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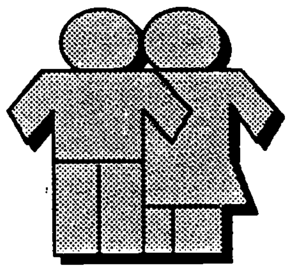
ABSTRACT

The objective of this naturalistic study was to describe the preservice, inservice, and life experiences of exemplary science teachers to determine what kinds of experiences have made a difference in their teaching practices. Six Elementary Science Presidential Awardees from Texas were identified by the Preservice Elementary Science Action Team of the Texas Statewide Science Systemic Initiative as the group of teachers to be studied. Interview questions were designed to focus on career history descriptions, attitudes regarding excellence in science teaching, significant preservice and inservice experiences, and individuals who influenced their career development. Analysis of the interview data revealed the following categories: (1) Significant Life History; (2) Mentorships, Collaborations, and Networks; (3) Characteristics of Exemplary Science Teachers; (4) Preservice Preparation Experiences; (5) Inservice Experiences; (6) The Nature of Teaching, Learning, and Science; and (7) Perceived Science Teaching Barriers. Implications for strengthening the preservice preparation of prospective elementary science teachers are discussed. Appendices include interview protocols. Contains 14 references. (Author/PVD)

PRESERVICE ELEMENTARY SCIENCE PROJECT

Interviews of Elementary Science Presidential Awardees: Patterns that Portray Excellence in Science Teaching



A Report Prepared for the
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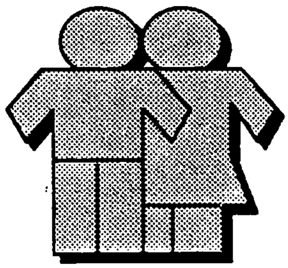

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How do kids learn? By interacting with stuff; they don't learn by the written page and that is what a new teacher is given. They [students] are given a text, a guide, worksheets ... a zillion worksheets. That's the kind of stuff they are given. They are not given the right stuff.

Kindergarten Teacher
1991 Elementary Science Presidential Awardee

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Abstract

The objective of this naturalistic study was to describe the preservice, inservice, and life experiences of exemplary science teachers to determine what kinds of experiences have made a difference in their teaching practices. Six Elementary Science Presidential Awardees from Texas were identified by the Preservice Elementary Science Action Team of the Texas Statewide Science Systemic Initiative as the group of teachers to be studied. Interview questions were crafted to focus on career history descriptions, attitudes regarding excellence in science teaching, significant preservice and inservice experiences, and individuals who influenced their career development. Analysis of the interview data was conducted using a constant comparative method of Glaser and Strauss (1967) and Lincoln and Guba (1985). Analysis revealed the following categories: *Significant Life History*; *Mentorships, Collaborations, and Networks*; *Characteristics of Exemplary Science Teachers*; *Preservice Preparation Experiences*; *Inservice Experiences*; *The Nature of Teaching, Learning, and Science*; and *Perceived Science Teaching Barriers*. Implications for strengthening the preservice preparation of prospective elementary science teachers are discussed.

Introduction

Artistry in teaching is not a common occurrence. It is an ideal.

(Elliot Eisner, p. 60)

What makes a good elementary science teacher? How can we nurture the craft of teaching science so that all young learners can benefit from optimal instruction? Can effective elementary science instruction be taught to prospective teachers in way such that these future teachers could feasibly follow in the footsteps of some of the best of their predecessors? In an effort to answer these questions, the Texas Statewide Systemic Initiative (Texas SSI) and the Preservice Elementary Science Preparation Action Team envisioned a way to learn about some of the "best of the best" Texas elementary science teachers -- by personal interaction with them. Conversations with highly accomplished science teachers may provide the Texas SSI with information regarding the direction and focus in strengthening the preparation of elementary teachers to teach science in ways that are relevant to the lives of young children.

Until recently, science education has not been considered basic in the elementary program (Loucks-Horsley, Kapitan, Carlson, Keuerbis, Clark, Melle, Sachse, & Watson, 1990). Consequently, science education has not received the attention and support at the national, state, and local level. Strong networks and implementation mechanisms characteristic of reading and mathematics programs have not been implemented (Loucks-Horsley, et al., 1990). Nonetheless, the spotlight on science education has intensified within the last few years through science reform efforts such as the American Association for the Advancement of Science's *Project 2061* and the National Research Council's *National Science Education Standards*. Both efforts recognize the need for adequate preparation of teachers of science (American Association for the Advancement of Science, 1990; National Research Council, 1996).

Honoring the need to give science education the "basic" status that it deserves, the National Science Foundation and the National Science Teachers Association began recognizing outstanding secondary science teachers with their prestigious Presidential Award for Excellence in Science Teaching in the 1980's. In 1990, elementary science teachers became eligible for the coveted award considered by American science educators to be the topmost distinction. Since 1990 six elementary school teachers in Texas have been nationally recognized for "embodying excellence in teaching, devotion to the learning needs of students, and upholding the high standards that exemplify American education at its finest" (National Science Foundation, 1995). Who are these teachers? What makes them special? What can they tell us about preparing future generations of exemplary science teachers?

The study of six portraits of exemplary teachers of science in the elementary grades leads to information regarding the development of preservice elementary science preparation programs. Personal stories about preservice, inservice and life experiences, from some of the "best of the best" in science teaching, provides directions for strengthening the preparation of elementary science teachers as well as enlighten and enrich us about the artistry of their craft.

This study synthesizes a volume of collected data from personal interviews with Texas' six Elementary Science Presidential Awardees for Excellence in Science Teaching. It is hoped that the revelations and insights that have resulted from this study will be of assistance in the formulation of a new concept and philosophy of elementary science teacher preparation as well as offer some enlightenment as to what might be the appropriate strategies for structuring worthwhile science teacher education programs.

Methodology

The story is the very stuff of teaching, the landscape within which we live as teachers and researchers, and within which the work of teachers can be seen as making sense.

(Freema Elbaz, p.3)

Design

The purpose of this study was to describe "what is going on" in the lives and practices of excellent elementary science teachers by "getting inside their heads" through in-depth interviews. A naturalistic inquiry methodology was the most appropriate design strategy. It is important to distinguish several presumptions regarding the unique methodology employed in this naturalistic study prior to describing the details of the selection of the informants, interview protocol, data gathering and content analysis procedures. These presumptions include an understanding of what defines naturalistic inquiry, understandings regarding issues of trustworthiness, and presumptions regarding the researcher.

Definition. Naturalistic inquiry is defined not at the level of method but at the level of paradigm. As the qualitative inquirer, I provisionally adopted the axioms of the naturalistic paradigm as described by Lincoln and Guba (1985) in their text, *Naturalistic Inquiry*. The work of naturalistic inquiry presumes heavy reliance on the human as the instrument. My personal set of understandings regarding excellent science teachers, my tacit knowledge regarding science teaching, played a significant role in the interview and analysis processes. Prior to implementation of the interviews, I made a serious effort to develop an initial design statement that includes a statement of problem, theoretical perspective, procedures, instrumentation, data analysis procedures and the establishment of a time schedule. Poking about in the lives of these very busy science teachers was therefore minimized. Finally, I made every effort to become acquainted with the informants through informal conversations on the telephone before the actual interviews.

Trustworthiness. Within the traditional quantitative research paradigm, the criteria that have evolved in response to questions regarding trustworthiness are termed *internal validity*, *external validity*, *reliability*, and *objectivity* (Lincoln & Guba, 1985). These criteria are inappropriate for the naturalistic study. An alternative set of criteria is proposed and defended by Lincoln and Guba (1985), and it is to these criteria that the I make every effort to adhere to while conducting my study. These criteria include *truth value*, *applicability*, *consistency*, and *neutrality*.

First, *truth value* has to do with credibility, the naturalist's substitute for internal validity. It involves a twofold task: first, to carry out the inquiry in such a way that the probability that the findings will be found to be credible is enhanced; and second, to demonstrate the credibility of the findings by having them approved by the constructors (the six informants). With attention to appropriate methodology and member checking, the *truth value* criterion is firmly met the naturalistic study.

Second, *applicability* relates to external validity or generalizability. In the naturalistic paradigm the term *transferability* is used to refer to the degree of similarity between two contexts. No attempt has been made to generalize the findings of this study to other outstanding science teachers. The researcher is aware that individuals who read this study may derive their own interpretations given the appropriate base of information, or "thick description" (Lincoln & Guba, 1985, p.125).

Third, *consistency* has to do with reliability, which typically is demonstrated by replication -- if two or more repetitions of essentially similar inquiry processes under essentially similar conditions yield essentially similar findings, the reliability of the inquiry is indisputably established (Lincoln & Guba, 1985). I address the issue of consistency through the acknowledgment of the tentativeness of the human as instrument. I realizes that my dependability is measured by my effort to seek means for taking into account both factors of instability and change.

Finally, a fourth criterion I adhere to is *neutrality*, which relates to objectivity in the conventional paradigm. This emphasis shifts from the investigator to the data themselves. Are they or are they not confirmable? By memoing, note taking, coding, and keeping a reflexive journal, I enhance the confirmability of the data in this naturalistic study.

About the Researcher. Before I present the findings of this study, I offer a few personal reflections about myself and, in some respects, reservations. Foremost, I am a certified elementary science teacher. In 1994 I was awarded the *Presidential Award for Excellence in Secondary Science Teaching* for my work teaching science to sixth, seventh, and eighth graders in a large urban school district in south central Texas. Through the interviews with the some of the "best of the best," I learned that there is indeed a cadre of elite elementary teachers who are committed to the teaching of science in the early grades. Some are decorated awardees, and others exist unrecognized in schools throughout the state. I realize that this study looks only at those teachers who, like myself, have the ambition to complete the paperwork and actively seek recognition and reward. Much can be learned from individuals who are representative of those who go that extra mile to receive the status and acknowledgment they justly deserve. However, it is important to keep in mind the other groups of exemplary elementary science teachers that may not share similar thoughts and ideas that are representative of this particular set of exemplary teachers.

With this said, I am confident that the descriptions, analyses, and interpretations of the six interviews conducted for the sake of this study honestly represent the voices of the six elementary science Presidential Awardees. I attempt to build cases, or at least draw illustrative examples, from the stories of these teachers keeping in mind that my reflections are grounded in my own experiences and observations of elementary science teaching. Harry Wolcott, a master ethnographer, explains the impossibility of the task of rendering unbiased descriptive analyses.

> In the very act of constructing data out of experience, the qualitative researcher singles out some things as worthy of note and relegates others to the background. Because it takes a human observer to accomplish that, there goes any possibility of providing "pure" description, sometimes referred to as lightheartedly as "immaculate perception."
>
> (Wolcott, 1994, p, 13)

My perceptions of exemplary science teaching, my thirteen years of public school teaching experience, and my work training science teachers have indeed tainted how I make sense of the data collected for this study. Nevertheless, personal sense-making and honest interpretation are the very essence of qualitative inquiry.

The Informants

For the sake of consistency within the study, informants were selected from an already established pool of excellent science teachers. The criteria outlined by the National Science Foundation and the National Science Teachers Association for the selection of the Presidential Awardees is what sets these six nationally recognized teachers apart from the rest of the population of science teachers. Based on the recommendations of the Preservice Elementary Science Action Team, I originally selected the five nationally recognized elementary science Presidential Awardees from Texas to interview. The sixth awardee was named in October of 1995 and was added to the sample shortly thereafter. Initial contacts were made with each informant in early Fall of 1995. The researcher solicited participation of each awardee in the proposed interview. All agreed to participate.

Collectively the six informants represent a total of 144 years of teaching experience, with most of these teaching years occurring in Texas. All six teachers are elementary education certified. The informants are not science specialists per se; but rather, bear the responsibility for teaching science as well as other content areas in their self-contained classrooms. The first informant, Paula, is a twenty-six year classroom veteran who, at the time of the interview, was teaching fifth grade in a working class urban community of about 50,000 people. The second informant, Sam, is a fifth grade teacher who has been teaching for fifteen years at the same elementary school in a large suburban community in central Texas. Meagan, the third informant, is an early childhood specialist and director of a private preschool in a culturally diverse, predominantly urban, south Texas city. She has been teaching pre-Kindergarten and Kindergarten for twelve years. Susan, the fourth informant, teaches Kindergarten in an affluent suburban community near the central Texas hill country. She has twenty five years of teaching experience. Marie, the fifth informant, teaches first grade in a small suburban community in the northeastern portion of the state and has been teaching for thirty three years. The sixth informant, Nancy, is a former elementary teacher who recently accepted a position as an assistant professor of science education at southern university outside of Texas. She has thirty three years of elementary teaching experience. Five informants are female and one is male. Five informants are Anglo American and one is part Cherokee Indian. Two informants, Sam and Susan, are husband and wife (Table 1).

Table 1.
Preservice Elementary Teacher Interviews: Informant Grade Levels, School Setting and Years of Teaching Experience

Informant		Grade Level	School Setting	Years of Teaching Experience
PA.1	Paula	5	urban	26
PA.2	Sam	5	suburban	15
PA.3	Meagan	Pre-K, K	urban	12
PA.4	Susan	Kindergarten	suburban	25
PA.5	Marie	1	suburban	33
PA.6	Nancy	3-5	suburban	33
Total	n = 6			144

Interview Protocol

Interview questions were generated during a brainstorming session with the Preservice Elementary Action Team during an initial meeting in October, 1995. These questions were narrowed to thirteen open-ended questions that comprised the first interview protocol. (See Appendix A.) The questions, which were organized initially into preconceived categories: *Career History*, *On Excellence*, *Significant Events*, and *Formal Education*, were used for the interviews of the first and second informants using a semi-structured interview approach. After a second meeting with the Action Team in February, 1996, the category designations were removed to be truer to the naturalistic method in which category development emerges on the basis of informants' plural responses. A revised protocol was established (Appendix B) and used for the subsequent interviews using a semi-structured interview approach. Slight revisions in the interview protocol were necessary to accommodate the last informant who was no longer teaching elementary science (See Appendix C).

Data Gathering

I made arrangements with each informant to conduct the interview in a place that was convenient to him or her. Three informants agreed to be interviewed after school in the natural settings of their classrooms; two were interviewed at a neutral site agreed upon by both myself and the informant; and one informant was interviewed at the university where she worked. The interviews were conducted between the months of November 1995 and April 1996.

The interviews were typically 1-1/2 to 3 hours in length. Every effort was made to keep each interview informal, friendly, and conversational (Spradley,1979; Fontana & Frey, 1994). A tape recorder was used to record each interview to ensure the accuracy of the field notes which were written before, during and after the interviews. Tape recordings of the interviews were transcribed. Personal reflections of each interview were recorded in my reflexive journal.

Data Analysis Strategy

In an effort to process the data collected from each of the six interviews, I used the constant comparative method as first described by Glaser and Strauss (1967) and later operationally defined by Lincoln and Guba (1985). This process involves comparing incidents applicable to each category, integrating categories and their processes, and delimiting the theory. As a way to organize the vast amount of information obtained from the interviews, I first unitized the data, then categorized the data, and then filled in the patterns. Member checks with the interviewees were conducted informally via the telephone and electronic mail.

Unitizing. Units were defined heuristically. I attempted to look for the smallest piece of information about the personal lives and work of these teachers. Each piece of information therefore could stand by itself and be interpretable in the absence of any additional information other than a broad understanding of the context in which the inquiry is carried out (Lincoln & Guba, 1985). The units were complete thoughts extracted directly from the interview transcripts. Units were typed and placed on index cards and assigned a number and a code that indicated the informant identification number and interview transcript page number from which the thought, insight, or statement was derived (Figure 1).

21 PA-3.IT-1

That was a wonderful experience. I was going to graduate school at night and then going into the classroom the next day.

Figure 1. Sample unitized data for card sort that indicates that the information on the card is the 21st unit of analysis from the third Presidential Awardee interview which was extracted from interview transcript page number 1.

Categorizing. Eight hundred and two cards resulted from the process of unitizing the information from the interviews. Categorizing involved the essential task of bringing together into provisional categories those cards that apparently relate to the same content; then devising rules that describe category properties. The rules justify the inclusion of every card that remains assigned to the category, provide a basis for later tests of replicability, and render the category set internally consistent (Lincoln & Guba, 1985).

With this purpose in mind, I began the card sort with the first set of cards from the first interview. The initial card's content was noted and set aside. The second card's content was noted, as were successive cards, using the researcher's tacit knowledge, intuition and personal insights. Decisions were made as to whether or not the unit on the subsequent card "looked like" or "felt like" those of the preceding cards. If the unit happened to be essentially similar to the preceding card, it was placed within the same category. All cards in the set were analyzed and decisions were made according to where the cards "fit" or "did not fit" into the total set. The cards that did not fit existed as separated entities and were given a different set of rules. All the while, I devised rules of inclusion and exclusion in certain categories. Tentative category names were given to the growing stacks of related cards. After the first interview analysis was complete, forty-three tentative categories emerged (see Appendix D).

The second through sixth sets of interview units were sorted using the same procedure as described above. These interview sets were integrated into category sets already established by the initial card sort. Seven additional categories were identified with the sorting of all six sets of cards (see Appendix E). A total of fifty tentative categories were established. A miscellaneous category set of eleven unassignable cards also resulted from the overall card sort. These cards were clearly irrelevant and represented less than two percent of the total set.

The next step in the process of categorization was to subsume the existing categories into larger categories and to attach a category name to the larger umbrella category. The category name captured the essence of the rule that formed the category. Seven larger umbrella categories resulted from the researcher's interaction with the data. Each umbrella category contained five or six subcategories. The broad categories that emerged were: *Significant Historical Events*; *Mentorships, Collaborations, and Networks*; *Characteristics of Exemplary*

Elementary Science Teachers; Preservice Preparation Experience; Inservice Experience; Teaching, Learning and Science Instruction; and Perceived Barriers to the Teaching of Science.

After the broad categories were established, I reviewed each one for overlap and examined the set for possible relationships among categories. Collection and processing of the data were completed on the basis criterion of exhaustion of sources (Lincoln & Guba, 1985). All six awardees had been interviewed, their data were recorded, categories had been saturated, the emergence of regularities were noted, and the sense was established that new information was far removed from the core of the viable categories and did not contribute usefully to the emergence of additional categories.

Member Checking. After the categorization process, a major "trustworthiness technique" (Lincoln & Guba, 1985) known as *member checking* was employed. I consulted with each informant to assess my success in producing a reconstruction of their original constructions. This process will be completed when each informant receives a copy of this report for examination and reaction.

Findings

Content analysis of the six teacher interviews revealed seven categories: *Significant History, Mentorships, Collaborations, and Networks; Characteristics of Exemplary Science Teachers, Preservice Preparation Experiences; Inservice Experiences; Reflections on Teaching, Learning, and Science;* and, *Perceived Barriers to Science Teaching* (Figure 2). Each category subsumed a number of subcategories that are identified in the concept map in Appendix F. The categories are articulated in the discussions that follow.

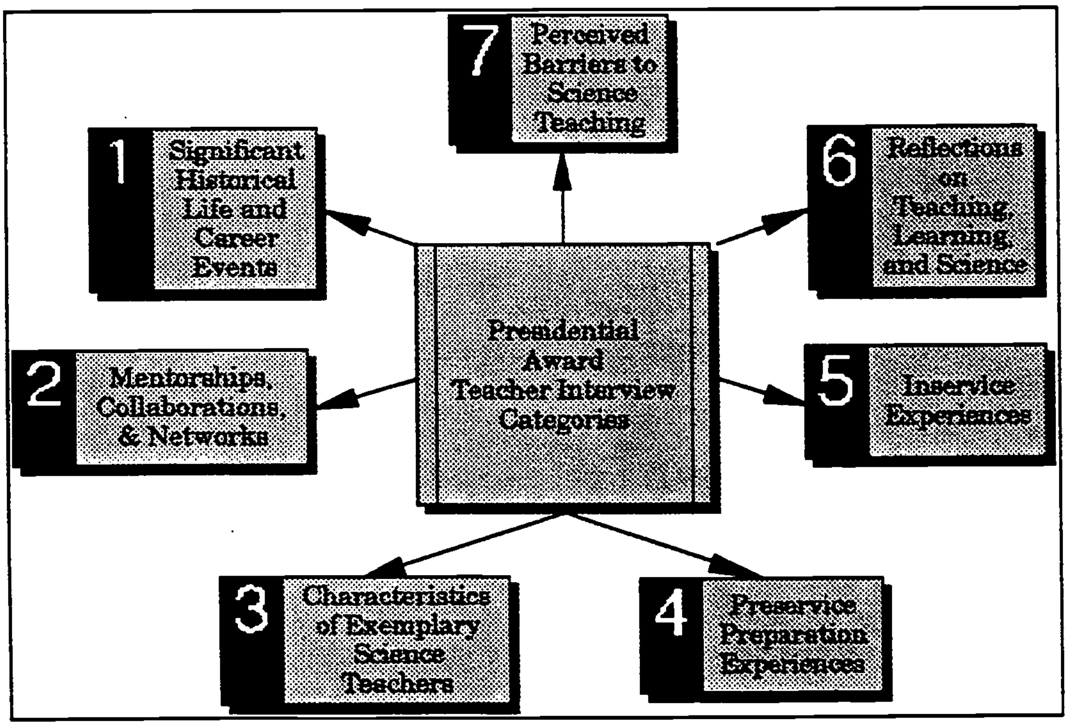

Figure 2. Concept Map of the Seven Teacher Interview Categories that resulted from the process of data analysis.

Category One: Significant History

Each informant provided rich descriptions of past events and experiences which they perceived as having something to do with their success as an elementary science teacher. In most cases the informants were able to easily recall information about their educational history, family and life events, career history, and how they came to teach science. Their individual significant histories follow.

Informant #1--Paula. Paula was born and schooled in Brazil. She earned her college degree from the Instituto de Educacao de Caetano de Campos, a school designed specifically for those seeking elementary teaching certification. For one semester during her college experience, Paula traveled to Germany to study the language with a special program funded by the German government. In 1958 she began teaching first graders in a private bilingual school, Portuguese and German, located in Brazil. After two years, she taught third grade in Germany and eventually returned to her first grade teaching assignment in Brazil where she agreed to teach German to high school students. After meeting her husband in 1964, Paula moved to the United States. She pursued a teaching certificate and master's degree in Special Education from Our Lady of the Lake University in San Antonio, Texas. In 1967, she taught special education at an inner city junior high school for a semester. Paula again moved with her husband, this time to Colorado, who was pursuing his doctorate. Together they raised their two small children and in 1970 found their way to Bryan, Texas. It was in this working class urban setting that Paula taught special education, mathematics, science, social studies, and gifted and talented education to fifth and sixth graders. She has worked as a collaborative teacher with the Elementary Professional Development School and Texas A&M University in addition to being a mentor teacher for field experience courses and elementary mathematics methods courses. She has also served as a research and education specialist for the College of Veterinary Medicine at Texas A&M University. At the time of the interview, Paula was teaching fifth grade students in a self-contained classroom.

Paula's spouse is the top administrator of the Texas Veterinary Medical Diagnostic Laboratory. They are both very proud of their children, a son who earned a Ph.D. in electrical engineering from the Massachusetts Institute of Technology and a daughter who received her Masters Degree in Mathematics from the University of Texas and is currently teaching mathematics.

As a young girl, Paula recalls having a menagerie of animals around the house -- dogs, cats, canaries and other exotic birds. Her parents were accepting of the small creatures as long as the responsibility for their care was hers and hers alone. She discovered at an early age that she could rear the offspring of some of her pets and sell them to others for a small profit.

Paula has raised over $42,000 through local fundraising projects to build a Discovery Hub in which various breeds of animals, from chickens to hedgehogs, are cared for, studied, and appreciated by all students in her school. She has also initiated a school bird emporium as a fifth grade business venture. She has received additional grant money for projects that include a rock garden, a sophisticated weather station, additional computers and a fish pond.

When asked about how she came to teach science, her response demonstrates shades of serendipity, "I wanted to teach science and it just happened" (PA-1.IT-2).

<u>Informant #2--Sam</u>. Sam was born and raised in Alaska. Childhood memories of "throwing rocks at wasps' nests, and sliding down hills on huge chunks of ice" (PA-2.IT-7) came to mind as he recalled his upbringing. He has two brothers and a sister but remembers that the only thing that he and his siblings did together was "build models during cold winter months in Alaska" (PA-2.IT-11). He doesn't credit his teaching inspiration to either of his siblings although he does describe their interesting careers.

> I have a sister who is flying 757's for USAir as a captain. I'm real proud of her. I have a brother who is the director of a science museum, and I have another brother who is a bankruptcy lawyer (PA-2.IT-11).

Sam admits that he was a lot different from other kids growing up. In fifth grade he brought some "duck guts" to school in a jar and was impressed when his teacher "actually pulled them out of the jar and laid them out" (PA-2.IT-7). Thinking back to high school, Sam remembers that he had more science courses than art classes in high school; but, was ". . .enamored with the possibility of trying that [artistic] part of my interest" (PA-2.IT-2). As a consequence, he tentatively pursued a studio art degree at Austin College in Sherman, Texas, keeping his love of science, especially oceanography, tucked not too far away.

> I was going to be an Oceanographer when I started my first semester...I had signed up for all of these science courses and I dropped them all and signed up for art courses (PA-2.IT-2).

Because of his interest in radio, television and film, Sam spent a semester at the University of Texas in Austin taking a film course. When he returned to Sherman, he accepted a position at a local television station. Eventually, he moved back to Austin to work in television advertising, and eventually became a promotions art director and weekend news director.

Sam remembers a story about a how he was introduced to the vocation of teaching. A friend who happened to be a classroom teacher invited him to speak to a group of students about studio art and creativity during a career day seminar. Sam enjoyed the experience immensely and returned occasionally to sing and play the guitar for the students. During one of these visits, Sam met his future wife Susan, a kindergarten teacher, and began to toy with the idea of going back to school to pursue a "more rewarding career" (PA-2.IT-3). At the age of 28, Sam returned to school at the University of Texas in Austin to become a teacher. His career as a teacher began at age 30. He recalls a particularly enlightening career change experience. He had gotten a part time job at the local college career center.

> I was their artist. I did brochures, slide shows and resumes. I took their little career test and it said that I would be a good teacher or a minister. Not being very religious, I figured teaching [was it for me]. I was on the right track (PA-2.IT-3/4).

Sam went to work in October for the same school where his wife Susan (also an informant in this study) was employed. He has taught third, fourth and fifth graders for fifteen years at this elementary school.

> I have only taught at one school. I've taught [at this elementary school] for fifteen years. Generally, it is self-contained everything. The only grouping that I have done, is that I taught a friend of mine's (a colleague's) [students] science. We traded off science and social studies (PA-2.IT-3).

<u>Informant #3--Meagan</u>. Meagan told her story beginning with her present position and working backwards. Her story was reconstructed as it was told.

Currently, Meagan serves as a director of a private pre-school in a large urban city in central Texas. She waits to hear about the possible funding of a National Science Foundation project to study gender equity in mathematics and science. Meagan has spent the last nine years teaching kindergarten and pre-Kindergarten. During this time she worked on a variety of projects including consulting work for the Texas Education Agency and *Project 2061*, a long term national science, mathematics, and technology reform project supported by the American Association for the Advancement of Science..

Prior to coming to San Antonio, Meagan was a pre-Kindergarten teacher in a small rural district outside of a larger urban setting in south Texas. She refers to that year of teaching in a small Texas community as a "beautiful year" (PA-3.IT-1).

> I thoroughly enjoyed the rural setting. It was preKindergarten through high school all in one campus. We all shared. It was a real community-oriented school. It was a neat experience (PA-3.IT-1).

Meagan also taught kindergarten for a year in Houston; then she decided that the city was not the place for her. Before her Houston experience, Meagan taught in a private school in Nacogdoches where she completed her graduate studies. She reflects on that experience.

> That was a wonderful learning experience. I was going to graduate school at night and then going in the classroom the next day. It was a seminar oriented graduate program...we would have discussions about what was happening in our actual classroom. We would go implement the next day what we were learning (PA-3.IT-1).

Meagan received both her bachelor's and master's degree in education from Stephen F. Austin University in Nacogdoches, Texas. She knew in junior high school that she was going to be a teacher but received "a bit of misguided information." She knew that a teaching career was an "acceptable" occupation at the time she was in school and she had her sights set on becoming a home economics teacher.

> My counselor said that I should be a secretary and that really angered me. I said, "No, I am going to be a teacher!" (PA-3.IT-2).

She went on to explain.

> I knew that I could be a teacher. Mainly, I wanted to be a teacher because I had [been exposed to] such bad teaching.

> School was boring to me. I never thought I was very bright because no one ever built me up or looked at me as an individual and I really resented it. And I knew that I was getting a lot of mixed messages and I had to do a lot of exploring on my own. I'm a teacher in spite of the way I was taught (PA-3.IT-2).

Special interest in science teaching came about when Meagan got involved with *Project 2061*.

> I loved science. I looked at science as just being the fun part of the curriculum. So, I always did a lot of really good hands-on stuff in my first years of teaching because it was just natural. When I was in *Project 2061,* I was learning all this stuff ... and really studying science. It just changed things for me. I saw the value of science and learning (PA-3.IT-2).

An early school experience sheds light on the limited extent of Megan's own elementary school science experience.

> In the second grade, I won the bean plant--the girls' bean plant...there were 5 girls in my class and 15 boys and one boy got the bean plant and one girl got the bean plant. None of the other girls really wanted to carry the dang thing; but, I really wanted it. First of all, we had planted it, nurtured it, and just the idea that something would grow was really exciting to me. That was probably one of the few hands-on experiences that I had when I was in the second grade (PA-3.IT-5).

The bean plant serves as a powerful metaphor for good science teaching. Megan's notion of nurturing holds true for her young son.

> I care for him as any mother would but I want every child to get what I want him to get. As a mother you have got to be there making sure that your child is getting it. I am also trying to make sure that everybody else's child is taken care of (PA.3-IT-5).

Informant #4--Susan. Susan grew up in New Orleans, Louisiana. She was an only child for fourteen years and recalls having her own tool box and wood to build things constantly. Her father was a geophysicist and her mother is described as a "mom but she was a naturalist" (PA-4.IT.6). She recalls experiences working with her mother in their family garden.

> I had lizards, I had frogs. I had snakes. We were doing stuff. We were experimenting with where to put plants and I was [even] understanding sun levels. We just had a lot of things going on (PA-4.IT-6).

Even though Susan demonstrated a propensity for the sciences at a young age, her parents did not explicitly encourage her to pursue a career in science.

> My parents didn't say go into science. But, what they did say was, "You can do any career you want to. Don't feel that you have to be a homemaker." They did encourage a science career of some kind ... physics. It was highly encouraged. There was no question that I was going to college. There was no question that I was going to do something in math or science. That was just the way it was going to be in my family (PA-4.IT-15).

Two significant junior high school experiences in Houston, Texas influenced Susan's interest in pursuing a science and mathematics related career. She vividly remembers them both.

> Houston, I guess that may have been the first time that I realized that I really loved science. Sixth grade ... you know you always wonder who was that one teacher that really [influenced] you. His name was Mr. Hickey. He was really into aerodynamics and so we spent a lot of the year with paper airplanes studying about flight. He was trying to get his pilot's license and we were doing a lot of that fun stuff in science and so I got hooked then (PA-4.IT-6).

In eighth grade Susan was selected for a special "Saturday Science" program.

> You had to qualify for the program and then one week you would spend the entire day at school on Saturday doing labs. It was all hands on. The next week we would be doing field experiences and so if you were studying forms of energy -- nuclear energy. You would do all the lab work and then you went to a nuclear reactor. And when we studied anatomy and physiology -- we studied, we did dissections, we dissected frogs, cats, sharks ... and all the things you could think of and then we went to the Galveston Medical School where the cadavers were (PA-4.IT-6).

Susan candidly admits that she did not set out to teach. She was interested in pursuing a career in science or engineering so she went to the University of Texas at Austin and took a lot of physics courses her first year. By her second semester, she decided to focus her attention on architecture. After only one semester, Susan decided that a teaching degree would be more feasible than one in architecture. Since her husband was also an architecture student, she figured that she could get a degree in teaching "really fast" (PA-4.IT-4).

> I could get out in education very fast, and get a teaching job. Then when he got his degree and license, I would go back and finish mine. That was the whole idea. And it was a typical story. He got his [degree] and we got a divorce (PA-4. IT-4).

By the time she graduated from the University of Texas with a minor in mathematics, she was already hooked on teaching.
For twenty five years, Susan taught Kindergarten through fourth grade in Austin, Texas. Eventually, she went back to the University of Texas for a master's degree in clinical remedial reading. It was around that time that she married Sam (also an

informant in this study). Susan is currently a Kindergarten teacher who enjoys teaching science lessons for children of other grade levels.

> We don't have science specialists. I am a kindergarten teacher. Because people know that I have an interest [in science], I've gone to other grade levels and done science (PA-4.IT-18).

<u>Informant #5--Marie</u>. Marie graduated from Abilene Christian University with a bachelor of science degree in elementary education in 1964 and received her kindergarten/early childhood endorsement from Texas Christian University in 1972. Her mother owned a school in Ft. Worth, Texas, where Marie spent her formative years.

> My mother owned a school and so we [brothers and sisters] started out doing little things for her while we were in school. We used the purple dittos that you put in the jelly and peeled them up. We made the dittos [for mom] when we were little kids (PA-5.IT-1).

Memories of rich experiences were conjured up when Marie thought back to that time in her life. She lived in a city but spent summers with her grandparents who lived on a farm.

> We would go down there and pick cotton ... and get ten cents a bag. This bag was taller than I was and it took me three days to get that dime (PA-5.IT-15/16).

Marie remembers observing the cotton she was picking,

> Look what happens when you pull this stuff out. See that little thing. Ooh and the ones with worms! We thought the worms were neat and of course, they [grandparents] hated the worms, the boll weevils. But I thought it was neat the way those things look with the little forked things on the end. And they were fun in the sand because you could put them

down and they would kind of burrow through and you could see the little raised up dirt (PA-5.IT-15/16).

She recalled another childhood event.

> We used to play with tarantulas. We used to throw cow patties at them to see how far they would jump. You didn't really hit them because you could hurt them. But, if you threw the cow patty and it hit near the side of the barn, then we would go over and measure how far it went (PA-5.IT-16).

And another.

> I can remember taking chicken eggs that the hen was sitting on and we would open them up to see what the [baby] chicken would look like when it was partly finished and partly not. We were just amazed. I can't believe we did that. I would just murder my [own] kids if they did that (PA-5.IT.6).

Marie's memories of informal science learning experiences are more positive than her memories of structured school science experiences. When asked about her high school science experiences, she recalled a frog dissection.

> In high school we dissected a frog. You know probably 20 other people had also been in that same frog. It was already open and the parts were already mutilated so to speak. So we used a lot of cards with pictures on it. [This experience was] not nearly to the extent to which my own elementary children do science (PA-5.IT-15).

Marie started teaching the summer before she graduated from Abilene Christian College after her cooperating teacher could not continue the position. She was hired for the fall semester and remained there for two years. She has taught kindergarten through third grade in three Texas towns. She currently teaches first grade in a self-contained elementary classroom in a rural, working class town in southeast Texas. Her husband worked for the Environmental Protection Agency buying and selling hazardous waste and is now self-employed. Together they have reared four children.

<u>Informant #6--Nancy</u>. As a young child, Nancy was fascinated with science, especially astronomy (PA-6.IT.4). She recalls spending a lot of time outside studying the constellations. She grew up in a large family with nine siblings all of whom were "high achievers" (PA.6-IT-5). In fact, she attributes much of her success to growing up in a large family.

> Due to my young experiences as a family member, and having that zest for learning, I became a high achiever and a supportive team member. I also learned the importance of social interactive skills of getting along with people and the importance of supportive relationships to help people academically (PA-6.IT-5).

Like the other five informants, Nancy recalled a significant life event that peaked her interest in science.

> I guess the first life experience that interested me in science is that my older sister became a design engineer with aerospace education. She was the oldest and she took the time to tell us what she was working on (she helped design the B58 bomber for General Dynamics). I was just a high school student at the time. It made me want to pursue science because I saw it as an achievement. But also, I would be helping society (PA-6.IT-7).

After a successful high school career, Nancy was encouraged to pursue a career in science or mathematics.

> This was a time that they were recruiting teachers. When I graduated from high school in 1958, we had just had Sputnik occur and because of the push to encourage people to become scientists and mathematicians, they wanted higher quality teachers out in the schools. So it was an era when they were recruiting outstanding college students to pursue teaching careers (PA-6.IT-4).

Nancy first teaching assignment was in Ft. Worth, Texas, in 1962. She taught fourth grade. Nancy married a research chemist that same year and together they moved to Galveston where she taught first grade. She then taught third grade in Conroe, Texas, before receiving her master's degree with a specialization in science from Sam Houston State University in Hunstville, Texas. Her graduate work was financed through a National Science Foundation fellowship and turned out to be a turning point in her teaching career.

> When I received that NSF fellowship at Sam Houston State and having the very best college professors. They took us out in the field. I learned about paleontology, rock strata, marine science, as well as astronomy. I learned how to use a planetarium, and then go out in the field and identify constellations. This just propelled me toward wanting to teach science to students (PA.6.IT.7).

After her science training at Sam Houston State, Nancy became a science specialist and taught science exclusively to all fifth graders. She went on to teach in a large affluent community near Houston and remained there as an elementary science teacher and district science department chair for twenty two years. She received her doctorate in curriculum and instruction from Texas A&M University in 1991 and is currently an assistant professor of science education at a small, southern university in Alabama.

A summary of each informant's teaching experience, educational institution, degrees earned, year degree was earned, and area of specialization is provided in Table 2.

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Table 2.
Informant, Teaching Experience by years and grade level, Educational Institutions Attended, Degrees Held, Area of Specialization, and Year Degree was Earned

Informant	Teaching Experience by Total Years	Teaching Experience by Grade Level	Undergraduate and Graduate Institutions Attended	Degrees Held	Specialization	Year Degree was Earned
Paula (PA-1)	26	1st-5th	Instituto de Educaco de Caetano do Campos, Brazil	B.S.	Elementary Education	1964
			St.Mary's University	M.Ed.	Special Education	1967
Sam (PA-2)	15	4th-5th	Austin College	B.A.	Studio Art/Radio, TV, Film	1973
			University of Texas at Austin	M.Ed.	Curriculum & Instruction	1983
Meagan (PA-3)	12	Pre-K-1st	Stephen F. Austin University	B.S.	Home Economics	1979
				M.Ed.	Early Childhood	1984
Susan (PA-4)	25	Kinder-5th	University of Texas at Austin	B.S.	Elementary Education	1971
				M.Ed.	Curriculum & Instruction	1974
Marie (PA-5)	33	1st-5th	Abilene Christian Unversity	B.S.	Elementary Education	1965
Nancy (PA-6)	33	1st-college	University of Texas at Austin	B.S.	Elementary Education	1962
			Sam Houston State University	M.S.	Science Education	1968
			Texas A&M University	Ed.D.	Curriculum & Instruction	1991

Category 2: Mentorships, Collaborations, and Networks

Category 2, *Mentorships, Collaborations, and Networks*, revealed several intriguing findings regarding the specific individuals who mentored, supported and encouraged the awardees to pursue and subsequently excel in science teaching careers. Formal and informal networks and collaborations with colleges, universities, professional organizations, business and industry; and other science teachers were category indicators. Other subcategories included the significant role of the spouse, the unmistakable role of parents and community members, and the role of recognition itself in building supportive collaborations with others.

Mentors and Other Support Groups. The Presidential Awardees had little difficulty recalling key individuals who mentored and encouraged them to pursue a science teaching career. For most of the awardees, the individual was someone affiliated with a college or university. For many, the individual was someone with whom the awardee had spent a considerable amount of time studying science and science education, such as a science supervisor or a workshop innovator.

> [Rick] has spent years helping me learn about the ocean because I had no biology background. He got me involved with the National Marine Science Educators Association. I'm on the board now (PA-4.IT-15/16).

Mentors are readily described as being instrumental in guiding, nurturing and supporting the natural enthusiasm and interest these teachers already demonstrated in science.

> [Mary Kay] has had a very strong influence on me. She has been supportive in areas that I did not feel strong in. She does not tend to coddle people. She sees a spark. She sees that interest. She sees someone who can take what she is doing and transfer that to the elementary classroom. She pushed [me]. She has gotten me involved in a lot of things (PA-4.IT-15).

Mentors provided tremendous emotional support for some awardees by valuing their individual strengths.

> From the very beginning that I was in the Project [she] valued me. Boy, that really made me and gave me a drive. I wanted to please her. I knew I could learn from her. I guess she helped me get started (PA-3.IT-3).

Mentors can encourage an outstanding elementary teacher to grow and think for herself or himself.

> [Terry] keeps me going and when I say, "I just don't agree with this." She'll say, "Well, what do you plan on doing about that? What could you do? Have you looked at the *Benchmarks for Science Literacy*? What do you think?" And I think, "OK, I know what to do ... go home and figure this out" (PA-5.IT.12).

In several cases mentors were responsible for the continued education and growth of the awardees who pursued advanced degrees and leadership positions. Administrators and supervisors were found to play a critical role in the support and mentorships of these outstanding science teachers. For example, Nancy noted the following about the role of innovative administrators and supervisors in school districts.

> If you are in a progressive school district with administrators and supervisors who are futuristic in their thinking and supportive of their staff members and faculty, then they start to mentor you (PA-6.IT-7).

Susan described the difficult decision she had to make when she did not feel that she had the support of the administration. She had worked hard to get the support for her science program at the central office level; without the support of her administration, she had to leave the school and find a new classroom to do her work.

> Probably the hardest decision I've ever made was because I felt so strongly about the administrative support and the central administrative support. I had already gotten the science support I had needed from those people; so, it was really hard for me to leave (PA-4.IT-3).

Marie explained that her assistant principal is "100 percent science" (PA-5.IT-7), which made it much easier to purchase the necessary supplies and materials for her classroom. This same assistant principal also played a significant role in the development of a school nature trail. Marie emphasized that her science effort was enhanced by her administrator's strong background in science.

Administrative support played a significant role in the empowerment the awardees to make important decisions regarding science budgets, programs, and instruction. Having been given a leadership position by her principal, one awardee was able to get the things she needed to teach science.

> My administrator provided me with a leadership position as a department chair and then allowed me to order all the

> science equipment and [to] assist teachers with the science equipment. Then when I had the idea ... to have the students teach the whole school about astronomy, [he] supported all my [science] initiatives (PA-6.IT-6).

The support of a mentor, institution, parent, community, and the state education agency creates a kind of courage to be innovative and to do things differently in Paula's science classroom.

> I felt like I had the support of Texas A&M. I [also] had the support of the Texas Education Agency and that gave me more courage to do things differently in my classroom ... and of course the parents liked that a lot and so I had the support of the parents as well (PA-1.IT-9).

<u>Collaborating and Networking</u>. The informants provided numerous examples of informal and formal collaboratives they have found to be professionally enriching and critical to their successful practices. The formal and informal networks identified by the science teachers included a wide variety of people and groups including custodians, cafeteria workers, the teacher next door, national organizations and university partnerships. These partnerships were essential to the success of all six informants. "The networking I do to better myself and better my profession is something that stands [out] as important for an educator" (PA-2.IT-4).

Learning from others is key to successful science teaching. As one teacher points out, "The Texas Council for Elementary Science (TCES) taught me that you could use the simplest of equipment to be effective" (PA-6.IT-7). She suggested a way to get science teachers talking to each other through the establishment of formal networks.

> I know that TCES has teachers who are members; but there is no definite avenue for them to share ideas except at state conventions. I really think that if we had networks within each school district. You could give science teachers an opportunity to interact during the school year. So if you had some kind of established network for beginning teachers who are interested in science and could have opportunities to go to an administration building and uplink via satellite and talk (PA-6.IT-12).

Susan described a rich collaborative experience with the National Aeronautic Space Administration, the University of Texas, the National Science Foundation, representatives from the White House staff, and two classroom teachers. The purpose of the collaboration was to convince all groups that the study of astronomy was important for young children. The teachers were treated to a flight on a meteor telescope called the Kiper to learn about astronomy and then were asked to accompany their astronomy professors to Capitol Hill to seek funding for their project. What made the collaboration so productive was the realization that all groups could benefit from one another. The teachers learned astronomy, the university professors gained insight from the teachers' practical knowledge of young learners, NASA would get their funding, and NSF would feel comfortable knowing that their money was well spent.

Spouses' Role in the Support of the Science Teacher. All but one informant mentioned that a spouse had some influence on the success of their career in science teaching. Three spouses of the awardees were scientists (veterinarian/microbiologist, research chemist, hazardous waste specialist). Two informants, Sam and Susan, are married and share similar job experiences. Paula explained that she "had been living with scientists since she met her husband" (PA-1.IT-4). She claims to have learned virology as she typed her husband's research papers. Much of her science background, she says, she learned through her husband's work. She has had opportunities to travel with her husband on African safari in Kenya; and she attends his international, national, and state meetings where she hears much about the latest advancements in microbiology and veterinary medicine.

Being married to a "highly educated person" (PA-6.IT-5) was identified as a great advantage to Nancy's teaching career. "He's a real scientist ... an excellent role model that I could observe from a distance or in close proximity" (PA-6.IT-5). Her spouse always discusses chemical projects "just like I was one of his peers" (PA-6.IT -5). He was very much a part of her classroom when he would come to speak to all the students about chemistry. He was responsible for locating a chemical company to sponsor the school's science fair.

Married informants, Sam and Susan, have a number of things in common including a "shared curiosity that comes along with an interest in science" (PA-2.IT-2). Sam comments that they both enjoy the same "eccentricities that science people get involved in like every time we go on a car trip, we come back with at least 100 pounds of rocks and that sort of thing" (PA-2.IT-3).

Interestingly, Sam attributed much of his success to Susan's passion for teaching. Sam's interest in teaching was ignited while teaching with his wife in the same school for several years. They continually "bounce ideas off one another" (PA-2.IT-12) and understand each other's dedication to the profession.

Communities of Learning. The awardees noted the important role of the community in terms of support for science teaching.

> If communities know that you are willing to make a contribution to all children, you just don't single out the cream of the crop, they see that your philosophy and your teaching strategies are for all students and the philosophy of Project 2061 -- science for all children -- is in fact a reality. Then you are supported and you're encouraged to seek higher ranks (PA-6.IT-6).

Parents were mentioned quite often as important supporters of good science education. One awardee said that she considered it a compliment when a parent showed up at school. Another noted that feedback from parents about how they perceive their child's progress in science as being significant.

> Based on the feedback I get from my parents, these kids are really carrying on some in-depth concepts with them and that's from kindergarten (PA-4.IT-13).

Category 3: Characteristics of Exemplary Science Teachers

The six Presidential Awardees gave their impressions of what characterizes the some of "best of the best" as related to their common traits. They identified self-efficacy, love of science, passion for teaching, and leadership skills. One teacher offered her honest reflection of what makes someone good at what they do.

> I don't know. What makes you successful? You know I wonder at times. I think, "Are you really [good] or do you just fool people?" I feel like [science teaching] is 100% of my life; everything I do is that. I take children on field trips; they come over to the house; I go places with their families. I don't know, that's just me (PA-5.IT-4).

Common Traits. Each informant suggested several personality traits that he or she felt were characteristic of good science teachers. According to the awardees, excellent science teachers have the following traits in common: creativity or "an interesting way of thinking" (PA-4.IT-10), conviction, drive, passion, persistence, curiosity, excellent management and negotiation skills, love of nature, and, most importantly, they are still in touch with their desire to learn and discover new things about their world.

> One of the qualities of being an elementary science teacher is being curious about everything you know, knowing a lot about a lot of stuff and not a whole lot about any [one] thing. (PA-2.IT-3).

"I also think that they [exemplary science teachers] are a diverse group. It is hard to just lump everyone together," cautions Meagan (PA-3.IT-4). However, Sam comments that most science teachers are easy to pick out of a crowd.

> You can be sitting with a bunch of teachers and pick out the science teachers through their conversations. They are usually talking about their experiments and dissections and stuff like that (PA-2.IT-5).

Exemplary science teachers are risk takers, or "go and getters," as Paula describes them (PA-1.IT-10). They are willing to go out of their way to put stuff in the hands of their students. As a matter of fact, Susan identified a "collectibility factor" or "stuff factor" as an important trait of excellent science teachers. Great science teachers find ways to collect materials and resources for their students.

> You have a vision for what you want to teach and you wind up collecting for it constantly. I envision that a majority of excellent science teachers [are] not able to park their car in their garage[s] (PA-4.IT-10).

Self-Efficacy. When asked how they would rate themselves as effective science teachers on a continuum from one to ten (with ten being the highest score), the six awardees rated themselves between 8 and 10. Most felt they had room for growth. One claimed that she is an effective science teacher *only* if she *is able to affect her students' lives forever.*

Love of Science. All six awardees mentioned how much they enjoyed science, not just teaching science, but the learning about the true nature of science, "Science is something that I have always loved" (PA-4.IT-6). "I like science. I enjoy it and I don't feel threatened by it. It's OK if you don't know something" (PA-5.IT-4).

Passion for Teaching. A companion subcategory to the *Love of Science* category is *A Passion for Teaching* that emerged from each of the narratives of these excellent science teachers. In fact, a total of thirty six cards were dedicated to this idea alone. Passion for teaching describes these award winning teachers' zest for their vocation. Each of the six teachers perceives his or her work as critical to the improvement of our society. One of Meagan's thoughts represent this subcategory well.

> I have a lot of passion about taking care of the world and taking care of each other and maybe it comes from my politics and all that; but, you can't be a teacher and not have real strong convictions about what you are doing; because, if you really believe in your heart that what you are doing is the right thing and that you are doing it with meaning and purpose, then you are going to be good at it and so that's what I think drives me (PA-3.IT-4).

Leadership. A significant subcategory subsumed under the larger category *Characteristics of Exemplary Science Teachers* is *Leadership*. The conversations with each of the six awardees revealed instances of leadership characteristics and experiences. These accomplished science teachers are involved in formal and informal leadership positions at the local, state, and national levels. Their expertise is called upon frequently to help others understand and appreciate science teaching. Nancy describes the purpose of her leadership role.

> I learned through STAT [Science Teachers Association of Texas]and TCES [Texas Council of Elementary Science] if you are in leadership positions, you able to better affect education; because you can offer programs for professional development (PA-6.IT-7).

Pam shares her reflection about realistic expectations for other science teachers and how she can not control the motivation of others, even as a Presidential Awardee.

> I have no expectations for the others out there right now. But, if somebody shows an interest, I'll go with it. But I can not make somebody want it. And I just have to realize that (PA-4.IT-12).

Several informants are workshop trainers for programs like AIMS, GEMS, and Project WILD. They spend most summers and their non-teaching time in the Fall and Spring writing curriculum, serving on committees, and contributing to their profession.

Recognizing Other Outstanding Science Teachers. When asked to identify other outstanding science teachers in Texas who perhaps had not received the kind of recognition they themselves had received from winning the Presidential Award, the informants were able to generate several names of teachers they knew of who are doing outstanding work in elementary science teaching. What distinguishes these outstanding teachers from the six Presidential Awardees is still an unanswered question. Perhaps the distinction stems from differences in created or serendipitous opportunity, presence of some source of inspiration, or something else. Additional research is necessary to answer this question adequately.

Category 4: Preservice Preparation Experiences

The six outstanding elementary science teachers recalled (with some difficulty) early college and university experiences regarding their preparation and training to become science teachers. They told stories about the degree of their personal science content preparation and offered suggestions for improving preservice education for prospective elementary science teachers.

Remembering Preservice Preparation. Most recollections of past preservice science preparation experiences by the outstanding science teachers were either unsubstantial or unavailable. Many informants did not have specific preservice training in science. Remarks ranged from "Not much was required" (PA-2.IT-8) and "Some of the courses were pretty squirrely" (PA-2.IT-8) to "I didn't have any preparation for teaching science, I did for reading" (PA-6.IT-9). In fact, Marie struggled to remember something substantial from her college science methods course. She was able to recall very little.

> I can remember the little thing about learning the names of the planets. The only big thing that I can remember is learning that little jingle about how to remember the names of the planets (PA-5.IT-13).

Pam did say that her science methods classes were "O.K., I mean they were interesting. I think they showed me the kind of things that you could do in science" (PA-4.IT-21). Two informants mentioned speech classes as being helpful to their future careers as teachers.

Even though some awardees claimed they did not have methods courses, many were able to describe other experiences that prepared them to teach. For example, Paula (who was schooled in Brazil) described a rich preservice experience with a professor who happened to be a pediatrician.

> We did not have science [methods] per se; but we had a pediatrician as a professor and he taught us about children's diseases. We had to be prepared to give shots to children [in Brazil]. We would practice on oranges. I enjoyed that class the best. I guess because it was science related (PA-1.IT-12).

Only one informant mentioned her cooperating teacher as an excellent role model for her future career as a science teacher. "My cooperating teacher was really innovative. Her room was full of plants and activities. There was active learning going on all the time" (PA-6.IT-9).

All informants did agree, however, that their graduate courses were much more meaningful and stimulating as a result of having already had classroom teaching experience. Meagan revealed an important discovery about herself that came about from her graduate school experience.

> The first most important thing from my college graduate school experience was when I learned how I learned ... I really learned to believe in myself and my abilities at that time (PA-3.IT-5).

<u>Science Content Preparation</u>. Informants' comments regarding their preparation or lack of preparation in science content constituted a subcategory subsumed under *Preservice Preparation*

Experiences. Sam admitted that he did not get any science content in his preservice experiences because his background was not science. "The science that I have learned, I picked up and I have no problem with that" (PA-2.IT-6). He continues, "Well, you don't have to take a *course* to know things" (PA-2.IT-6). He provides this explanation of how other things may be more important than knowledge of science content.

> One of the difficulties of working on the chemistry TEKS committee is that I know what I teach; but I just know it at a pretty shallow level which is O.K. I find it interesting what they [high school teachers] teach stoichiometry and all that stuff is way over my head, but at the elementary level, there needs to be someone that is willing to nurture curiosity and that intrinsic desire to learn (PA-2.IT-6).

Several awardees felt strongly about science content. "I think the knowledge of content is critical for being a good science teacher," says Nancy (PA-6.IT-10). She had the benefit of some excellent science content courses during her university preparation. "The experiences that I received at the university level were actually in my content classes of biology and chemistry" (PA-6.IT-9). Marie remembered a college chemistry course that was particularly enlightening. She makes a point to say that it was a regular chemistry course and not one for elementary education majors.

Marie shares why she thinks science content knowledge is helpful in teaching science to young children.

> I think the more knowledge that I have, the more secure I feel asking questions and turning them loose to do research for themselves. If I know that that's not going to

explode and I know that it's safe because of whatever knowledge I have on acids and bases. Then I don't mind letting them go over and tinker (PA-5.IT-14).

Several informants mentioned that their high school science courses were helpful in preparing them to teach science. "In high school I had a very strong biology course" (PA-1.IT.13). For some of the informants this was the extent of their formal science content experience.

Susan discovered how *not* to teach science through a college physics course she was taking as an undergraduate. There were 350 students in the lecture oriented-course and the professor advocated memorizing the formulas for the tests. Without understanding those formulas, Pam felt that she was not learning physics. Through this science content course, a new understanding of teaching pedagogy was derived for this informant. She learned that there was so much more to teaching physics than having students regurgitate meaningless formulas. Learning had to be "hands-on" and worthwhile.

Ideas for Improving Preservice Preparation. Without much prompting, several informants offered their suggestions for improving preservice science preparation. There was a pattern among responses regarding the degree of emphasis on science content. Awardees who had been teaching for more than twenty five years, particularly Susan and Nancy, felt strongly about the need for increased emphasis at the preservice level on science content knowledge.

> We need to teach preservice teachers to be critical readers of science content. They need to learn how to do major research before teaching kids science concepts (PA-4.IT-22/23).

> They have to have science content. They have to have updated content. Which means you are going to have to have your professors keeping up (PA-4.IT-23).

> Well, number one I think it needs to start in high school with all kids being required to take four years of science (PA-4.IT-21).

Awardees that had been teaching for fewer than fifteen years (like Meagan and Sam) indicated that understanding how children learn is most critical to preservice preparation.

> I think everybody should take an early [childhood] education course because that is where you really learn from Piaget's work and that sort of thing about how children learn (PA-3.IT-2).

Other suggestions included balancing scientific field experiences with laboratory activities; implementing collaborative internships between classroom teachers and preservice students for extended periods of time; and initiating worthwhile, practical activities with prospective teachers of science.

> I think it should be run similar to some of the NSF institutes where there is field work balanced with lab (PA-4.IT-21).

> I think they need to see good science instruction modeled for them for more than one semester (PA-4.IT-21).

> It is too late by the time you get to student teaching. You don't know what you are getting into. I don't think they should have observations. I think it should be an internship (PA-4.IT-21).

> I think you are going to have to get preservice teachers out in field situations [like on the beach in Port Aransas for an extended period of time]. That's when teachers get excited (PA-2.IT-8).

> It would be neat if you could couple a program between a school and university so that, if you wanted to have interns go through field experiences first, they could offer those field experiences to the kids in the schools and you would have an extra hand to go through and take the kids through some of these (PA-2.IT-22).

> Discuss ideas like, "Should teachers be held accountable for standardized test grades in science?" [and] that sort of thing (PA-2.IT-9).

Susan elaborates on the need for integration of all science disciplines including life science, earth science, chemistry and physics. She believes that a firm foundation in each science content area should lead to faded the boundaries between the disciplines and increased opportunities for preservice teachers to integrate science.

> I think they need to do internships in all areas in science. I believe in integration and that needs to be the fourth semester they take. They need to understand all the science content [areas] (PA-4.IT-22).

In summary, the awardees suggest that preservice science preparation could be improved by requiring more science content classes and spending significant time on teaching how children learn. Field-based opportunities in rich science settings, establishing meaningful internships and partnerships between universities and schools, and coupling preservice teachers with good role models are featured as possible improvements to elementary science preparation programs. Discussing issues in science education for preservice teachers in seminar-type settings, and emphasizing skills in critical reading of science content and scientific research are highlighted as essential components of preservice science programs.

Category 5: Inservice Experiences

This category was uncovered when the exemplary science teachers recalled several powerful inservice experiences that influenced their science teaching. There are three subcategories subsumed in this broad category. They are *Professional Development*, which refers to formal training offered by an individual's school district, university, or another organization; *Continuous Growth*, which includes remarks made by the teachers regarding the importance of continuous learning and the need to stay current in science; and *Experiences that Impacted Science Teaching*, which addresses the informal experiences that changed the way science instruction was perceived by the informants.

Professional Development. The professional development experiences that played a significant role in the development of these outstanding science teachers were typically described by the informants as intensive, long term, relevant to the teaching of science content, and in many cases out in the field. For example, Pam describes NSF supported institutes as particularly worthwhile.

> All these workshops were NSF funded so they paid you a stipend to go, they paid all of your materials; but, so much of it was field experiences and really getting the background [in science]. I like those courses. (PA-4.IT-7)

Nancy recalls a momentous institute sponsored by the National Science Foundation and Sam Houston State University that she attended early in her teaching career. She, along with nineteen other teachers from around the U.S., enrolled in rigorous science and math courses as well as numerous field experiences. "We took physics, zoology, botany, geology, and paleontology" (PA-6.IT-2).

> Most teachers who left Sam Houston with a graduate degree moved into university [positions]. There was one teacher who now teaches at Colorado Springs in the geology department (PA-6.IT-2).

Marie, who has been teaching for 33 years, recalls a particularly memorable professional development experience in science.

> We did Project Learning Tree [offered by] Baylor College of Medicine and Rice University. It's open to all Houston teachers and it is absolutely fantastic. I have been to millions of workshops to say the least. And to go to one after you have been teaching for 30 something years and to come out of there and say that there were only two things that they did that you were already doing is amazing (PA-5.IT-7).

Nancy, Sam, and Marie mentioned that professional development courses directed toward technology were very useful. "And then with my computer training, I learned how to use technology to better my instruction" (PA-6.IT.7). Marie uses her computer to put up a daily inquiry question for her first grade students. Her screen saver reads, "Mrs. G. loves science!" and flashes on the screen for students to see throughout the day.

Continuous Growth. All of the informants discussed the importance of continuous growth for science teachers, such as attending professional workshops and trainings, reading *Science News*, surfing the Internet, and spending vacations doing things related to science. They thoughtfully expressed that they understood their learning is not finite and that the dynamic nature of science is incredibly challenging.

> You have to have the idea that you don't know it all -- that you are a constant learner ... and, that science is probably one of the fastest changing fields. You have to be a constant learner in science. There is still so much I need to organize and know and I still have a long ways to go even with twenty five years [of teaching experience]. I have a long way to go (PA-4.IT-9,13).

Meagan made an interesting point about perceptions of others regarding the continuous growth of successful teachers. "I guess sometimes the better you get at stuff, the harder it is to find people who still think you need to grow. Perhaps that just makes you work a little harder" (PA-3.IT-5).

Experiences that Influenced Science Teaching. Positive learning experiences that influenced science teaching ranged from memories of watching science programs like *Mr. Wizard* and *Mr. Science* to a five year experience with a national science, mathematics and technology reform project, *Project 2061*. All six Presidential Awardees could recall intensely significant experiences that left lasting imprints on their science teaching careers. Marie remembered a first grade teacher who "made a tremendous impression on me as a teacher" (PA-5.IT-6). Paula recalled an honors institute designed for excellent science teachers in which for the first time she had an opportunity to find out what other good science teachers were doing in their classrooms.

> I had a hard time doing certain things in the classroom. For example, field trips...when the essential elements came out, districts said we couldn't go on field trips; because, we had to cover the essential elements. But then when I went with [Dr.Janke], I saw that other teachers in other places are doing things differently, and so could I and this is when I started doing things differently (PA-1.IT-8/9).

Paula identified her travel experiences as having a strong influence on her science teaching. "We went to the Grand Canyon. We did a lot of traveling together exploring and learning about science" (PA-1.IT-8).

Category 6: The Nature of Teaching, Learning & Science. An intriguing category to emerge from the content analysis was *The Nature of Teaching, Learning, & Science*. In this category the outstanding elementary science teachers demonstrated not only their understanding of children and how children learn science; they also painted individual pictures of their own understanding of their uniqueness as science educators -- their intrinsic understanding of how to teach science effectively to children through motivation, integration and high expectations for *all* learners.

Understanding Children's Understanding. "Kids have an intrinsic desire to learn and better themselves and it's just [a matter of] tapping into that" (PA-2.IT-12). Sam's statement about children's learning is one that was repeated several times through the numerous stories the six teachers told about teaching. In fact, Susan had this to say about finding a way to reach children.

> I don't think there is anything that I can't teach a kindergartner if I can show it to them. A lot of them are not language developed, but, I think if they can do it and look at it and dance it and eat it and sing ... then they learn (PA-4.IT-20).

She goes on to share her frustration about how some children are taught science.

> How do kids learn? By interacting with stuff; they don't learn by the written page and that is what a new teacher is given. They [the students] are given a text, a guide, worksheets ... a zillion worksheets. That's the kind of stuff they are given. They are not given the right stuff. (PA-4.IT-10)

All six informants talked about the great respect they had for the children they teach. "I respect their abilities and try to look at what I do in a holistic way ... that I am preparing kids who are going to be leaders in this world" (PA-3.UT-4). These outstanding science teachers know what is important for their students to learn and they understand how to get it across to them.

> One of the most important things in elementary school is self esteem and love of learning. I want my students not just to be science students; but to be a student, to be somebody that enjoys learning (PA-2.IT-6).

According to Paula, "All children are gifted. All children have some gift. And we can reach all children regardless of race, capability, and background, through science" (PA-1.IT-10). An understanding of the needs of diverse groups of learners was important to all six outstanding elementary science teachers.

Understanding of Self as Learner and Teacher. Just as these outstanding teachers understand their students' understanding, they also illustrate deep reflective power and understanding of themselves as learners and teachers. For example, Marie claims that, "It is real hard for me to look at something and not think [about it]" (PA-5.IT-4). She also knows that she has an interest in seeing how things work and likes to examine their interrelationships. Sam does not claim to know why he is a good science teacher. He offers that it is just the way he is. He suggests that being a good teacher is basic to his nature: "I just enjoy learning about things, how things work and why things happen the way they happen" (PA-2.IT-6).

Marie reassessed her teaching methods after deciding that she was just giving information to her students. She was once prepared to simply "impart information" to her students.

> After a while you realize I could have used that information to give [students a] question and let them discover it. So, I have kind of revamped what I do and give out less information and do more questioning strategies (PA-5.IT-14).

She admitted that the best lesson she ever taught was one in which she did not teach at all; she learned from what her students had done. In this situation, both she and her students were learners. Susan spent considerable time addressing the issue of teacher's guides versus teaching from the heart.

> I have never been somebody in which you can hand me a guide and say, "Just teach this." I'll go through the guide and look at the activities I like and copy them and put them in a file ... The guide usually goes on a shelf somewhere; because I have got to be able to teach from my heart and not from sitting with a book and have the questions in front of me. It has to be natural (PA-4.IT-5).

Susan adds, "It was driving me crazy having the teacher's edition and trying to figure out what they wanted me to do with it and knowing that it wasn't meeting the needs of the kids" (PA-4.IT-5). Susan had to learn how to help kids make connections on their own through the personalization of instruction rather than through prescribed activities in some teacher's guide.

Integration and Reading Issues. This subcategory surfaced as a result of numerous illustrations of science lessons described by each of the informants regarding the nature of science instruction in their classrooms. The pre-Kindergarten, kindergarten and first grade informants emphasized the importance of reading in their curriculum. The two fifth grade teachers did emphasize reading as a critical skill, but did not consider it as significant as the primary teachers. One first grade informant had this to say about reading.

> Oh, for years and years, reading was my number one, always reading. I am not going to say that science overpowers reading; because, I am still very much a reading teacher. Science is my reading (PA-5.IT-13).

Marie's remark, "Science is my reading," indicates that she has discovered a way to integrate science into her reading curriculum.

Other examples of how these exemplary science teachers integrate science and reading are prevalent in much of the interview data.

> Now I understand that children have to learn to read; but if you don't have a need to know those words, then why are you going to do that. Children just have to have a need to know. And one of the best ways to do that is to make it have some value and most things go back to science. All things do [have value] in my class (PA-5.IT-3).

Susan also integrates science and reading,

> Once I got my reading done [completing a master's degree in clinical reading] and I figured out how to teach kids. I figured that I could go back and integrate things I wanted to. You don't just read to read. You read because you want to find out some information and one of the most exciting things to kids in elementary school is science (PA-4.IT-5).

Sam and Paula revealed that science was used as a vehicle for learning in their classrooms. "Science is just how I happen to handle learning" (PA-2.IT-6) and "I was not teaching science; but I was integrating science concepts in my reading and writing. I was using science for all of my subjects" (PA-1.IT-8).

<u>Category 7: Perceived Barriers to Science Teaching</u>

This final category yielded a number of distinct barriers or things that inhibit the teaching of good science. Each awardee pinpointed the difficulties that science teachers face in their planning and delivery of science instruction. The informants also provided examples of ways they have personally discovered for overcoming these difficulties.

Identification of Barriers which Inhibit Science Teaching

Numerous barriers were identified by the exemplary science teachers. The obstacles ranged from the issues of lack of standardized testing, accountability, and support in science teaching, to lack of appropriate tools and science equipment for the science classroom. Below are representative statements that speak to the general deterrents in science teaching.

> Science is usually taught at the end of the day when teachers are tired (PA-6.IT-7).
>
> Science is something that requires more time. You have to stop at the store. You have to go out to your garden to get flowers and leaves (PA-6.IT-8).
>
> It takes more planning (PA-6.IT-8).
>
> It is a very involved subject to teach. It takes more understanding of the students ... you have to teach students how to think (PA-6.IT-8).
>
> It's difficult to change teachers who have an attitude toward science in which [they believe] it's just as effective to read and answer questions rather than do hands-on learning (PA-6.IT-9).
>
> We are a textbook driven society (PA-6.IT-10).
>
> The problem with science is that it needs space, storage for materials and money to buy the material and it's a lot of work to prepare ... and some people don't want to bother with it. It's hard work (PA-5.IT-17).
>
> Truly there are some people that are there [teaching] that don't want to be there (PA-5.IT-17).
>
> I think where they [the State] has fallen short is by not giving us materials to teach the way they want us to. When

> you give people nothing but a science textbook, then they teach from a science textbook which is not process [oriented]. And I think that's the thing to overcome (PA-4.IT-13).

> Just like testing. [Science] is not important. Reading and math are always there, but science and extra-curricular [activities] are not (PA-5.IT-12).

> I haven't felt a lot of support (PA-3.IT-5).

The informants mentioned the immense financial burden of teaching science. Several teachers in the study estimated the personal "out of pocket" expense used to purchase supplies and materials for teaching science in their classrooms to be a good portion of their teaching salaries.

> I had a saltwater aquarium in my classroom and a freshwater [tank] each year. And just to supply fish food and all of the animals for those particular types of aquarium, it's all out of pocket (PA-6.IT-8).

Another intriguing barrier which may be unique to this exemplary group of science teachers is the notion of posing a threat to others. Susan addressed the issue of being a threat to other teachers and some administrators because of her talent for, and knowledge of, science.

> I think you get resistance from those who feel the pressure that they should be doing the same amount of stuff in science. That's a threat. You can be a threat to administrators if you know more than they do (PA-4.IT-11).

The barriers highlighted by these exemplary teachers are common to *all* teachers. Time, lack of resources, financial support, are encumbrances that teachers must face daily in their work, yet all six Presidential Awardees demonstrated that these barriers are mere challenges that, with perseverance and dedication, can ultimately be overcome.

Overcoming Science Teaching Barriers. This subcategory emerged from the six individuals' statements related to finding ways to do what they truly believe is important for children and science instruction. Each obstacle mentioned in the preceding subcategory is seen as something that can be overcome with innovative strategies, creative problem solving, hard work, and perseverance demonstrated by each these outstanding science teaching. They let nothing deter their science teaching.

> I've walked into classrooms that had four tables and sixteen chairs and they said, "Go ahead and teach." I didn't find that to be limiting, I just got out boxes and paper and went from there building structures. I built trains and furniture for the kids out of boxes. I wouldn't let that [lack of resources] limit me or keep kids from having what they needed (PA-3.IT-5).

Nancy suggested that with the development of the *National Science Education Standards* and *Benchmarks for Science Literacy*, there is hope that science will be a priority in elementary schools of the future. These documents might be useful by providing the support and structure necessary to improve science instruction in elementary science classrooms.

The challenge of making what one has work is one that is welcomed by these extraordinary teachers. In fact, they see the current structure of their elementary school curricula as an ideal one for the teaching of science. They enjoy their individual freedom to design integrative learning experiences for children without the pressure of feeling as if they should be using a state adopted textbook. "At the elementary level enjoying science means any of the disciplines ... which gives us a certain amount of freedom in elementary school" (PA-2. IT-3).

What Have We Learned?

Having described the seven categories that emerged from my interaction with the data collected from the six teacher interviews, I now turn to the more formidable challenges of analysis and interpretation. In the preceding pages I have reported the data in a way that I hope begins to speak for itself. I have left much of the setting to communicate directly to the reader using the words of the six informants. Now that I have told the story, I must attempt to tell how that happened to be the way I told it. I now move beyond mere description to the identification some essential features of the data and interpretation that answers the questions: What is to be made of it all? What have we learned?

Category One, *Significant History,* reveals that each informant shares a rich and interesting but entirely unique upbringing. Many spent their early years in states other than Texas and one grew up in a different country. The awardees shared memories of "doing science" at young ages and each memory was unique to the individual's cultural setting -- raising animals in Brazil or playing with tarantulas on Grandma's Texas farm.

Parents were identified by a few awardees as great supporters of their natural curiosity as young children. Some awardees grew up with brothers and sisters who are credited with having a considerable influence on their success, while others do not identify their siblings as having any impact whatsoever. Several experiences, including NSF institutes, *Project 2061* involvement, and working with other science teachers, were highlighted as significantly impacting each science teacher's career development. One teacher, with over thirty years of teaching experience, emphasized the impact of the post-Sputnik era on her own science education. She attributed her strong science background to the push during the late fifties to direct girls towards careers in mathematics and science. The two awardees with twelve and fifteen years of teaching experience indicated through their narratives that understanding the child as learner was most important to the teaching of science. Is this an indication that changing trends in science education reform as reflected in our history since Sputnik may have had an impact on the educational philosophies of the awardees?

Although an array of differences regarding the exemplary teachers' individual histories is evident, one important commonality surfaces. Not a single awardee set out to teach science per se. All six awardees became science teachers by chance. Science just happened to be the subject each began to cultivate while teaching sometime during their practice in his or her self-contained classroom. Through the pursuit of advanced degrees, participation in National Science Foundation, American Association for the Advancement of Science, and university-sponsored institutes, and interaction with other teachers, their successful science teaching careers were born.

Category Two, *Mentorships, Collaborations, and Networks*, reveals that the six awardees identified a variety of sources of inspiration in their science teaching careers, including local science specialists or coordinators, university professors, administrators, other science teachers, scientists, and spouses. The awardees also indicated notable formal and informal collaborations and networks with professional organizations and local, state, and national projects. Individual and group relationships were perceived by all six awardees as instrumental in the development of their science teaching careers as well as in their personal understanding of the nature of science.

Category Three, *Characteristics of Exemplary Science Teachers*, unveils a common set of characteristics of exemplary science teachers that is similar to descriptions of highly effective individuals. These common traits are conviction, drive, passion, persistence, curiosity, leadership, risk taking, and the belief in life-long learning. These traits are not unlike Stephen Covey's habits of highly effective people: *habit of proactivity*; *habit of vision, of purpose, of mission*; *habit of integrity, or discipline, of keeping that commitment*; *habit of seeking first to understand and then to be understood*; *habit of synergy*; and the *habit of sharpening the saw*, in other words, constantly renewing oneself physically, mentally, and spiritually (Covey, 1994).

The six awardees conduct inservice training and are involved in leadership positions on the local, state, and national level. They feel well qualified to teach science. As a result, they spend a considerable portions of their lives teaching science no only to their young learners but also to other teachers.

Category Four, *Preservice Preparation*, indicates that most of the exemplary teachers placed little value on their preservice preparation experiences. Very little science content knowledge was gained during preservice preparation. We should remember, however, that during their undergraduate preparation, these teachers had no idea that they would be teaching science. Most of their science knowledge was gained through cogent high school experiences, college science courses taken as non-education majors, and inspirational science-centered inservice experiences.

Two paradoxical beliefs are illustrated by the awardees. One belief suggests that the more science content the teacher knows, the better she or he will teach science. The other suggests that a focus on the way children learn will bring about an interest in science and create substantial knowledge and better teaching practices. These beliefs are reflected in the awardees' suggestions regarding preservice preparation. Some awardees propose that greater attention to science content should be a part of the preservice program; others feel that an emphasis on how children learn science should be the focus of preparation programs. All six agree that elementary school field experiences, including practical classroom experience *and* field experiences like field trips in rich science settings (museums, science research laboratories, or the Texas coast) are essential components of effective science teacher preparation programs.

Category Five, *Inservice Experiences*, reveals that the teachers identified at least one powerful inservice learning experience. *Powerful* is defined by these teachers as an experience that uplifted, inspired, and changed the way they thought about science instruction. For each teacher the experience was different. Nancy became involved in science teaching after attending an NSF-sponsored institute that emphasized an in-depth study of science content areas. Paula was inspired by an honor's institute for science teachers sponsored by a large university that took teachers from across the state to rich field settings to study science. Meagan spent several intensive summers at universities throughout the country working with teachers developing national science curriculum models. Susan traveled to Washington, D.C., with a group of astronomers and university professors to pitch a space science curriculum project. Her husband, Sam, currently develops technology-enhanced science classrooms with university researchers. Marie, after twenty five years of classroom teaching, attended an intensive university sponsored summer institute in which she learned new strategies for teaching science. All six teachers recognize the importance of their own continuous growth in science teaching. They actively seek ways to "sharpen their saws" (Covey, 1994,p. xi).

Category Six, the *Nature of Teaching, Learning and Science,* suggests that the awardees share a strong sense of understanding or talent that allows them to think about how children learn science best. They also feel that every child given the right set of tools and appropriate instruction has some potential for learning science. All six exemplary teachers were reflective of their own teaching and learning strategies. They have the ability to translate science content knowledge into effective pedagogical strategies that ensure student learning. The awardees definitely understand that teaching must be natural and come from the heart in order for it to be worthwhile and effective for their students.

Although reading takes precedence in most of the classrooms of the awardees teaching the early grades, they have found ways to integrate science with reading and other subjects. Science is not limited to thirty minutes at the end of the day in these teachers' classrooms. Threads of science content are woven throughout each day through various reading, language arts, social studies, mathematics, and art activities. Science is used as a vehicle for learning at all levels.

Category Seven, *Perceived Barriers to Science Teaching*, identifies deterrents to the teaching of science as well as strategies to overcome them. The Presidential Awardees identified common barriers that impact the teaching of science. Their perceptions were similar to what most teachers claim to be deterrents to effective teaching: insufficient time to prepare for science and to teach science; unavailable or difficult to obtain resources for science instruction; and lack of support for science programs in general. The awardees describe a number of strategies to overcome science teaching barriers, which include seeking grants to purchase supplies and materials, involving community members in the quest for providing improved science resources, and linking with universities that share common concerns about science teaching. This suggests that elementary science teachers who possess skills in grant writing, networking, and collaborating with universities and other schools might be effective in lifting many of the obstacles that often interfere with good science instruction.

Implications For Strengthening The Preparation of Prospective Elementary Science Teachers

> The Presidential Awards for Excellence in Science and Mathematics Teaching program was established at the National Science Foundation (NSF) in 1983 to identify outstanding teachers of science and mathematics, K-12, who will serve as models for their colleagues and who will form a leadership core to help advance the major reform movements in these disciplines.
>
> (National Science Foundation, 1996)

Paula, Sam, Meagan, Susan, Marie, and Nancy are models for excellence in elementary science teaching. They teach us through their personal conversations that numerous considerations are addressed by individuals and institutions interested in strengthening the preparation of prospective elementary science teachers.

The Presidential Awardees teach us that the process of developing excellence in science teaching is multifaceted. Regarding the development of early interest in science, the common thread that weaves their stories together is an innate curiosity and interest in the natural world that began early in their lives even though the stories regarding upbringing and educational experiences are unique to each individual. Nonetheless, each individual discovered a common path of success and recognition for professional excellence. This suggests that the path starts early in preparing and supporting prospective teachers of science. The benefits that young children can reap from early science experiences include not only science literacy but also the possibility of rewarding careers in science and science teaching.

Individual characteristics of outstanding teachers include traits such as curiosity, perseverance, drive, passion, and risk taking, with some suggestion that these characteristics continue to develop over time. From early childhood experiences throughout their lifetimes these traits have been nurtured and satisfied, time and time again. A preservice program that nurtures these habits of mind in the novice teacher could feasibly craft the much needed effective science teachers of the twenty-first century.

The six Presidential Awardees generally feel unfulfilled by their own preservice preparation courses. Their methods courses emphasized generic teaching skills that had little use until they encountered specific instances in their own classrooms. (This is true for other methods courses as well.) These teachers suggest that instruction in pedagogy grounded in specific content creates understanding and enrichment in science teaching abilities. Preservice preparation should be a time of great enlightenment and opportunity for prospective teachers. Increased field experiences both in elementary schools and science-rich settings provide relevant contexts for the professional development of preservice teachers.

A critical component for further development of science teacher preparation programs is the creation of connections with effective science teachers already in the profession. Experienced elementary teachers have discovered strategies for teaching science successfully that have much to offer the novice educator.

Establishing a network of personal mentorships leads many to professional growth and development in science teaching. Similarly, collaboration with education and science education faculty, scientists, and other stakeholders is a powerful venue for strengthening elementary science preparation programs.

Thoughtful and worthwhile inservice experiences build strong elementary science educators. The professional growth and development for the awardees occurred over the course of their entire teaching careers. Brief one-shot training experiences did little to strengthen the skills of these science teachers. Prolonged, diverse, and meaningful professional development is necessary for prospective teachers entering their teaching practice. Opportunity for continuous growth must include interaction with other professionals in both educational and scientific communities. Inservice experiences promoting personal reflection, collaboration with other teachers of science, and intensive exploration of science and science teaching strategies are considered most beneficial by outstanding elementary science teachers.

The exemplary elementary science teachers also teach us the importance of student-centered teaching and inquiry-based science instruction. These instructional approaches must be a component of all science preparation programs. Novice teachers who know how to position the child at the center of instruction and to provide opportunities to explore and design inquiry-based science activities are not dependent on a science textbook as their only guide to science instruction. In addition, strategies that link science instruction to reading, mathematics, social studies, and fine arts increase children's exposure to science in multiple learning contexts. When science is viewed as an essential part of the curriculum, science literacy develops naturally. The content and process of science are learned through all kinds of experiences that require learners to extend their integrative powers in problem solving and thus support their active pursuit of answers to questions about the natural world.

Finally, as in all aspects of teaching, there are barriers that teachers perceive as keeping them from teaching science in their classrooms. However, as we have learned from some of the "best of the best," there is no insurmountable barrier when the appropriate energy or creativity is applied to it. This implies that effective programs for strengthening the science preparation of elementary teachers include strategies that assist prospective teachers in identifying barriers and designing solutions to overcome them. Grant writing, networking, and making use of available resources are critical activities for effective teachers of science. Future teachers of science need to understand the importance of developing strategies for confronting inevitable science teaching challenges.

Can effective science instruction be taught to prospective teachers in a way such that these future teachers could follow in the footsteps of these examples of the "best of the best" in science teaching? The answer to this question is a resounding *yes*. The six elementary science Presidential Awardees have provided personal stories and thoughts that are indeed relevant to the preparation of science teachers. From their conversations we gained valuable insights in how to "craft" excellence in science teaching.

What insights have we gained from interviewing Texas Elementary Science Presidential Awardees? First, individual life histories and prior experiences rich in science contexts are important in the lives of effective science teachers and must be recognized if the preparation of effective science teachers is to be improved. Second, exemplary traits and personal characteristics must be nurtured throughout a teachers' career. Third, preservice and inservice experiences must be fulfilling and meaningful. Fourth, formal and informal mentorships with scientists are critical. Fifth, emphasis on student-centered and inquiry-based instructional models must be emphasized. And finally, strategies for overcoming barriers to science teaching must be developed. These insights gained from our representations of the "best of the best" provide information that can be directly applied to programs that prepare elementary teachers to teach science that is relevant to the lives of young learners and critical to the needs of tomorrow's decision makers and problem solvers.

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PESPII–Open Ended Interview Protocol

Career History

1. Please describe your career history. How long have you been teaching? Where have you taught? What grade levels and subjects have you taught?

2. Why did you become a teacher?

3. Who or what was instrumental in the development of your professional teaching career?

4. What science experience(s) have impacted your career choice?

On Excellence

1. You have been identified as an outstanding elementary science educator, to what do you attribute your excellence in science teaching?

2. In your view, what attributes might outstanding elementary science educators have in common?

3. On a continuum of 1-10, 10 being the highest, how would you rate your effectiveness as a science educator? Why?

Significant Events

1. Please identify any significant life event(s) that you feel has strongly impacted the direction of your career as a science educator.

2. How do you view yourself as a continuing learner of science?

Formal Education

1. Think back to your college preparation courses. What course or courses stand out in your mind as effective and useful in your teaching?

2. What did you learn about teaching in your education courses?

3. What did you learn about science in your education courses?

4. What did you learn about yourself as a preservice teacher in your undergraduate program?

Appendix B

Unstructured Interview Protocol
(Revised 3-21-96)

1. Describe your career history. How long have you been teaching? Where have you taught? What grade levels have you taught?

2. Why did you become a teacher/science teacher? Who or what was instrumental in the development of your professional science teaching career?

3. You have been identified as an outstanding elementary science educator, to what do you attribute your success?

4. In your view, what attributes might outstanding elementary science educators have in common?

5. On a continuum of 1-10, 10 being the highest, how would you rate your effectiveness as a science educator?

6. What, if any, significant life event(s) do you feel have impacted the direction of your career as a science educator.

7. What barriers have you had to overcome in your teaching of science?

8. What did you learn about science and science teaching in your preservice preparation classes? How is it different from what your classroom experience has been like?

9. What effect does your knowledge of science content have on your teaching of science?

10. What is your opinion of existing science preparation programs in Texas?

11. Describe your typical day.

Appendix C

Interview #6 Revised Protocol (4-15-96)

1. Describe your typical day.

2. Describe your career history. How many years have you been teaching? What grade levels you have taught--where you have taught...etc..

3. Why did you become a teacher/science teacher? Who or what was instrumental in the development of our professional science teaching career?

4. You have been identified as an outstanding elementary science educator, to what do you attribute your success?

5. On a continuum of 1-10, 10 being the highest, how would you rate your effectiveness as a science educator?

6. What, if any, significant life event(s) do you feel have impacted the direction of your career as a science educator?

7. What barriers have you had to overcome in your teaching of science both in public schools and at the university level?

8. What did you learn about science and science teaching in your preservice preparation classes? How is it different from what your classroom experience has been like?

9. What effect does your knowledge of science content have on your teaching of science?

10. What was the strongest part of your science teacher education experience? The weakest part?

11. If you could change any aspect of your science teacher education program to ensure that future teachers are better prepared what would you change and how?

12. You have been involved in teacher education since your own science teacher preparation, what are your impressions of current science teacher education practices?

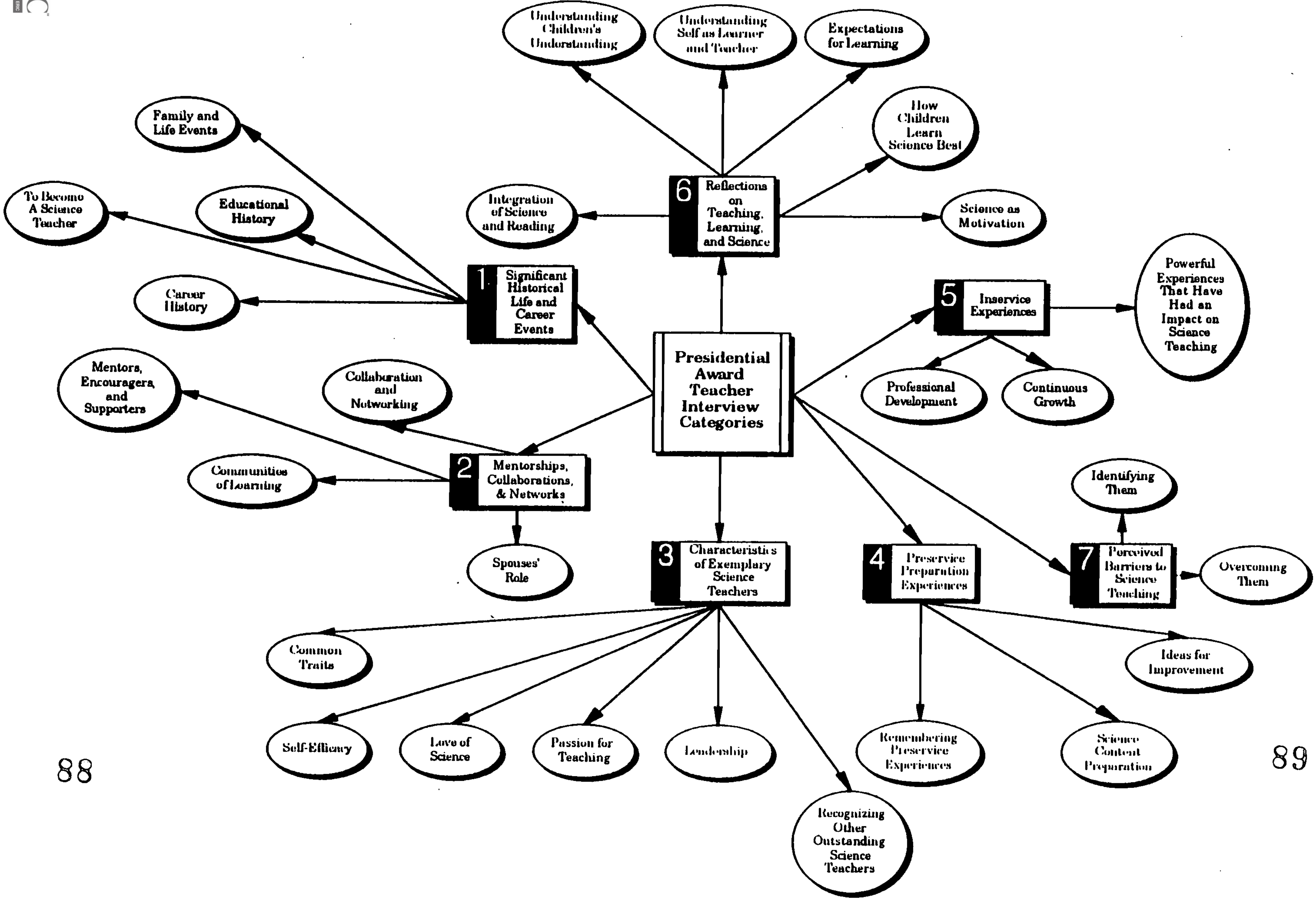
13. Can you recommend any other outstanding elementary science educators?

14. Are there any questions that you feel that I need to ask that I haven't asked that are significant to the improvement of science teacher preparation?

Appendices D & E
Initial Sub Category Listings

1. Educational experience
2. Career history
3. Family history
4. Spouse's role in science teaching
5. Freedom to teach science
6. How I came to teach science
7. "Stuff" I need to teach science
8. Using science a vehicle to motivate children to learn
9. Thoughts, beliefs, ideas about education in general
10. Reflections on why I do what I do
11. Aspirations of becoming a teacher
12. Commitment to the profession
13. Professional development
14. Continuous learning
15. Barriers to science teaching
16. Evidence of overcoming barriers
17. Informal support systems
18. Formal support systems
19. Mentors
20. Networking
21. Collaboration
22. Recognition and respect
23. "They" who don't know
24. Common traits
25. Positive science teaching experiences
26. Problems in science education
27. Leadership
28. Attitudes toward students
29. Understanding children's understanding
30. Ideal science curriculum experiences
31. Integrating science
32. Self-efficacy
33. Preservice recollections
34. Personal thoughts on preservice preparation
35. Technology issues
36. Love of science
37. Understanding of self as teacher
38. Understanding of self as learner
39. Science Content knowledge preparation
40. Ideas for improving preservice education
41. Communication with students
42. Early formal science experiences
43. TAAS issues
44. On being a threat*
45. Reading and science*
46. Gender issues*
47. Freedom to teach*
48. Time*
49. Money*
50. Overcoming barriers*

**additional categories*



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