time to do all that is necessary to provide a meaningful learning environment, and at the same time maintain my personal commitments and responsibilities. As I engage in alternative practices to lecture/demonstration, time for traditional coverage of the curriculum was not possible. My principal and thesis advisor are very supportive, however, and have encouraged me to continue. Still, I have to struggle with the fact that teachers are still individuals with a life outside the classroom.

Although the constructivist paradigm provides a framework for viewing learning, it does not provide the specifics for each child, nor for the same student in all situations. For example, the student who enjoys and benefits greatly from the concept mapping, is not always responsible during field activities. Also, as I introduced new activities I continued to do the readings in the text, albeit a slower pace than the previous year. Even so, the lecture/demonstration and homework readings remained difficult for some students. And while I feel that different ways of approaching meaningful learning are very important, the lecture/demonstration and text reading also are beneficial and important.

The biggest part of being a teacher researcher is trying to juggle an active community service and family life, with full time work in the classroom. Beyond that I have to put in the time necessary to fulfill the research agenda of readings, homework, and data gathering necessary for the completion of the requirements of my master's degree program.

As I look upon myself as a teacher/research I feel that, although I feel research is inherent in the teaching profession itself, it is not always acknowledged. From a constructivist perspective all students have a different experience base, both in formal schooling and outside. They have different orientations to science and different learning modalities. In planning for the day-to-day activities teachers must be reflective practitioners. We must get to know, as best as can be done, each student's particular learning style and how their orientations mesh with a "scientific" view. This is research-in-action. And yet, when I was doing so in my classroom previous to my understanding of constructivism, I never felt as though I was doing "research". Research for me was "out there, somewhere". It was something done "to" a classroom, not in and with a classroom. I felt a sense of relief and joy when I discovered that what I was doing in the classroom was valued by my advisor and the other master's candidates in my classes.

One outcome of our narrative inquiry, beyond the immediate impact upon our own practices, is to question the future direction of research into the practice of all science educators. Given that our research has been influenced by constructivism and feminist epistemology we certainly sense the need to examine the nature of science education with a focus on how can we develop a new focus in the science education of all teachers. Our research suggests that true collaboration by practitioners at all levels is needed.

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