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Paper Title: A Study of Changes in Student Teacher Ideas About the Nature of Science During Participation in Independent Research Projects

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Abstract: During the last half century there has been worldwide recognition that one of the most important goals of science education is the development of students' understanding of the nature of science (Science for All Americans, 1989; Science 5-16: A Statement of Policy, 1985). Despite efforts to bring this about, research continues to show that for a variety of reasons, many students and teachers hold views about the nature of knowledge acquisition which have been judged to be limited or inadequate (Lederman, 1986, 1992; Carey and Strauss, 1968; Rubba, Horner and Smith, 1981). There has been no lack of research on the nature of both student and teacher ideas about the nature of science and its impact on science learning. Studies have been conducted to identify teachers' views of the nature of science. Work has been devoted to changing students' and teachers' views, and investigations have been conducted to determine how teacher views of science influence classroom practice. Reflection on the research by Lederman (1986, 1992) challenges the view that student and teacher views are currently "adequate or inadequate." He suggests that the problem is complex, and our definitions of adequacy must be clarified.

No research studies have been found which investigate the changes that occur in student teacher thinking during participation in independent investigations, the actual involvement with the experience of science. The purpose of this paper is to describe the approach and findings of a research project presently in progress which studies changes in student teacher thinking about the nature of systematic investigation in science during their participation in an independent research project. A review of the literature on teacher and preservice teacher views on the nature of science thinking is useful in framing the present project and is presented in the following sections.

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A Study of Changes in Student Teacher Ideas About the Nature of Science During Participation in Independent Research Projects

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INTRODUCTION

During the last half century there has been worldwide recognition that one of the most important goals of science education is the development of students' understanding of the nature of science (Science for All Americans, 1989; Science 5-16: A Statement of Policy, 1985). Despite efforts to bring this about, research continues to show that for a variety of reasons, many students and teachers hold views about the nature of knowledge acquisition which have been judged to be limited or inadequate (Lederman, 1986, 1992; Carey and Strauss, 1968; Rubba, Horner and Smith, 1981). There has been no lack of research on the nature of both student and teacher ideas about the nature of science and its impact on science learning. Studies have been conducted to identify teachers' views of the nature of science. Work has been devoted to changing students' and teachers' views, and investigations have been conducted to determine how teacher views of science influence classroom practice. Reflection on the research by Lederman (1986, 1992) challenges the view that student and teacher views are currently "adequate or inadequate." He suggests that the problem is complex, and our definitions of adequacy must be clarified.

No research studies have been found which investigate the changes that occur in student teacher thinking during participation in independent investigations, the actual involvement with the experience of science. The purpose of this paper is to describe the approach and findings of a research project presently in progress which studies changes in student teacher thinking about the nature of systematic investigation in science during their participation in an independent research project. A review of the literature on teacher and preservice teacher views on the nature of science thinking is useful in framing the present project and is presented in the following sections.

THE RESEARCH PROJECT: INVESTIGATING STUDENT TEACHER VIEWS ON THE NATURE OF SCIENCE

During a pre-service course in curriculum and instruction in elementary science, students were assigned the task of designing independent investigations to answer questions of their own selection. Ideas about the nature of knowledge acquisition were documented prior to, during, and following involvement in the assignment. Following the experience, students were shown the documented changes which occurred in their personal ideas. In reflective interviews they were invited to comment on their participation in the investigations and describe specific features of the experience which contributed to changes in their ideas about the conduct of investigations in science.

ASSUMPTIONS ABOUT PRESERVICE TEACHER LEARNING IN SCIENCE

This project is a study of preservice teacher learning during participation in independent research projects. The work is based upon the belief that an understanding of an active, personally involving image of science is important for the person who will be teaching children science. For the last four years, the instructor has involved student teachers in an independent research assignment as part of their coursework in teaching methods in elementary science, and has worked with inservice teachers in the development of approaches to help children learn systematic approaches in the investigation of their own questions (Shapiro, 1979). Reflection on student experiences in this work showed the value of studies which begin to tell us the kinds of changes in learning that occur regarding preservice student ideas about the nature of science during participation in independent investigations in science.

RESEARCH ON PRESERVICE AND PRACTICING TEACHER VIEWS ABOUT THE NATURE OF KNOWLEDGE

Preservice teacher views have been analyzed suggesting that prospective science teachers hold inadequate or incomplete views of science (Carey and Strauss, 1968). In a study by Bloom (1989), many students expressed frustration with their science learning experiences, yet felt encouraged to continue in science by their own interest in nature. A large number of students suggested that the purpose of science is to benefit humankind. This anthropocentric view of the nature of science influenced their ideas in science learning. Ogunniyi (1982) investigated student teachers' considerations of the language of science reflecting the philosophical structures of various philosophers of science. He discovered that both prospective science teachers and science majors subscribed to an inductive view of science. Following a course in logic, preservice science teachers demonstrated a more prominent deductive view of the nature of science. Koulaidis and Ogborn (1989) found that there are identifiable differences in teachers' views about the "philosophical-empirical basis of science." The authors suggest one of the possible reasons for the general shift of views might be a move towards consistency with pedagogical positions put forward in current curriculum reform documents, and suggested that this link should be further studied.

A study conducted by Ogunniyi (1982) is supported in similar work by Cobern (1989). These projects investigated culturally different views about the nature of science between American and Nigerian preservice teachers. Nigerian students viewed science as producing useful technology. They also viewed scientists as "nationalistic and secretive about their work."

There is some suggestion that a focus on the nature of science in science teaching can help to restructure and change negative attitudes to science teaching (Riley, 1979; Koballa and Coble, 1979; Carey and Strauss, 1968; Lucas and Dooley, 1982; Sharmann, 1989). The picture of science teaching and learning is far more complex, however, as evidenced by several studies suggesting that some approaches to instruction have little or no effect on the abandonment of views of teaching and learning by preservice and practicing teachers' understandings of the nature of science (Lucas and Dooley, 1982; Lederman and Zeidler, 1987; Aguirre, Haggerty and Linder, 1990).

THE INTERACTION OF IDEAS ABOUT THE NATURE OF SCIENCE AND CLASSROOM PRACTICE

Billeh and Hasan (1975) attempted to determine the factors affecting the acquisition of knowledge about the nature of science. The emerging picture suggests that the problem is very complex. In addition to personal views, the way that the nature of science is portrayed is largely dependent on contextual features of the school learning environment, such as textbook resources, cumulative examinations, administrative and classroom organizational approaches. A number of authors challenge the contention that teachers' ideas about the nature of science actually influence teaching behavior (Lederman and Zeidler, 1987; Munby and Russell, 1987; Pope and Gilbert 1983; Brickhouse, 1989). Munby and Russell (1987) suggested that "the epistemology of science is not deliberately neglected by teachers, but rather, the epistemology of school as an organization overwhelms the epistemological features of science, or of any other disciplined body of knowledge (p.8). Pope and Gilbert (1983) asked to what extent are teachers' metaphors concerning the nature of science shared and employed by students.

STUDENT TEACHERS LEARNING TO TEACH SCIENCE: THE IMPORTANCE OF RESEARCH ON STUDENT TEACHER IDEAS ABOUT SCIENCE

Unless they have been science majors, student teachers typically enter their science methods courses with a very limited science course work background. Many speak of negative experiences in their limited encounters in the science classroom, express a sense of lack of success and inadequacy – a fear of teaching a topic which they believe they know little about. These problems can have a potential impact far beyond the teacher's experience. If teachers are not assisted in developing confidence and competence in the understanding of the nature of inquiry in science, the cycle repeats itself with new teachers providing the same limited encounters with science investigations for science learning.

Although the potential of experiences like the traditional science fair exists to develop understanding of the nature of science and positive attitudes towards science knowledge, it is more often the case that students enter science methodology classrooms with limited and very often negative experiences in carrying out and displaying, and sharing the knowledge gained in independent research projects. This, coupled with the increased stress on inquiry and independent research as a prominent feature of science instruction in elementary and secondary classrooms, makes understanding of what is gained when students conduct investigations of interest both theoretically and practically.

DATA COLLECTION IN THE RESEARCH PROJECT

In the project, currently in progress, data has been gathered over a four year period from over 150 students as they worked on the assignment, "Inviting Investigations." This assignment was developed for students in the course, Curriculum and Instruction in Elementary Science Education. The assignment asks students to undertake a systematic study to answer a question of their choice. Student teachers are encouraged to select a problem question which might typically be asked by a child. Students are encouraged to keep the problem as simple as possible. Simplicity is stressed throughout the project as even what appears to be the most simple question can pose complex problems when variables must be identified and controlled. Another important reason for simplicity is that student teachers prepare their project results for presentation to peers and for groups of children. As needed, the instructor is available to help students in the question selection process. Several class discussions cover the nature of a suitable question for investigation and appropriate approaches to research design. Students keep a journal record of their activities, approaches and results, and develop a display for the purpose of summarizing and conveying project findings to an audience of peers and children.

Beyond the mere presentation of results, the displays are used by the student teacher to demonstrate to an audience what is involved in undertaking work in such a study. In the presentation of their displays, student teachers demonstrate the approach taken in conducting the experiment beginning first by explaining why and how their particular question was posed or how it was selected. Other features of the presentation include: descriptions of how the topic was narrowed into a testable question, how data was collected, what kinds of problems were encountered during the progress of the study and how these were resolved. Students indicate how their journal record was constructed and how it contained a systematic record of the progress of the study. The data collected in the study are used to show how the record of information was used to develop the conclusions of the study which in turn helped to answer the questions posed in the study.

Throughout the term, in addition to regular activities and discussion in class regarding the design of investigations, each student teacher was urged to speak with the instructor regularly about progress in the investigation. Students were also encouraged to ask for equipment and help from the laboratory assistant.

DATA SOURCES

Several data sources were used in the study of student learning about the nature of science: 1. A survey to gather information on the individual's background, interest and confidence in science teaching. 2. A definition of science provided by the student on the first day of class. 3. A statement written by the student one week following the completion of the project, indicating whether the definition was supported or changed by the experience of conducting an investigation. 4. During the last year of the project, 50 students completed Repertory grid charts using provided constructs based on the procedures of systematic investigation. The grids were administered on the first day of class and the week following completion of the projects. 5. Notes made during and following interviews with students regarding the selection and progress of projects. 6. Transcriptions of interviews in which students commented on changes made in the repertory grid ratings. In addition students commented on the overall experience of involvement in the project. 7. Complete records of students' project notes, journals and reflections on the assignment.

Interviews with the student teachers were conducted by five graduate students and research assistants and were transcribed for analysis.

THE USE OF PERSONAL CONSTRUCTS

A major source of data collected for the case reports was a set of reported changes in personal constructs regarding ideas about undertaking independent inquiry. Personal constructs are essentially linguistic categorization systems which allow insight into the ways individuals organize thinking about events and phenomenon. (Kelly, 1955).

Student teachers filled out the repertory grid on the first day of class prior to receiving the investigation assignment, and prior to any form of instruction in the course. Following completion of the projects, the same grids were again filled out by students. This happened during the last week of the first term of class, without reference to the original grids.

The grids consisted of "provided constructs" as opposed to individually elicited constructs. The provided constructs were developed based on typical responses from a pilot group of students interviewed during the previous year. Each student was given the same list of 15 constructs (Table 1) which consisted of terms and phrases commonly used by students when describing typical steps in conducting an investigation.

These constructs were used to provide descriptive ratings for 12 elements. At the top of each page was listed one a step considered typical experiences in the conduct of similar investigations by pilot student in the previous year. The elements are listed in Table 2. Students participating in the study, therefore filled out a sheet of constructs rating each of the twelve elements separately. An example of the first sheet completed by each student is shown in Table 3.

Table 1
Provided Constructs

1. Creating my own ideas/ Just following directions.
2. Challenging, problematic, troublesome/ Easy simple.
3. Shaping the investigation/ Conducting the investigation.
4. Having some idea beforehand about the project outcome/ Having no idea what will result from the study.
5. Using the imagination- spontaneous ideas/ Recipe-like prescriptive work.
6. Frustrating experience/ Salifying experience.
7. Creating new knowledge/ Discovering what exists-the way things are.
8. Doing real science/ Doing things unrelated to science.
9. Personally meaningful, interesting/ Not particularly meaningful or interesting.
10. Rational, logical activity/ Affective - feelings and emotions involved.
11. Experience with the phenomena/ Observing objectively.
12. Theoretical work/ Practical work.
13. Using the "scientific method" to solve the problem/ Not using any particular method.
14. Important work in science/ Less important work in science.
15. Process oriented/ Product oriented.

Table 2

Elements

1. A problem or topic of interest is selected for investigation.
2. The topic is developed into a testable question.
3. Factors and variables which may affect the outcome of the investigation are identified and defined.
4. An idea about how the investigation will turn out is developed.
5. Materials and equipment needed to conduct the investigation are collected.
6. Observations are collected and recorded to answer the problem question.
7. Improvements must be made to the original design of the investigation.
8. An unusual or unexpected result is produced.
9. The investigation does not run smoothly.
10. The results of the investigation are recorded.
11. Conclusions are drawn from the results of the investigation.
12. The findings and conclusions are organized for public presentation.

Table 3
Sample of Element #1 and all Constructs

Element 1. A problem or topic of interest is selected for investigation

	1	2	3	4	5	
1. Creating my own ideas						1. Just following directions.
2. Challenging, problematic, troublesome						2. Easy, simple
3. Shaping the investigation						3. Conducting the investigation
4. Having some idea beforehand about the project outcome						4. Having no idea what will result from the study
5. Using the imagination- spontaneous ideas						5. Recipe-like prescriptive work
6. Frustrating experience						6. Satisfying experience
7. Creating new knowledge/ideas						7. Discovering what exists-the way things are
8. Doing real science						8. Doing things unrelated to science
9. Personally meaningful, interesting						9. Not particularly meaningful or interesting
10. Rational, logical activity						10. Affective- feelings and emotions involved
11. Experience with the phenomena						11. Observing objectively
12. Theoretical work						12. Practical work
13. Using "the scientific method" to solve the problem						13. Not using any particular method
14. Important work in science						14. Less important work in science
15. Process oriented						15. Product oriented

Table 4

Jen's Repertory Grid Chart: Example Constructs and Element #1 - Pre-and Post Responses

1. A problem or topic of interest is selected for investigation.

	1	2	3	4	5	
1. Creating my own ideas	X	O				1. Just following directions.
2. Challenging, problematic, troublesome		X	O			2. Easy, simple
3. Shaping the investigation	O		X			3. Conducting the investigation
4. Having some idea beforehand about the project outcome			X	O		4. Having no idea what will result from the study
5. Using the imagination-spontaneous ideas	N					5. Recipe-like prescriptive work
6. Frustrating experience		O			X	6. Satisfying experience
7. Creating new knowledge/ideas	X	O				7. Discovering what exists-the way things are
8. Doing real science	X			O		8. Doing things unrelated to science
9. Personally meaningful, interesting	X	O				9. Not particularly meaningful or interesting
10. Rational, logical activity		X			O	10. Affective- feelings and emotions involved
11. Experience with the phenomena			O			11. Observing objectively
12. Theoretical work		O		X		12. Practical work
13. Using "the scientific method" to solve the problem				N		13. Not using any particular method
14. Important work in science		N				14. Less important work in science
15. Process oriented		N				15. Product oriented

O = Placement at beginning of the term
X = Placement at the end of the term
N = No Change

USING PERSONAL CONSTRUCTS IN THE DEVELOPMENT OF CASE REPORTS

Participants in the research project completed both sets of construct forms, one prior to undertaking the investigation and one following completion of the project. A number of students were interviewed during participation in the research project. In addition, students were interviewed following completion of the second set of repertory grids. Significant movement on the repertory grid charts became an important discussion focus in the interview and allowed insight into student thinking about conducting investigations.

Of particular interest were changes indicated by movement by two or more squares in one direction or the other. In most cases, individuals actually made complete reversals in their placement of elements on the construct charts. Discussion of these changes during the interview allowed a conversation focus which helped the student describe how his or her thinking had been changed during the term. Some examples of the themes of these discussions are presented following the introduction of Jen, a participant in the study.

THE DELINEATION OF CASE STUDY THEMES

Selected students reviewed the changes made on their construct charts with an interviewer who asked for discussion on the changes as they related to the individual's investigation. The repertory grid interviews were audio-recorded and transcribed for analysis. In the review of the transcriptions and other research material, themes of change in student thinking were coded and developed into themes of change in thinking about knowledge acquisition were developed. Seven areas of change were delineated and are presented in Table 5.

Table 5
Change Themes

I. Changes in thinking in response to the question, "What is Science?"
II. Changes in ideas about the features of systematic inquiry
III. Changes in thinking about the possibilities of personal participation in the investigation experience.
IV. Changes in views about sense of self as science learner
V. Changes in views about science as conveyance of knowledge to others
VI. Changes in ideas about the importance of taking a critical perspective on knowledge acquisition in science
VII. Changes concerning ideas about the usefulness ofindependent investigations as a learning approach in the elementary science classroom.

JEN - A CASE STUDY OF CHANGE IN THINKING ABOUT

KNOWLEDGE ACQUISITION IN SCIENCE

Jen's involvement in the project is described below. Three of the Change Theme areas are used to discuss the kinds of changes which occurred in her thinking.

Jen

Jen is a student in her final year of the teacher preparation program. At the beginning of the term, she stated that she felt somewhat lacking in confidence in her ability to teach science in the elementary program. Jen stated "I don't feel that I have a lot of background knowledge." Jen and her partner were invited to participate in the interview portion of the project for several reasons: 1) Their background experiences were highly representative of the larger group; 2) Both were lacking in initial confidence in their understanding of science; and 3) They were experiencing difficulties in the initial design of their project which they were willing to explore and discuss.

Theme I. Changes in Thinking in Response to the Question, "What is Science?"

Despite her view that she possessed an inadequate science background, Jen provided a fairly comprehensive response to the question on the first day of class:

1.) Science is information that has been tested and retested often enough that it is now considered fact.
2.) Science is a large part of our lives as we use technology everyday.
3.) Scientific study will never end.
4.) Science involves studying everyday occurrence and studying situations that occur very infrequently.

Changes occurred in her thinking about science which seemed readily apparent to Jen on the last day of class. Following the design and implementation of the investigation she stated that she had changed some of her ideas about science and confirmed others. In a systematic review of her statement she commented on item one:

> *After doing my experiment I realize that science is not just information that has been proven. Science is about studying any type of information whether it has been proven or not. I see science as more of a process of inquiry than factual information.*

Regarding statement number two, she commented:

> *This statement was partly confirmed for me and partly changed. Science is a large part of our lives. After doing my experiment with bananas I have begun to ask myself questions about other everyday occurrences, for example, why does snow go crusty after a few warm days...science is not necessarily technology. I now see science as studying and observing anything in our world.*

Jen retained her belief stated in number three:

> *I do still believe that scientific study will never end.*

She confirmed her understanding stated in number four that

> *...science involves studying everyday occurrences and studying situations that occur very infrequently. What I didn't know before I started was how complicated experiments with everyday occurrences could be. My problem was variables.*

Theme II. Changes in Ideas About the Features of Systematic Inquiry

The majority of students undertaking the project stated that one of the greatest challenges was the selection of a research topic. As was typical of most students undertaking work on the investigation assignment, Jen and her partner, Lorna, took a great deal of time to select an appropriate topic for investigation. As one of Jen's younger sisters was working on a science project using fruit, and Lorna worked in a grocery store produce room, fruit emerged as a topic of interest and a tentative question was developed. Lorna made an appointment with me to discuss the feasibility of a project designed to determine "Where do fruits ripen best?" Jen and Lorna intended to use several different types of fruits, place them in different location in the home and "see" which were the best places for ripening. Lorna suggested, "We might put one on the radiator, one in my room, one on the window, maybe one in the fridge, then see which are the best places for ripening." The instructor stressed several points during the conversations: Class lessons emphasized the importance of clarifying the change or variable condition which was being studied or tested. The variance in the range of ripening time for the six fruits made it very difficult to determine whether the investigators would find that it was the location, the stage of ripening of the particular fruit, or the nature of the particular fruit being used that was the most important feature to consider.

We worked together to determine how these concerns might be dealt with. As we discussed the possibility of considering only a single fruit, Lorna mentioned that she was in charge of bananas in the grocery store where she worked. She knew a great deal about the stages of ripening of bananas, from their storage and arrival on trucks to the store to determining when they should be placed on the shelves. Bananas were selected as the fruit to be studied. But back to the problem question as it had now changed, "Where do bananas ripen best? The student investigators now realized that all of the fruit used would have to be at the same stage of ripeness. What about the placement of the fruit? What would be different about each place the investigators chose? We worked to rephrase the question to further isolate just which factors were affecting the ripening. Each location offered different conditions of light, temperature, humidity. We reorganized the project further by rephrasing the original question further. From, "Where does the fruit ripen best?" to "Where do bananas ripen best? to "Under what conditions do bananas ripen best?"

Still we were not finished. What did we mean by "best"? The investigators realized that we could not readily agree on the subjective meaning of the term, and, if we were to study the topic, we would need to be able to keep records of our progress over time. We decided that "best" for us would mean "quickest" and could be readily documented. We rewrote the question once again: "Under what conditions do bananas ripen most quickly?" The students indicated that they now felt ready to proceed with the project.

Reviewing Changes in Thinking About the Nature of Knowledge Acquisition

The experiences with the investigations allowed us to probe changes in thinking about the nature of knowledge acquisition in science in progress. Jen made significant shifts in movement on personal construct charts regarding areas associated with these first stages of the development of their investigation. These shifts are shown in Tables 6, 7 and 8. Constructs that have shifted radically are highlighted in bold print. Discussion surrounding these dramatic changes suggested changes in Jen's thinking. Her ideas were probed to understand the nature of changes in her thinking about knowledge acquisition in science.

As indicated in Table 6, Jen made dramatic shifts in several areas of thinking about the selection of a problem for investigation. These areas will be described here to show how the repertory grid charts were used to provide depth and focus during the interviews. Jen made a complete reversal in her thinking about problem selection. Initially she considered it to be a 'Frustrating experience,' shifting to it being a 'Satisfying one.' She shifted from considering problem selection to be 'Doing things unrelated to science' to 'Doing real science,' and she made the shift from 'Affective -feelings and emotions' involved to considering the activity to be a 'Rational, logical activity.'

When asked about her construct changes, Jen spoke about her initial reaction to the assignment. At first she questioned the 'point of it,' considering it just another assignment to do in a methods class. In the end, however, she found the experience worthwhile and satisfying. She particularly valued the experience of working through the difficulties she and her partner experienced in setting up the design of her project.

> *You find that there were more problems going along than, you know, doing a project like this might seem very simple, but really it wasn't when it came down to it. There were more difficulties. We had a problem with variables. Like just trying to make the test consistent. Um, we found out that experimenting isn't as easy as you think it could be. There's so many variables and factors that come into it.*

Table 6
Constructs Showing Reversals In Thinking (Indicated in Bold)

Element 1. A problem or topic of interest is selected for investigation.

	1	2	3	4	5	
1. Creating my own ideas	X	O				1. Just following directions.
2. Challenging, problematic, troublesome		X	O			2. Easy, simple
3. Shaping the investigation	O		X			3. Conducting the investigation
4. Having some idea beforehand about the project outcome			X	O		4. Having no idea what will result from the study
5. Using the imagination-spontaneous ideas	N					5. Recipe-like prescriptive work
6. FRUSTRATING EXPERIENCE		**O**			**X**	**6. SATISFYING EXPERIENCE**
7. Creating new knowledge/ideas	X	O				7. Discovering what exists-the way things are
8. DOING REAL SCIENCE	**X**			**O**		**8. DOING THINGS UNRELATED TO SCIENCE**
9. Personally meaningful, interesting	X	O				9. Not particularly meaningful or interesting
10. RATIONAL, LOGICAL ACTIVITY		**X**			**O**	**10. AFFECTIVE - FEELINGS AND EMOTIONS INVOLVED**
11. Experience with the phenomena			O			11. Observing objectively
12. Theoretical work		O		X		12. Practical work
13. Using "the scientific method" to solve the problem				N		13. Not using any particular method
14. Important work in science		N				14. Less important work in science
15. Process oriented		N				15. Product oriented

O = Placement at beginning of the term
X = Placement at the end of the term
N = No Change

Table 7

Constructs Showing Reversals In Thinking (Indicated in Bold)

Element 2. The topic is developed into a testable question.

	1	2	3	4	5	
1. Creating my own ideas	X	O				1. Just following directions.
2. Challenging, problematic, troublesome			X	O		2. Easy, simple
3. SHAPING THE INVESTIGATION	**X**				**O**	**3. CONDUCTING THE INVESTIGATION**
4. HAVING SOME IDEA BEFOREHAND ABOUT THE PROJECT OUTCOME		**X**			**O**	**4. HAVING NO IDEA WHAT WILL RESULT FROM THE STUDY**
5. USING THE IMAGINATION-SPONTANEOUS IDEAS	**X**				**O**	**5. RECIPE-LIKE PRESCRIPTIVE WORK**
6. Frustrating experience			O	X		6. Satisfying experience
7. Creating new knowledge/ideas			X	O		7. Discovering what exists-the way things are
8. Doing real science	X	O				8. Doing things unrelated to science
9. Personally meaningful, interesting	X		O			9. Not particularly meaningful or interesting
10. Rational, logical activity	O		X			10. Affective- feelings and emotions involved
11. Experience with the phenomena			X	O		11. Observing objectively
12. THEORETICAL WORK		**X**			**O**	**12. PRACTICAL WORK**
13. Using "the scientific method" to solve the problem	O	X				13. Not using any particular method
14. Important work in science	N					14. Less important work in science
15. Process oriented	N					15. Product oriented

O = Placement at beginning of the term
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N = No Change

Table 8
Constructs Showing Complete Reversals (Indicated in Bold)

Element 3. Factors and variables which may affect the outcome of the investigation are identified and defined.

	1	2	3	4	5	
1. CREATING MY OWN IDEAS	**X**			**O**		**1. JUST FOLLOWING DIRECTIONS**
2. Challenging, problematic, troublesome	X		O			2. Easy, simple
3. SHAPING THE INVESTIGATION	**X**				**O**	**3. CONDUCTING THE INVESTIGATION**
4. Having some idea beforehand about the project outcome		N				4. Having no idea what will result from the study
5. USING THE IMAGINATION-SPONTANEOUS IDEAS	**X**			**O**		**5. RECIPE-LIKE PRESCRIPTIVE WORK**
6. FRUSTRATING EXPERIENCE		**O**			**X**	**6. SATISFYING EXPERIENCE**
7. CREATING NEW KNOWLEDGE/IDEAS	**X**			**O**		**7. DISCOVERING WHAT EXISTS-THE WAY THINGS ARE**
8. Doing real science	N					8. Doing things unrelated to science
9. Personally meaningful, interesting	X	O				9. Not particularly meaningful or interesting
10. Rational, logical activity	N					10. Affective- feelings and emotions involved
11. Experience with the phenomena			X	O		11. Observing objectively
12. Theoretical work	O		X			12. Practical work
13. Using "the scientific method" to solve the problem	X		O			13. Not using any particular method
14. Important work in science	N					14. Less important work in science
15. Process oriented	N					15. Product oriented

O = Placement at beginning of the term
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N = No Change

Jen stated that she found it more satisfying "because we had to change our question, and I really learned from it in the end". She pointed out that it was necessary to clarify and change the question to such an extent that she began to value the rational, logical features of the experience which began to predominate her view of involvement in independent investigations. She stated that she was really doing science - not just "some project somewhere."

I had always had an idea that science was, like I say, lab coats and a check list of everything that had to be done, and you know, you had to stick to that. That was the rules. But by the end of our project, I realized that we had to think of a lot of things ourselves -- that um, weren't just what somebody could tell us. That's what you had to do. We had to figure it out ourselves and use our imagination to solve the problem.

For Jen, learning science had previously meant learning science from a textbook and by laboratory recipe. This conveyed to her an image of science that did not include personal involvement.

When I thought of science before I thought of ah, your microscope and your bunsen burner and (laughing) you just work with those tools in the lab, there, and um, just after doing the experiment, I found that, you know, we had to figure out what we could use <u>ourselves</u>. And, um it wasn't just, um, certain things that were in a science lab that you could use. You could use all your knowledge to figure out what to do. It ended up not being just the product that we found out. We learned so much going all the way through.

Jen stated further,

We learned what variables <u>actually were</u>. Because, you know, I knew what a variable was, um, but I thought somebody could just say, well, here's your variables, go to it. But I realized when I was doing it, you couldn't just put a banana wherever you wanted because there were so many variables acting on it.

<u>Theme VII. Changes concerning ideas about the usefulness of independent investigations as a learning approach in the elementary science classroom.</u>

Jen's valuing of the feature of her involvement in the systematic investigation extended
beyond her own experience. She reflected on how her experience might influence her work
with children:

> *I have never done a science investigation such as this before this class. After having such an enjoyable experience, I believe that I will use it in my classroom so that my students will also have an enjoyable, worthwhile learning experience. It will affect how I work with students in the classroom. I learned a lot by asking my own questions and finding my own answers. This made the project meaningful for me. I believe that students will find science more meaningful if they can investigate their own questions. The best thing about experimenting is that one can usually come across more information than they intended to. An hypothesis can be proven correct or incorrect but there is other information to be found along the way. For example, I thought I knew where bananas ripened the most quickly but I did not know that they would turn hard on the side left in the sun or that they never turned yellow but went straight from green to brown in the fridge. I now believe that it would be great experience for children to 'stumble' upon surprises in their own investigations. This knowledge will mean more to them if they figure it out themselves than if they read it in a book.*

DISCUSSION OF FEATURES OF THE STUDY

The purpose of this study has been to discern changes that occur for students concerning their thinking about the nature of science during participation in independent research projects. A second goal has been to consider the value of this work in the preparation of teachers in elementary science methods courses.

Two features of the project allowed the student and interviewer to engage in conversation which allowed deep reflection on students' changing ideas about the nature of knowledge acquisition in science. First, because students had completed own individual projects, they were able to make specific comments on the experience and how it contributed to their thinking. Second, the use of personal construct shifts allowed reflection on features of change in student thinking which not immediately apparent to students.

Changes in thinking were highly personal, and in many cases dramatic shifts occurred. Through discussing the dramatic construct shifts that occurred during the assignment, we were able to develop a set of change themes regarding the acquisition of science knowledge which were representative of the whole group of students participating in the experience.

An interesting secondary finding suggests that the few students in the program who had strong science backgrounds made fewer changes in their constructs than non-science majors. This was the case even when science majors held absolutist views prior to the study. This finding warrants further study.

Student change themes are currently being examined to determine those constructs which tended to shift for students to provide a statistical comparison of changes in the group as a population.

Another significant finding has been the indication by over 90% of students that they had never experienced science as investigation in any of their classes either in primary or secondary school. This means that the majority of students completed their secondary programs missed the opportunity to participate in the practice of the very nature of science itself. Of those who had some involvement in research or investigation, the most frequently reported experience was the school science fair. A report by Cummins (1993) shows that even when students participate in science fair projects, they are rarely encouraged to conduct nonexperimental studies, which may contribute to the promotion of a somewhat limited or rigid view of the nature of science.

The assignment, "Inviting Investigations" sought to present a different view of science to learners. It was designed to involve students in the experience of science at its most creative, as the opportunity to synthesize existing facts with science processes to produce new knowledge. Participants in the project indicated positive benefit in a number of ways. Jen mentioned the substantial amount of personal involvement in the project which required thought and careful attention to detail. She demonstrated an appreciation of the importance of a willingness to make changes in order to solve a problem, to persevere, the interest in continuing to be surprised, to cooperate with her research partner and to develop ways of communicating her findings with others.

It is significant that the majority of students interviewed mentioned during interviews, about the value of an approach to classroom teaching which allows children to pose their own problem questions, develop a means of systematically answering the question and sharing the results with others.

The question of whether or not the experiences of teacher preparation courses actually affect the understanding and teaching behavior of student teachers has been must answered both positively and negatively, seeming to provide an unclear picture of the impact of teacher preparation programs. What is clear is that the problem must be viewed as a complex of interweaving environmental and contextual factors. Lederman and Zeidler (1987) suggest that besides teacher conceptions of science, other contextual factors may influence teachers' approaches and may determine whether a teacher is able to put into practice personal views about the nature of science.

The present project not only made the researchers aware of the nature of change in students' thinking about the nature of scientific investigation, but provided insight into how student teachers themselves view the benefits in their future in the classroom. Prominent shifts were made in Jen's case from objectivist understandings of science to a sense of involvement in the construction of knowledge. These were observed in her increased talk of a sense of ownership of the process, of satisfaction, surprise and intrigue with the project. That significant change did occur for Jen, who regarded herself lacking in confidence to teach science makes her comment on the effect of the project on her own teaching the more meaningful. Many participants in the project said that they used the investigation in their student teaching experience. Perhaps a project such as this can bring new insight to student teachers to help change approaches to working with elementary children, providing the intellectual experience, insight and support needed to show child the benefits of involvement with "the face of science that does not yet know," helping to break the cycle portraying science as an impersonal, lifeless regurgitation of product and fact.

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