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The impact of whole-plant instruction preservice elementary teachers' understanding of plant science principles

Christine Collins Hypolite

Louisiana State University and Agricultural and Mechanical College, chypol1@lsu.edu

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THE IMPACT OF WHOLE-PLANT INSTRUCTION ON PRESERVICE ELEMENTARY TEACHERS’ UNDERSTANDING OF PLANT SCIENCE PRINCIPLES

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Curriculum and Instruction

by

Christine Collins Hypolite
B.A., Nicholls State University, 1978
M.Ed., Nicholls State University, 1980
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DEDICATION

In Memory of My Father

Harold Vincent Collins, Sr.
ACKNOWLEDGMENTS

The achievements in our lives are accomplished by study, hard work, and knowing that we have done our very best. My mother said, “whatever you choose to become in life make it the very best you”. But, few things in life can be achieved in complete autonomy. The support that we receive from others provides us with the nurturing that humans need to thrive; and to this end I must say I have been truly nurtured.

To all of my family, who have always encouraged me to seek my dreams and supported me in achieving them, this could not have been possible without you. Thank you for all of the late night calls, ‘lost’ weekends, cooked meals, words of encouragement when I needed them most, lending ear, and prayers.

Thank you to my mom, Shirley, for the support you have given me throughout my life. You have been a role model of perseverance and courage, and it is through your modeling that I have learned the skills I needed to seek my dreams.

To my sisters, thank you to each of you for providing me with a special gift that has helped me through this journey. Thank you for the patience to endure(Allyson), for the understanding that I am not in this alone, all is possible through prayer (Carolyn) and for desire to learn more(Sylvia).

To my husband, Shelby, thank you for your support. All of the long evenings, missed events, travels to Baton Rouge, cooked meals, laundry days, and just being there were an important part of my being able to accomplish this goal and it could not have been done without your support.

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TABLE OF CONTENTS

DEDICATION .............................................................................................................................. iii

ACKNOWLEDGMENTS ........................................................................................................ iv

LIST OF TABLES .................................................................................................................. viii

LIST OF FIGURES ............................................................................................................... ix

ABSTRACT ............................................................................................................................ x

INTRODUCTION .................................................................................................................... 1
  The TIMSS Report ............................................................................................................ 2
  The National Assessment of Educational Progress ..................................................... 3
  No Child Left Behind ...................................................................................................... 4
  National Council for Accreditation of Teacher Education (NCATE) .......................... 4
  Teacher Preparation and Learning .............................................................................. 6
  Human Constructivism ................................................................................................. 7
  Biology Reform ............................................................................................................. 9
  Rationale for the Study ................................................................................................. 11
  Research Questions ...................................................................................................... 12
  Definition of Terms ...................................................................................................... 12
  Gowin’s Vee .................................................................................................................. 13

LITERATURE REVIEW ........................................................................................................ 15
  Knowledge Construction .............................................................................................. 15
  Situated Knowledge ...................................................................................................... 16
  Knowledge Dependency ............................................................................................... 17
  Human Constructivism ................................................................................................. 19
  Meaningful Learning .................................................................................................... 20
  Conceptual Change ...................................................................................................... 21
  Alternative Conceptions ............................................................................................... 22
  Cooperative Learning .................................................................................................. 24
  Multiple Intelligences ................................................................................................. 25
  Inquiry-Based Learning ............................................................................................... 26
  Concept Mapping ......................................................................................................... 27
  Plant Science Concepts and Principles ....................................................................... 29
  Research Methodology ............................................................................................... 31
METHODS ............................................................................................................33
   Overview of Research .......................................................................................33
   Research Design ..............................................................................................33
   Description of Research Site .............................................................................34
   Research Participants .....................................................................................35
   Data Collection .................................................................................................35
   Protection of Human Subjects .........................................................................37
   Data Analysis ....................................................................................................37
   The Whole-Plant Unit of Study ........................................................................39
   Development of the Milestones in Understanding Plant Science Scale (MUPSS) .........................................................................................40

RESULTS AND DISCUSSION ............................................................................42
   The Preservice Elementary Teacher ................................................................42
   Pre- and Postinstruction Tests ..........................................................................42
   Performance on MUPSS ....................................................................................43
   Activity One Participant Results .......................................................................43
   Activity Two Participant Results ......................................................................43
   Activity Three Participant Results ....................................................................44
   Activity Four Participant Results .....................................................................44
   Activity Five Participant Results .....................................................................45
   Activity Six Participant Results ........................................................................45
   Purposive Group Results ..................................................................................45
   Research Questions ..........................................................................................46

SUMMARY AND CONCLUSIONS ......................................................................55
   Limitations of the Study ...................................................................................56
   Implications for Further Research ....................................................................56

REFERENCES ......................................................................................................58

APPENDIX A: NATIONAL COUNCIL FOR ACCREDITATION OF TEACHER EDUCATION ............................................................................................72

APPENDIX B: UNIFYING BIOLOGICAL PRINCIPLES ........................................74

APPENDIX C: PRINCIPLES OF PLANT BIOLOGY ...........................................75

APPENDIX D: NATIONAL SCIENCE EDUCATION STANDARD .......................77

APPENDIX E: GOWIN’S VEE DIAGRAM OF RESEARCH ..................................79

APPENDIX F: HOWARD GARDNER’S MULTIPLE INTELLIGENCES ..................80

APPENDIX G: PRE-INSTRUCTIONAL TEST .......................................................81
LIST OF TABLES

1. Ethnic Composition of the Region Compared to the University……..34
2. Summary of Analysis of Artifacts……………………………………..43
3. Preservice Elementary Teachers Incorrect Responses to Preinstruction Test Questions………………………………………49
4. Preservice Elementary Teachers Incorrect Responses to Postinstruction Test Questions………………………………………..50
LIST OF FIGURES

1. Gowin’s Vee Diagram.........................................................13

2. Concept Map.................................................................28
ABSTRACT

The purpose of this research was to determine how an inquiry-based, whole-plant instructional strategy would affect preservice elementary teachers’ understanding of plant science principles. This study probed: what preservice teachers know about plant biology concepts before and after instruction, their views of the interrelatedness of plant parts and the environment, how growing a plant affects preservice teachers’ understanding, and which types of activity-rich plant themes studies, if any, affect preservice elementary teachers’ understandings. The participants in the study were enrolled in two elementary science methods class sections at a state university. Each group was administered a preinstructional test at the beginning of the study. The treatment group participated in inquiry-based activities related to the Principles of Plant Biology (American Society of Plant Biologists, 2001), while the comparison group studied those same concepts through traditional instructional methods. A focus group was formed from the treatment group to participate in co-concept mapping sessions. The participants’ understandings were assessed through artifacts from activities, a comparison of pre- and postinstructional tests, and the concept maps generated by the focus group. Results of the research indicated that the whole-plant, inquiry-based instructional strategy can be applied to teach preservice elementary teachers plant biology while modeling the human constructivist approach. The results further indicated that this approach enhanced their understanding of plant science content knowledge, as well as pedagogical knowledge. The results also showed that a whole-plant approach to teaching plant science concepts is an instructional strategy that is feasible for the elementary school. The theoretical framework for this study was Human Constructivist learning theory (Mintzes & Wandersee, 1998). The content knowledge and instructional strategy was informed by the Principles of Plant Biology (American Society of Plant Biologists, 2001) and Botany for the Next Millennium (Botanical Society of America, 1995). As a result of this study, a better understanding of the factors that influence preservice elementary teachers’ knowledge of plant science principles may benefit elementary science educator in preparing teachers that are “highly qualified.”
INTRODUCTION

Reform efforts in science education have been ongoing for almost a half-century. Historically, the emphasis of reform has been placed on the curriculum and student performance on tests as the source of science improvement. However, the focus of science research and education has changed, both in the organization of areas within science and in the purpose of science. According to Hurd (1997), research in the natural sciences has become more socially driven. The science facts, theories, and laws of traditional science disciplines are now more transdisciplinary in focus, forming alliances between natural and social sciences to provide for human resources.

Research findings suggest that while Americans hold science in high regard, they do not consider themselves prepared for the complex political, social, ethical, and economic issues that involve science (National Health Museum, 2003). Concurrently, evidence from international comparisons, as well as research conducted solely in the United States, indicates that there has been neither improvement in learners’ science test scores nor systemic change in science education.

The issue of science reform was brought to the public’s attention in 1983 with the publication of the National Commission on Excellence in Education’s report, *A Nation At Risk* (NCEE, 1983). This report startled the nation about the reality of the quality of its K-12 schools. It indicated that the United States placed last in international achievement tests. The average achievement of high school learners was shown to be lower than it was when Sputnik was launched 26 years earlier, and there was a steady decline in the College Board’s Scholastic Aptitude Test (SAT) scores (NCEE, 1983). *A Nation At Risk* became a “call to arms” for educators and policy-makers in what later would become known as the first wave of educational reform.

One of the greatest changes introduced in this first wave of reform was standardization. This process was an attempt to provide the science education community with a uniform framework with which to develop science curricula. In 1989, the American Association for the Advancement of Science (AAAS) published *Science for All Americans: A Project 2061 Report on Literacy Goals, in Science, Mathematics, and Technology*; this publication provided the foundation of science curricula in the 1990’s. The AAAS took a second step in the pursuit of reform in 1993 with the publication of *Benchmarks for Science Literacy* (*Benchmarks*). These two publications served as a guide to educators, describing the levels of understanding that learners needed to achieve in becoming scientifically literate. The AAAS described a scientifically literate person as one who is able to understand the basic facts and principles of science, but also understands their application and implication to the world (AAAS, 1993; DeBoer, 2000).

In addition to the pursuit of scientific literacy established in the publications of the AAAS, a publication was later released by the National Research Council (NRC) in 1996, entitled *The National Science Education Standards* (*Standards*). The *Standards* were an effort by the scientific and education community to provide consistency in the science curriculum. As stated in the *Standards*, “The standards do not dictate the order, organization, or framework for science programs” (p. 8); the *Standards* have been designed to serve as a guide (NRC, 1996).
Although the majority of states adopted the Standards (NRC, 1996) requiring periodic standardized testing of learners, the efforts of standardizing the curricula at the national level had little effect on student learning and comprehension. The Nation’s Report Card: Science 2000 (NCES, 2000) indicated that the average scores of fourth and eighth graders failed to improve between 1996 and 2000, and scores for twelfth graders fell significantly (Fratt, 2002). Studies conducted by Fuhrman and Elmore (1990), Clune (1989), and McCarthy (1990) (cited in Developmental Years, 2003), suggest that the reform efforts that were made in the teaching profession and administration were not always consistent with the lines of communication to implement effective education strategies; thus, very few changes occurred in instructional strategies. The Third International Mathematics and Science Study of 1999 characterized the U.S. mathematics and science curricula as “a mile wide and an inch deep (cited in Fratt, 2002, p.2).” The perception of the curriculum was one that was overflowing with content, and shallow in understanding.

The TIMSS Report

In the effort to assess science literacy in the United States, students have participated in both international and national assessments. The Third International Mathematics and Science Study (TIMSS), sponsored by the International Association for the Evaluation of Educational Achievement, was the largest international education study undertaken, with a half-billion learners from 41 nations participating. The TIMSS study (NCES, 2003) compared the mathematics and science achievement of students, midway through elementary school, midway through lower secondary school, and at the upper end of secondary school. The study also conducted content assessments, curriculum analyses, and teacher surveys (Cochran, 2003). Researchers’ reviews of the TIMSS study found the data collection and analysis to be significant, and they were relatively positive (Schmidt, 1996).

TIMSS offers important findings in three key areas: learner achievement, curriculum, and teaching. Comparisons of the results of the 1995 study and the 1999 study at the eighth-grade levels among the 23 nations that participated at the eighth-grade levels, evidenced no change in mathematics and science achievement of eighth-grade learners in the United States. The fourth graders of 1995 and the eighth graders of 1999 formed a cohort group. When the mathematics and science performance scores of this group were compared relative to other nations, the data indicated that the United States’ achievement scores did not improve (Westerlund & West, 2001). These compelling data are evidence that the U.S. learners are failing to learn mathematics and science (Nelson, 1999).

Although the Standards (NRC, 1996) provide guidelines for the development of science curricula, there is no national science curriculum. The TIMSS curriculum study conducted by researchers at Michigan State University concluded that it appears that U.S. mathematics and science curricula lack the coherence, focus, and rigor of the curricula used in other countries that participated in TIMSS (Shavelson, 1997). William Schmidt, coordinator of the Michigan State University-based study, A Splintered Vision, states that “The U.S. science curriculum attempts too much and is repetitive from year to year. The U.S. curriculum tends to favor breadth instead of depth” (Checkley, 2003, p.1).
The researchers found that, in terms of learner achievement, “less is more.” Instead of studying 65 topics, as indicated by one U.S. eighth-grade curriculum, it was suggested that it may be more feasible to teach fewer topics in order to provide a quality curriculum in line with the international average of participating countries.

The TIMSS study then considered the teacher as a component of learner achievement. Data were collected to determine teacher impact on student learning by surveying teachers and learners, and then videotaping eighth-grade classes in the United States, Germany, and Japan. The 1999 study found that teachers in the United States had the tendency to rely on worksheets and didactic forms of teaching focusing on skill application and how to obtain answers, instead of more inquiry-based, hands-on learning that promotes problem solving and thinking (Greene et al., 2003). TIMSS researchers found that teachers often taught lessons that lacked cohesion (Schmidt, 1996); instead, the teacher typically attempted to teach too many topics within a school year. The TIMSS data yield valuable insights for educators, parents, and the business community, showing that the quest for educational reform is necessary and should continue.

The National Assessment of Educational Progress

The National Assessment of Educational Progress (NAEP) (NCES, 2000) is the United States’ only ongoing research project of learner achievement in core subject areas. The test, administered by the National Center for Education Statistics (NCES), involved science assessment of approximately 47,000 learners in 2,100 public schools in grades 4, 8, and 12. Results from the 1996 and 2000 study are based on a representative sample of learners in the nation based on the states that participated in the study (NCES, 2000).

Between 1996 and 2000, no observed statistical differences between the average science scores of the fourth- and eighth-grade learners were noted; moreover, the average scores of the twelfth-grade learners actually declined (NCES, 2000). Results reported for each region indicated that, in the 2000 study, the average scores for fourth and eighth grades were higher in the Northeast and Central regions than they were in the Southeast and West. Among twelfth graders, the average scores were higher in the Northeast and Central regions than in the Southeast region (O’Sullivan, et al., 2003).

NAEP (NCES, 2000) results also consider the context in which science learning occurs via the data collection. Researchers caution that on the NAEP, the relationship between contextual variables and learner performances are not necessarily causal (O’Sullivan, et al., 2003). The results indicated that fourth graders whose teachers reported the learners worked in groups scored higher, on average, than those who engaged in mainly individual tasks. These results were consistent with eighth-grade findings.

The results of the TIMSS (NCES, 2003) and the NAEP (NCES, 2000) indicate that despite the series of reform efforts that have taken place in the past 20 years, learner achievement has failed to demonstrate significant improvement. Neither the TIMSS report nor the NAEP can be considered as a photograph of our educational system, but they are a sketch of the challenges that lie ahead. The data from these reports should be used to address the lack of focus and dilution of topics in the curriculum (Shavelson, 1997) and to illustrate the fact that classroom practices have to focus on the improvement of the learning process (pedagogy) to improve the classroom of the future.
No Child Left Behind

On January 8, 2002, President Bush signed the No Child Left Behind Act, laying the groundwork for sweeping changes in education at both the national and state levels. President Bush and Congress cited the NAEP (NCES, 2000) science test scores for twelfth graders, in which 82% performed below the proficient level, as an indicator of the plight of American education (U. S. Department of Education, 2002). The President called for increasing the ranks of mathematics and science teachers in classrooms by 2006, with teachers who are knowledgeable and experienced in mathematics and science.

No Child Left Behind calls for “highly qualified” teachers who have had sufficient, advanced coursework in science, thereby raising the teacher’s content knowledge level in order to teach effectively in the classroom. It requires states to develop plans with annual, measurable objectives that will ensure that all mathematics and science teachers are “highly qualified” by the end of the 2005-2006 school year (U. S. Department of Education, 2002). The Math and Science Partnership Program, that the Act institutes, establishes a collaboration between K-12 math and science educators and university faculty, with the goal of strengthening programs at both levels. It assumes that the one factor that can make the most difference in improving learner achievement is having a knowledgeable, skillful teacher in front of the classroom (National Commission on Teaching and America’s Future, 1996).

National Council for Accreditation of Teacher Education (NCATE)

“Teacher Education plays an important role in science education reform. Some reformers say that changing teacher education is the first step to dramatic change in science education. Equipping teachers to bring about science literacy for all is certainly an intellectual and practical challenge of great societal importance” (AAAS, 1998, p. 189).

NCATE is a non-profit, non-governmental organization, comprised of over 30 national professional associations that represents the education profession at large. NCATE’s mission is accountability and improvement in teacher preparation. The organization seeks to achieve its mission through establishing standards for teacher education programs, holding accredited institutions accountable for meeting standards, and encouraging unaccredited institutions to strive for professional excellence by working toward accreditation (NCATE, 2002). NCATE is recognized by the U.S. Department of Education as the professional accrediting body for colleges and universities that prepare teachers and other professional personnel for work in elementary and secondary schools.

In the 1970’s, NCATE’s accreditation standards focused on the curriculum. The purpose was to assure the quality of the types of courses offered to teacher candidates. In response to A Nation At Risk (NCEE, 1983), NCATE revised its accrediting standards to focus on the ability of higher education faculty and teacher candidates to “…articulate the knowledge base and to … apply it” (Williams, et al, 2003, p. xiv).

The influx of technology in the 1990’s provided more data collection, more analysis, and greater dissemination of student achievement information and results of teacher candidates’ performance on licensing examinations. Thus, the state of our educational system became evident to the nation. The data collected through reports such as TIMSS (NCES, 2003) and NAEP (NCES, 2000) initiated the call for teachers who were both knowledgeable of the subject matter and able to teach students. Data from several studies
were reviewed in 1992 and provided evidence that a direct correlation exists between teachers who are fully prepared and learner achievement (Darling-Hammond, 1992). Based on the findings of such research, NCATE revised its standards to become performance-based benchmarks.

NCATE, acting not only as an accrediting agency, but also as a force for reform of teacher preparation, presented a revised set of standards in 2000 that focused on candidate performance. According to NCATE, performance-based assessment answers two questions: ‘What do teachers know?’ and ‘Can they teach so that student achievement improves?’ (Williams, et al., 2003). The revised system is based upon the teacher candidate demonstrating content knowledge and applying theory to practice (Wise, 2003). According to NCATE, the most important factors in improving learner achievement are teachers’ knowledge of the content and their ability to teach it.

NCATE’s teacher candidate performance standards focus on learning outcomes. NCATE ties student performance directly to teacher effectiveness. In the endeavor to impact student learning positively, Standard 1 of the NCATE Unit Standards (NCATE, 2002) states that in order for teacher candidates’ performance to be considered as acceptable: (a) they should know the subject matter that they plan to teach as shown by their ability to explain important principles and concepts delineated in professional, state, and institutional standards, (b) they should have a broad knowledge of instructional strategies that draws upon content and pedagogical knowledge and skills from professional, state, and institutional standards, (c) they should use their professional knowledge and pedagogical knowledge and skills, delineated in the standard, to facilitate learning, and (d) they should be familiar with the dispositions expected of professionals (Appendix A).

Teacher education plays an important role in reform efforts, especially in science education. Reform efforts focused only on new curriculum without adequate teacher education appear to be “doomed,” says John Cannon and David Crowther (1997). After spending one-million dollars on a new hands-on, activity-based curriculum, a Nevada School district saw their program fail due to a lack of teacher education (Cannon and Crowther, 1997). A study conducted by Educational Testing System, How Teaching Matters (ETS, 2000), concluded that teacher preparation and development have a direct correlation with learner achievement in mathematics and science (ETS, 2000).

The results of the ETS study (NCES, 2000) support the NCATE standards (NCATE, 2002) that require candidates to be competent in their subject matter, discipline, and content-specific pedagogy (NCATE, 2002). The results indicate that learner achievement increases when teachers are skilled in their subject matter content and implement hands-on experiences in their classroom. The National Commission on Teaching and America’s Future found that a significant predictor of learner achievement is the proportion of teachers that were trained in NCATE-accredited institutions that are hired by a school system (National Commission on Teaching and America’s Future, 1996). Trumbull (1999) points out there are discrepancies between how prospective science teachers are taught in universities and how they are expected to teach science. Trumbull suggests that the solution to this dilemma is to teach the teacher candidate as they will teach, providing them with opportunities to develop both content and pedagogical knowledge (Trumbull, 1999).
Teacher Preparation and Learning

Teachers’ understanding of content, learning, and pedagogical practices is an essential element in their ability to prepare students to become successful science learners. Teacher quality is becoming increasingly important as the nation’s technological economy demands even greater skills, and states enact higher learner standards for promotion and graduation (Darling-Hammond, 1992).

Research from studies consistently suggests that teachers’ expertise accounts for significant achievement differences in student scores (Educational Testing Service, 2000; Rivkin, S., Hanushek, E., & Kain, J., 1998). Sanders and Rivers (1996) report data from a study in Tennessee indicated two equally performing second graders can be separated by as many as 50 percentile points by the time they reach fifth grade, solely as a result of being taught by teachers whose effectiveness varies greatly. In order for changes to occur in science education, school personnel must change (Bybee, 1995). Research suggests that teachers’ content knowledge and pedagogical knowledge (e.g., how to interpret science content for science learners) are significant factors in increasing student performance (Shulman, 1986).

Perceiving the preservice teacher as learner is a crucial step in understanding how they learn. “Preservice teachers bring at least 15 years of formal educational experience to their preparation for a teaching career. This extensive experience as a learner is powerful in shaping beliefs about teaching and learning, but, is also limited, because it lacks the perspective given by the teaching role and by consideration of alternative beliefs” (Northfield, Gunstone, & Erickson, 1996, p.201).

Teacher learning is analogous to student learning in that teachers actively construct knowledge about teaching based upon their experiences and prior knowledge (Dana, Campbell, & Lunetta, 1997). The construction process that occurs with learners suggests that it also occurs with teachers as they try to make meaningful understanding of the content, the teaching process, and the pedagogical content. Hewson and Hewson (1989) studied learning to teach science and suggest that prospective teachers construct conceptions of teaching science that are composed of cognitive structures that include: (a) the rationale for teaching, (b) knowledge, learning and science, (c) disciplinary knowledge, and (d) pedagogical knowledge.

Empirical studies suggest that learners hold preinstructional conceptions that are frequently in direct contrast to the science concepts taught in school. Often the instructional concepts are embedded in the learners’ understanding of the concept and these are difficult to change (Mintzes, Wandersee, & Novak 2001; Treagust, Duit, & Fraser, 1996). Preservice teachers often hold some of the same alternative conceptions (erroneous ideas) as their students (Trumbull, 1999), developing them through their informal and formal learning experiences.

Alternative conceptions, sometimes known in the literature as misconceptions, are often challenged by the learner’s academic experiences (AAAS, 1998; Kyle & Shymansky, 1989; Lorsback, Tobin, Buscol, & La Master, 1995; Perkins, 1993); thus, they hold steadfastly intact. Wandersee, Mintzes, and Novak (1994) reviewed more than 3,000 studies of pupils’ misconceptions in science. The review of these studies suggested there is a need for teachers to be well grounded in both content and pedagogical knowledge.
Most teacher education programs advocate innovative and effective methods of teaching, but do so in a traditional, teacher-centered manner. Teacher education activities that attempt to improve science education in elementary schools often reinforce the status quo rather than challenge it (Dana, Campbell, & Lunetta, 1997). Professors have the tendency to fail to use the methods they endorse; therefore, it is not surprising when preservice teachers fail to make use of the innovative practices in their own classrooms. The content knowledge and experiences of the preservice teacher influence the teaching practices employed by the novice teacher and the future successes of their students (Warkentin & Bates, 1994). Reform efforts have attempted to transform the role of the teacher from a dispenser of knowledge to facilitator of learning. This new role requires the teacher to have a deeper understanding of basic science concepts to successfully guide children’s science learning (Silverstein, 1993).

Research findings suggest that the education of preservice teachers should provide them with experiences that challenge their alternative conceptions not only of science concepts, but also of teaching and learning (Dana, Campbell, & Lunetta, 1997). The truism that “one learns best by doing” is applicable to the experiences suggested for preservice teachers. If teachers are to be responsible for sowing and reaping the harvest visualized by reform, then they have to consider themselves as knowledgeable and capable to teach for that purpose. Through active participation in educational programs that support inquiry, and interaction opportunities during learning and practice-teaching experiences, preservice teachers become empowered to facilitate change (Keys & Bryan, 2001). Liberman and Miller (1990) suggest that effective preservice development programs must not operate as a deficit model. In the deficit model, the purpose of the program is to remediate or repair the deficiencies in the preservice teacher’s knowledge and skills; instead, a more productive model is an asset, one in which preservice teachers are viewed as both learners of science and of science-related pedagogy.

Essentially, preservice teacher education programs are responsible for engaging preservice teachers in experiences in which they construct knowledge about learning and teaching science that is meaningful and connected to classroom practices, in order to sustain reform efforts in the schools. Science instruction for preservice teachers should provide them with the same types of opportunities as their future students, by learning science through an inquiry-based approach (NRC, 1996).

**Human Constructivism**

After nearly a century of thought and action, much of science teaching still fails to result in the understanding and application of science (Gallagher, 2000). Research findings show that the traditional approaches to instruction are alive and well, in spite of the fact that reform efforts calling for curricular and instructional changes have been prevalent for an extensive period of time. The classic transmissionist approach, in which content is directly transferred from teacher to learner, is still the preferred method of instruction for many teachers in the United States. This form of instruction which emphasizes memorization as learning, and the use of textbooks as curriculum (Gallagher, 2000; Weiss cited in Mestre, 2001) often results in incoherent content, inconsistencies in understanding, and a lack of depth in content.

Up to this point, the design of schooling reflected a metaphor of an industrial assembly line. The administrators were managers, the teachers were workers, and the learners were products (Ellis, 2002). The learner arrived as an empty vessel at the factory,
waiting to be “filled” by the instructor (Finkelstein, 2003) with a discourse of facts. Research findings suggest that teacher-centered lessons are a nonproductive form of instruction. Driver suggests that in science education the notion of teachers telling scientific facts or the transmitting of knowledge to learners has permeated our educational practices and conceptions despite years of scholarly reports to the contrary (Driver, 1995).

The idea that learners are passive receptors of information is in direct contrast to the constructivist approach to conceptual understanding that is advocated in science education reform efforts. The constructivist perspective of science learning recognizes that science knowledge is not something the teacher possesses and transfers to learners; rather, learners actively construct their own knowledge (Dana, et al., 1997; Glasersfeld, 1989; Vygotsky, 1978).

Constructivism represents a paradigm shift from an epistemology that focused on levels of knowledge and reinforcement to an epistemology that assumes that learners construct their own knowledge because of interaction with their environment (Dana & Davis, 1993; Gagnon & Collay, 2000). Constructivism as an epistemology is based on these tenets: (a) knowledge is constructed not transmitted; (b) prior knowledge impacts the learning process; (c) initial understanding is local; and (d) building useful knowledge structures requires effective and purposeful activity (University of Massachusetts, 2002).

The process of learning in the constructivist perspective changes from the rote memorization of large amounts of facts presented by lecture to inquiry-based opportunities where learners are engaged in constructing their own knowledge. In the constructivist classroom, learners are actively engaged in “doing.” Through exploration, multiple perspectives, and representations of concepts and content, learners are encouraged to “experience” the learning process. Learning is a process based on the learner’s growing understanding of concepts; allowing them to organize and classify information (Novak & Gowin, 1984). Knowledge construction takes place in individual contexts, through making connections between prior knowledge and new knowledge. Knowledge is reflected in the conceptual interrelatedness and interdisciplinary connections demonstrated by the learner (Murphy, 1997). Constructivists place the learner at the center of the enterprise; the idea is that the learner constructs knowledge rather than absorbs it (Brooks & Brooks, 1993).

Education has undergone major shifts in thinking about learning, knowledge, and conditions promoting the many dimensions of learning. Constructivism has been a dominant force in the paradigm shift for conceptualization of the learner and the learning process. Through the attempt to make sense of the knowledge construction process, many versions of constructivism have developed. Good, Wandersee, and St. Julien (1993), refer to these multiple versions of constructivism as the many “faces” of constructivism to emphasize the range of implied meanings of this education movement. The authors recognize 15 faces associated with constructivism. Although, constructivism cannot be adequately represented by a single universal point of view, the conception of the role of the learner and the learning process provides a central tenet among the paradigm of perspectives. Good, Wandersee, and St. Julien (1993) conclude that:

Constructivism may prove a useful and even unifying force in theorizing and practice of science education, but such a happy outcome can result only from a confrontation with the real differences that exist among
different constructivisms. Therefore, the best strategy may be to read – widely and deeply about the emerging philosophy of constructivism to reserve judgment about its potential to improve science education, and check its congruence with modern learning theory and the findings of cognitive science (pp. 84-85).

Although constructivism is a theory about learning rather than a description for teaching, strides have been made toward understanding the relationship between practice and constructivist theory. Tobin (1993), in recognizing the different perspectives that have evolved during this process, states that, “There is room for different scholars to emphasize different aspects of knowing” (p. xvi). He continues to explain that embedded within the term constructivist, is the opportunity for diversity, and differences that are likely to occur:

The evolution of constructivist thinking in different ways in different groups is anticipated because of the myriad diverse challenges, idiosyncratic situations in which scholarship is embedded, that face those who undertake research and scholarly activities in today’s complex world (Tobin, 1993, p. xvi).

Constructivism is described as consisting of two basic principles: one, that knowledge is not received passively, and two, that learners construct viable explanations from their experiences. Novak (1998) proposed a constructivist model that is based on meaning and understanding. Novak’s Human Constructivism is an effort to integrate the psychology of human learning and the epistemology of knowledge production (Mintzes & Wandersee, 1998). According to Novak (1998), it is the interplay between thought, feeling, and actions that provide the experiences in and to which new concepts are linked; it is the interplay that produces the kind of meaningful learning that is unique to humans; hence, the term human constructivism.

According to Mintzes and Wandersee (1998), “A theory of learning offers the heuristic and predictive power of a psychological model of human learning together with the analytical and explanatory potential embodied in a unique philosophical perspective on conceptual change” (p. 47). The Human Constructivist theory challenges the mode of learning that Freire (1993) refers to as a “banking” model, where the teacher fills the learner with deposits of information that the teacher deems as true, and that goes unchallenged or unacted upon by the learner. Instead, within human constructivism, the teacher acts as facilitator and negotiator of meaning, while recognizing that knowledge construction is an active process that is unique to each learner.

Biology Reform

In the past 50 years, there have been great strides in the contributions of knowledge to the field of biology. Researchers have discovered links among living things through understanding the structure of DNA, mapping the genomes of humans, worms, insects, and plants, and opening the doors to further research in areas ranging from cell functions to ecological interactions (Morse, 2003). As the fields of scientific knowledge have expanded, so have the goals of biology instruction. The American Association for the Advancement of Science (AAAS, 1998) identified the goal of biology instruction as producing learners who can be described as biologically literate. According to the Biological Sciences Curriculum Study (BCSS, 1993), a biologically-literate individual can be defined as one who is capable of making informed decisions concerning
biologically related concerns or topics as citizens, as personal and public decision-makers, and as employees in the global economic network.

That Biology Science Curriculum Study (1993) report, designed to improve biology curricula and the understanding of the characteristics of science, described the scientific knowledge, values of science, methods and processes of science inquiry, principles, and concepts in biology that are essential for developing a biologically literate individual. In the report, the BSCS established characteristics of science that are essential for understanding the nature of biological knowledge. These characteristics included: (a) biological knowledge is tentative and subject to change, (b) biological knowledge is universal and public, (c) biological knowledge is empirical, (d) biological knowledge is replicable, and (e) biological knowledge is historic. Based upon these characteristics of biological knowledge, it can be surmised that biological knowledge, in accordance with these tenets, is scientific knowledge based on verifiable data and logical reasoning.

The vast amount of biological concepts and principles are often subdivided with very little emphasis given to the interrelatedness of those principles. The BSCS organized all the key biological concepts, principles, and theories into six major principles, providing for a logical understanding of the interdependence that lies in the center of the nature of biology. The BSCS’s *Unifying Biological Principles* outlines the six major principles with an explanation of the function of each in living systems (Ameny, et. al, 1999).

How can the study of plants achieve the goal of developing a biologically literate public? The motto of the Royal Botanic Gardens, Kew, very simply responds to this question in its description of the impact of plant: “All life depends on plants.” Plants are the common biotic feature of every environment, and central to our understanding of the world (BSA, 1995).

Even with the importance of plants to our existence, research findings suggest that the study of plants has been deemphasized in classes because of a lack of interest by learners, because of botany lessons that fail to capture learners’ attention, or a lack of focus on the topic by instructors (Darley, 1990; Reinsvold, 1999). Wandersee and Schussler (2001) suggest that humans have a greater interest in animals than plants due to the natural constraints placed on visual information processing systems. Wandersee and Schussler refer to this inability to see or notice plants, even in one’s own environment as, *plant blindness*.

In its publication *Botany for the Next Millennium*, the Botanical Society of America (1995) spearheaded an integrative approach to facilitate the awareness of plants in the curriculum. A whole-plant approach to understanding plant science concepts and principles, as advocated by the Botanical Society of America (1995) encourages the learner to develop a perspective of the interrelatedness of plants as organisms (despite their differences), as well as an understanding of the effects plants have upon the environment. According to Balick and Cox (1996), the more learners are involved with plants and develop a sense of value for their importance to our environment, the more likely the prevalence of plant blindness will decrease (Wandersee & Schussler, 2001).

The whole-plant approach to understanding plant concepts is a unique instructional strategy because the focus is not only related to the learners’ interaction with new knowledge, but requires that the new knowledge be organized with one’s prior knowledge so that the whole is constantly being related to its parts. Misconceptions
about plants are common and persistent (Reinsvold, 1999). An example, cited by Reinsvold (1999), is that many learners believe that plants make their food from the soil rather than manufacture their own carbohydrates from carbon dioxide and water in photosynthesis. Through the process of confronting previously learned knowledge with new scientific knowledge, misconceptions are challenged, often allowing the learner to construct connections to create meaningful learning.

The American Society of Plant Biologists developed 12 big ideas for plant science education, *Principles of Plant Biology* (Appendix C), which are aligned with the National Science Standards (NRC, 1996) (Appendix D). These documents serve as a guide to the scientific phenomena that should be addressed in plant science at the elementary school level. Through these documents, the importance of an understanding of organisms, life cycles of organisms, and the complex interaction among all components of an ecosystem is established (NRC, 1996). If plants are used as model organisms to teach biological principles that are common to all organisms, then it will not be necessary to add more content to an already crowded curriculum (Reinsvold, 1999).

**Rationale for the Study**

The move to improve science goals and curricula has been taking place for the last 30 years. Research results such as the TIMSS (NCES, 2003) study and the NAEP (NCES, 2000) have indicated that the level of improvement in students’ understanding of science concepts has not shown significant progress. Furthermore, according to the 2003 ACT test, only 26% of the high school students taking the test reached the established benchmark score for science of 24 or better (ACT Newsroom, 2003). Students’ performance on ACT scores is considered to be an important indicator of their readiness for college biology. NSTA president, Dr. John Penick, stated that higher student achievement in science can only be obtained by providing every student with a competent teacher who has a strong background in science (NSTA, 2003). The teacher is a critical factor in the development of student performance.

The pedagogical and cognitive practices of teachers are being challenged to change and to support human constructivist methods, which advocate that students learn best when they are in an inquiry-based environment that allows them to personally construct knowledge. Despite research findings that have found teacher-centered lessons to be non-productive, lecturing continues to be the primary method of instruction in our schools. Angelo (1991) found that in most science classes, the instructor spends more than 90% of the class time lecturing and reviewing factual content. Some theorists have posited that student misconceptions continue to occur, even into adulthood, because instructors have not developed the content knowledge or pedagogical skills to stimulate students’ lifelong learning. Instead, students have resorted to memorization of facts for short-term use, without any regard to connections to other disciplines, daily life events, or future use.

Systemic change, the goal of current reform efforts, requires that dramatic changes in teaching practices take place in order to have an impact on student performance. Teachers must learn about and experiment with scientific knowledge and new pedagogical skills in order to be able to implement them in their classrooms. The Biological Science Curriculum Study (BSCS, 1993) states that a constructivist approach to learning is needed, not only for students, but for teachers as well.
Teacher development should be the focus of teacher education programs instead of teacher training. Through reflective practices, teachers can be empowered to study and implement improvements in content and pedagogical practices (Ellis, 2002).

Research Questions

1. How does a whole-plant approach to meaningful science instruction affect preservice elementary teachers’ understanding of plant science concepts and principles?

   **Subquestions:**
   
   2. What do preservice elementary teacher education students know about basic concepts and principles of plant biology, before and after a science methods class unit on teaching and learning about plants?
   
   3. How well do preservice elementary teacher education students understand the interrelatedness of plant parts with the plant’s environment (a whole-plant perspective)?
   
   4. How does the process of growing their own plant affect preservice teachers’ understanding of scientific inquiry, and of plant science concepts and principles?
   
   5. Which activities within the activity-rich plant unit being studied enhance preservice elementary teachers’ understanding of inquiry-based plant science concepts and principles the most and the least?

Definition of Terms

**Alternative conceptions**—steadfast explanatory viewpoint constructed by the learner that is not in agreement with current scientific thought.

**Botany for the Next Millennium**—framework for identifying science education goals in botanical science and their application to the community developed by the Botanical Society of America (1995).

**Conceptual change**—change of a learner’s concept from a previous understanding to a new understanding.

**Graphic**—a visual representation of information to aid in understanding; form may be graphs, charts, diagrams, pictures, tables, drawings, and maps.

**Human Constructivism**—the meaningful constructive integration of thinking, feeling, and acting that occurs in human learning and in new knowledge construction.

**Inquiry-based learning**—the question-driven activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world through multifaceted activities.

**Knowledge construction**—individual development of conceptual knowledge through interaction with the physical environment and other persons in the environment.

**Meaningful learning**—non-arbitrary, substantive relating of new ideas or verbal propositions to existing knowledge.

**Preservice elementary teacher**—a student enrolled in a university teacher education program training to become a teacher in a kindergarten through eighth-grade classroom.

**Principles of Plant Biology**—basic plant biology concepts for science education intended to help students gain a better understanding of plant biology, developed by the American Society of Plant Biologists (2001).

**Scientific literacy**—the knowledge and understanding of scientific concepts and processes, mathematics, and technology, to make sense of events that occur in daily life.
**Standards**—a publication that is based on the premise that all students deserve the opportunity to become scientifically literate. The document provides national guidelines for the science content to be learned in grades K-12, instructional approaches, professional development, and assessment of science (NRC, 1996).

**System**—a collection of parts and/or processes that interact with each other to form a unified whole.

**Whole-plant instruction**—an integrated system-based perspective for understanding all plant organs as composing an entire living organism (BSA, 1995).

**Gowin’s Vee**

Gowin’s Knowledge Vee is a visual representation of the relationships between basic epistemological elements. Trowbridge and Wandersee (1998) describe the Vee as a graphical depiction of science activity “as it moves from the events to data collection to data transformation to knowledge claims to value claims as a research project is being planned or completed” (p.112).

Gowin identifies 12 elements in the Vee, each element contributing to the development of meaning and knowledge in the research (Novak, 1998). Mintzes, Wandersee, and Novak (2000) suggest that the Vee provides the learner with important feedback that enhances student understanding and learning as demonstrated in the Knowledge Vee in Figure 1.

The center of the Vee describes the research focus question, along with any subquestions that may be answered by the research. The lower part, beneath the Vee, describes events and objects to be studied to answer the focus question. On the right side of the Vee is the methodological (“doing”) part of the research. It identifies the records and transformations that will be made and interpreted to yield a set of value and knowledge claims. The left side of the Vee is the conceptual/theoretical (“thinking”) component of the graphic. This side specifies the relevant concepts, principles, theories, philosophies, and worldview influencing the study.

<table>
<thead>
<tr>
<th>THEORETICAL/CONCEPTUAL</th>
<th>FOCUS QUESTION:</th>
<th>METHODOLOGICAL</th>
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<tr>
<td>Philosophy</td>
<td>Answers require an active interplay between the right side and left side</td>
<td>Claims: Value Knowledge Transformations Records</td>
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<td>Theories</td>
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<td>Principles/Conceptual Systems</td>
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<td>Concepts: Perceived regularities in events or objects</td>
<td>EVENTS/OBJECTS</td>
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**Figure 1. Gowin’s Vee.** Illustrates the conceptual and methodological elements that interact in the process of knowledge construction.
Gowin’s Vee is considered as a useful guide in understanding the relationship between theory and practice. The knowledge for the Vee for this research was acquired through library research, Internet research, coursework, book reviews, and interviews with colleagues. The graphic representation of this knowledge, as shown in Appendix E, provided a means for the study to be continually assessed and redirected when necessary.
LITERATURE REVIEW

The economic, social, and technical changes of the 21st century are having a dramatic impact on our perspective of work and education. The workplace is moving from an individualized, task-oriented environment to one with collaborative groups that depend upon networking and expert knowledge for success. As a result of these changes, educational institutions are required to find new pedagogies, cognitive models, and practices to cope with the challenges of an emerging society (Tan, Zhu, & Zhou, 1996).

The review of the literature for the study focuses on theoretical perspectives that support the interrelatedness of learning. These perspectives rely on a cognitive theory that calls for a paradigm shift away from the behaviorist psychologies that reduce learning to a process of acquisition of content from a text or teacher-directed instruction, a practice that is still evident in most schools today. Noticeably absent from the behaviorist approach is the process used by individuals to learn, and to determine if the learning was meaningful. This review examines the constructivist context for understanding how learners construct knowledge, the environment that supports the learner, the social nature of learning, and the role of the teacher in the learning process.

Knowledge Construction

During the Renaissance, the scientific method evolved as the perceived method of uncovering ‘the truth.’ The German philosopher, Immanuel Kant, rejected the possibility of arriving at a precise grasp of absolute knowledge. Kant’s philosophy introduced the human mind as an active originator of experience rather than a passive recipient of perception. According to Kant, knowledge is a co-evolution of understanding and sensibility, of both our faculty and our senses (Wilkerson, 1976).

Constructivism can be traced to the 18th century and the work of the Neapolitan philosopher Giambattista Vico, who held that humans can only understand clearly what they have themselves constructed. Vico’s treatise De antiquissima Italorum sapientia (On the Most Ancient Wisdom of the Italians, 1710) written as part of a criticism of Rene Descartes theory of metaphysics, provided his basic tenet of the human knower (Giambattista Vico Institute, 2003). Vico stated his principle as verum ipsum factum, that the knower can know only what the human knower has constructed (Johns Hopkins University Press, 2003). His critics countered that he could not provide a solid demonstration that what he asserted was true of the real world.

The first contemporaries to work with the ideas presented by Vico and Kant were Jean Piaget and John Dewey. Dewey, an early contributor to the constructivist epistemology, emphasized the importance of viewing the student as engaged with the environment in a process of continuous “trying” or “undergoing” through the process of reconstructing knowledge; for Dewey, education depended on action. Engaging the learner in problem-solving situations stimulates thinking rather than having content simply addressed (Bredo, 1997). Dewey stated, “the reconstruction or reorganization of experience which adds to the meaning of experience, increases the ability to direct the course of subsequent experience” (Dewey, 1997, p. 76). His philosophy suggested a greater emphasis on the scientific method and the inclusion of more pragmatic topics in the curriculum (Dana, et al., 1997).
Jean Piaget's contribution to constructivism is based on his view of the psychological development of children. Piaget's theory is rooted in the role of the learner as being one where the child is actively engaged in the learning process. Piaget viewed the learner as possessing existing mental structures that are acted upon when learning takes place, “a way of explaining how people come to know the world” (cited in Brooks & Brooks, 1993). He described the process as follows: When a new idea is presented, if it is unfamiliar to the learner, it causes a state of disequilibrium or questioning in the mind of the learner. Given preferred state of equilibrium as the motivating factor, the learner attempts to “make sense” of this new knowledge in relation to prior experiences. If learners are able to come to terms with new knowledge within the confines of existing knowledge, then they can accommodate and assimilate the new knowledge within their current knowledge structure.

Piagetian constructivism generally regards the purpose of education as educating the individual child in a manner that supports the child’s interests and needs. Critics consider the approach decontextualized in terms of learning and teaching. It is their contention that this approach eliminates the “influence of the classroom culture and the broader culture context” (Vadeboncoeur, 1997), as well as disregards power issues (Martin, 1994; Richardson, 1997; Vadeboncoeur, 1997).

Vygotsky’s social constructivism theory emphasizes education for social transformation, and reflects a theory of human development that situates the individual within a socio-cultural context (Richardson, 1997). Vygotsky’s learning theory suggests the notion that children learn concepts as they negotiate everyday concepts and adult concepts. According to Vygotsky (1978), learning is accentuated by social interaction, which allows for the development of connections between existing knowledge and new knowledge. To accomplish the goal of social transformation and reconstruction, the context of education must be deconstructed. The cultural assumptions, power relationships, and historical influences that support it must be exposed, critiqued, and when necessary, altered (Myers, 1996 cited in Abdal-Haqq, 1998).

**Situated Knowledge**

“Cognitive apprenticeships support learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge” (Brown, Collins & Duguid, 1989, p. 17). Situated knowledge, according to Brown, Collins and Duguid (1989), depends on circumstances formed within subjects, intricacies and culture, and thus it can never exist independently. Lave (1993) proposes that learning, as it normally occurs, is a function of the activity, context, and culture in which it occurs. This contrasts with most classroom learning activities, which involve knowledge that is abstract and shorn of context.

A critical element in fostering learning is to have children carry out tasks and solve problems in an environment that anticipates and mirrors how the knowledge will be used in the future. Learning content in multiple contexts provides the opportunity to learn in a dual form—knowing the content as is, and how it can be applied.
Lave (1993) suggests learning is a *legitimate peripheral participation in communities of practice*, meaning that:

(a) learning as apprenticeships is a social role—the role changes as a part of “learning;”
(b) the learner’s role as participant or co-creator—the activity will eventually become a joint effort; and
(c) the learner becomes a contributing member of the community—not just a person who is working on related tasks (Bredo, 1997, pp. 37-38).

DiSessa (1988) claims that she approves of much of “situated cognition” but is of the opinion that it misses some important insights of the past. In DiSessa’s view, situated cognition rests on three pillars: it affirms the fundamental situatedness of knowledge socio-historically; it realizes that cognition is materially situated; and it problematizes representations. DiSessa goes on to claim that frames of reference do not have to be socially represented because the individual represents them. She accepts the fact of social influences on thought; she treats reasoning as fundamentally an individual process.

Although DiSessa disputes the role of situation in learning, Lave and Wegener (1991) cite five different studies demonstrating a gradual acquisition of knowledge, and skills as novices learned from experts in the context of everyday life. Lave suggested that knowledge should be presented in authentic context, since disassociating cognition comes from its context serves to limit cognitive growth. The principal theme in situated cognition is the assertion that thinking and learning are fundamentally dependent for their proper functioning on the immediate situation of action (Brown, et al, 1989).

Resnick (1989) posits that traditional instructional theory assumes that knowledge and skill can be analyzed into component parts that function the same way no matter where they are used. This assumption is the foundation for the building-from-the-bottom approach that characterizes most current school and technical instruction. This bottom-up approach reduces the learners ability to function, according to Resnick, due to these limitations: (a) students who learn isolated facts are less likely to retain facts, and (b) skills need to be practiced in the environment in which they will be used.

The Standards (NRC, 1996) state that understanding science requires that an individual integrate types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, and ways to use the ideas to explain and predict other phenomena. Catherine Fosnot describes the constructivist learning process as, “Learning is not discovering more, but interpreting through a different scheme or structure” (cited in Brooks and Brooks, 1993, p. 5). According to the Benchmarks (AAAS, 1993), the purpose of science education is to develop a scientifically literate populace; that is, persons that have the knowledge and understanding of scientific concepts and principles required for understanding natural phenomena and making wise scientific decisions in a civic, economic, and cultural perspective.

**Knowledge Dependency**

Resnick (1989) describes knowledge-dependent learning as the process of using current knowledge to construct new knowledge. A main tenet of the constructivist model is that new knowledge must be constructed based upon prior knowledge, or as Resnick refers to it, current knowledge.
Constructivism is based upon the premise that students learn by doing rather than by observing. In the learning process, students analyze and re-analyze their understanding of a concept; thus, building a cognitive framework for new knowledge that is dependent on prior knowledge. This practice of students becoming actively engaged in the learning process by making cognitive connections between prior and new knowledge is evident in the works of Piaget.

Piaget’s description of the cognitive process, outlined in his Cognitive Development model, views knowledge construction as a convergence of new and prior knowledge. Piaget’s description of the cognitive process claims that when a new idea is presented, the learner begins the process of trying to associate the new knowledge to something in which they are familiar (Piaget, 1999, p.1). If the information is new to the learner, it causes a state of disequilibrium or raises questions in the mind of the learner. The state of equilibrium being the motivating factor, the learner attempts to “make sense” of this new knowledge in relation to prior experiences. If the learner is able to come to terms with this new knowledge within the confines of existing knowledge, she or he then accommodates and assimilates the knowledge in her or his current knowledge structure. However, a major goal of science education is to help students build meaningful relationships. Appleton (1989) suggests that if students’ disequilibrium is not addressed and teacher interventions employed, the new knowledge will have no meaning.

Lev Vygotsky (1978) stated that children learn through interaction, and curricula should be designed to emphasize interactions between learner and tasks. A second aspect of Vygotsky’s theory is the idea that children have a level of actual development (an area of work they can do alone) and a zone of proximal development (what they have the potential to do with appropriate adult assistance). Vygotsky (1978) states that what children can do with the assistance of others is “even more indicative of their mental development than what they can do alone (p. 85).” The adult assists the student by providing support at the level that is needed. The scaffolding process allows teachers to coach students to achieve their own level of understanding. The social interaction between the student, teacher, and other students reinforces the student’s knowledge acquisition.

Kroll and Black (1993) define constructivism as the acquisition of knowledge through active involvement with content, not imitation or memorization of material. The nature of learning is recursive; that is, repeated consideration of important concepts in differing contexts promotes understanding. Educators have begun to accept the idea that learning is a constructive process and that children must be taught so they are able to construct for themselves a basic knowledge of science. A key element to the construction process is to help prospective teachers change their theories of teaching to include reflections on the learning process (Black and Ammon, 1992; Duckworth, 1987; Fosnot, 1989; and Kroll and Black, 1993). Preservice teachers who are placed in learning situations that allow them to participate in a knowledge building process are more likely to become more reflective about their own personal theories of how the world works.

Resnick (1989) suggests that an awareness of the learner’s knowledge base is essential to any future knowledge acquisitions. Construction of knowledge is viewed as a self-regulatory process which learners are provided with the environment and metacognitive skills to construct and monitor their own meaning.
Human Constructivism

Substantial progress has been made in the exploration of human learning through contributions to this field by science educators. Generally, the contributions can be classified as efforts that address how students understand and misunderstand central concepts in biological and physical science and the emergence of a cognitive science (Mintzes, Wandersee, and Novak, 1998). The results of these research efforts have made substantial contributions to a view of learning known as Human Constructivism.

The origin of the Human Constructivist theory lies in the meaningful reception theory of David Ausubel. Ausubel’s theory is based upon how individuals learn large amounts of “meaningful material” in schools. Ausubel’s theory states that new material depends greatly on one’s existing cognitive structure, or what the learner already knows. (Ausubel, 1968). According to Ausubel’s meaningful learning theory, what the learner knows is the single most important factor influencing future learning.

Ausubel (1968) states that learning is based on a hierarchal process in which new material is related to relevant existing cognitive structures. A major mode of creating the subsuming bridge between existing and new knowledge is the use of an advanced organizer. The organizer can provide a visual connection between existing material and new material. Although Ausubel’s meaningful learning theory has become a major influence on the cognitive model of Human Constructivism, the curriculum delivery he advocates is often criticized for its inconsistency.

Joseph Novak, a science education researcher, realized that Ausubel’s work provided a hierarchal framework for understanding a vast spectrum of seemingly unrelated propositions and events related to one another by meaning (Ausubel, Novak, & Hanesian, 1978). Novak’s interest lies in relating Ausubel’s focus on concepts and propositional learning as the basis on which individuals construct their own meanings (Novak & Gowin, 1984).

Novak’s Human Constructivist theory integrates the psychology of human learning and the epistemology of knowledge production (Mintzes, Wandersee, and Novak, 1998). Rote learning is dependent on memorization, which means that new knowledge is not incorporated into existing knowledge. Meaningful learning requires the learner to form links between new knowledge and appropriate existing knowledge. Humans give meaning to concepts by the integration of the way they think, feel and act; all of these provide the experiences necessary to link new concepts. According to Novak (1998), it is the interplay between thinking, feeling and acting that produces meaningful learning, something that is unique to humans; hence, the term *human constructivism*.

According to the Human Constructivist theory, it is important for learners to see themselves as active participants in the learning process, not just passive recipients of knowledge. Learning occurs when the learner is actively engaged in the process. The building of a unique conceptual framework is an active process that requires consciously connecting new knowledge to existing knowledge, and testing it against one’s perception of real world objects and events and the knowledge constructed by others (Mintzes & Wandersee, 1998).
Purposeful inquiry supports the Human Constructivist model of becoming actively engaged in learning through hands-on activities. Through active engagement in activities, the learner develops understanding, which promotes higher level thinking, an important part of making connections between existing and new knowledge. Reflective exercises solidify the process by allowing learners to “think and feel” about the actions they have taken, thus seeking meaning and consciously making connections.

A significant implication of constructivism is that teachers must shift their attention away from themselves as effective presenters of scientific information toward a focus on students’ cognitive needs to learn science with understanding (Dana, Campbell, & Lunetta, 1997). In order for teachers to produce this type of environment for students, they need to provide students with more than the traditional “canned” activities. The implication for preservice elementary teachers is that this type of teaching environment requires they have more discipline-specific skills and knowledge to teach successfully.

**Meaningful Learning**

The distinction between rote and meaningful learning is the most important of Ausubel’s contributions. Meaningful learning serves as the critical driver of conceptual change. Meaningful learning refers to knowledge that is non-arbitrary, non-verbatim, well-integrated, substantive incorporation of new knowledge into long-term memory (Mintzes, Wandersee, & Novak, 1998).

The process of meaningful understanding is the result of mindful learning (Langer, 1997; Gagne, 1977). A mindful approach to learning has three characteristics: the continuous creation of new categories, openness to new information, and an implicit awareness of more than one perspective (Langer, 1997). Learners who practice mindful strategies are more likely to ask questions, seek out different perspectives, and then reflect upon this information to form their own cognitive links. The state of being mindful affects meaningful learning in that the learner makes a deliberate commitment to build links between the new knowledge and his/her existing cognitive structure. In contrast to a mindful approach, Langer describes mindlessness as being trapped by old ideas, practices and perspectives. This learner has the tendency to accept information or learn skills without understanding. A mindless learner manipulates the knowledge arbitrarily or does not attempt to make the appropriate links with existing knowledge, and thus the learner is resorting to rote learning. Unfortunately, rote learning accounts for a substantial amount of learning in many schools and in most science classrooms (Mintzes, Wandersee, & Novak, 1998).

The theory of meaningful learning acknowledges that the learner possesses prior experiences, of which sometimes they may be unaware, that are an integral part of their making sense of new knowledge. The learning environment required for meaningful learning to take place must be supportive, so that all background experiences related to the new knowledge can be brought to the foreground and challenged, so that new or better understandings can be established. Instruction is affected by the academic, social, and emotional needs of the student; lessons that are taught solely from a skills-based approach can teach less by focusing on isolated, decontextualized facts. Such instruction becomes boring and meaningless, thus losing the student’s interest to become engaged in the learning process, a necessary commitment in order for meaningful learning to take place. The role of the teacher is to establish an environment where learners have the opportunity to use their minds, and also to create and interpret text (Delpit, 1995).
Meaningful learning relies on the learner’s ability to make connections between prior and new knowledge; in other words, the learning has to occur within a culture in which the student can make those connections. Although culture may seem to have little to do with the success of the learning process, it is actually essential to the success of the students’ achievement of meaningful learning. Cultural beliefs and practices influence what students when they learn to speak, read, write, and communicate effectively.

Brown, Collins, and Duguid (1989) suggest that often the practices of school deny students the chance to engage successfully with the lesson, because the culture in which learning takes place is not relevant. If learners cannot successfully make the connections between what is taught in the classroom and their prior knowledge or experiences, they often resort to rote learning. That is, they can pass the test, but still are unable to use the domain’s conceptual tools in authentic ways.

For the science classroom, meaningful learning occurs when teachers are able to take into consideration differences in students such as gender, culture, race, ethnicity, and academic abilities when designing activities that provide for authentic practice. The promotion of meaningful learning is not only about providing the learner with the tools, but also encouraging the application of the tools as practitioners--building skills and knowledge through their own knowledge-making process.

**Conceptual Change**

Vygotsky envisioned the conceptual growth process as an intricately interwoven system by which students make sense of everyday concepts in terms of school concepts, and school concepts in terms of everyday understanding (Howe, 1996). Based upon this theory, the primary conditions for learning occurs when students are confronted with concepts that are different from those that are currently a part of their knowledge base. For example, if a student believes that photosynthesis takes place in plants, but only if the roots are surrounded by soil (assuming this is the only condition in which the student has observed plants), the moment that s/he is introduced to hydroponics, the disequilibrium posited by Piaget occurs. There is now a conceptual conflict between her/his prior knowledge and the new knowledge; the role of the teacher is to intervene and assist the student to accommodate the new concepts and promote equilibration.

According to Posner, Strike, Hewson, and Gertzog (1982), the interaction between new and existing concepts with the outcome being dependent on the nature of the interaction defines conceptual change. “In conceptual change, new ideas are not merely added to old ones; they interact with them, sometimes requiring the alteration of both ideas” (Strike & Posner, 1985, p. 215). Posner, Strike, Hewson, and Gertzog (1982) have suggested four prerequisites for conceptual change: (a) students must experience dissatisfaction with their current conceptions, (b) students must develop at least a minimal understanding of the concept, (c) the concept must be plausible, and (d) students must see the concept as useful in several different situations (pp. 211-227).

Watson and Kopnicke (1990) contradict the existing assumption that learners accommodate their thinking to fit the latest observation; instead, they suggest several barriers to conceptual change. The first of those barriers is the refusal of children to admit their theory is wrong. Children are often reluctant to admit errors and will find ways to adjust their old ideas before assimilating new ones. Language is also considered to be a barrier to conceptual change. A teacher seeking conceptual change should be cautious with vocabulary.
Students who have become comfortable with the use of terminology may have difficulty mastering new vocabulary and concepts; and may cling even more tenaciously to their old beliefs. Watson and Kopnicek suggested that more research should be conducted to study the views held by children and this has been done.

Mintzes, Wandersee, and Novak (1997) suggest that conceptual change approaches, as varied as they may be, should focus on helping students learn how to learn. The authors quote White and Gunstone, stating, “If meta-learning can be taught, then the problem of how to bring about conceptual change may be solved.” Although children come to school with preconceived ideas, if they are taught how to reason about these ideas for themselves, they may be less resistant to relinquish alternative conceptions or misconceptions after these have been challenged directly.

Alternative Conceptions

John Locke described the human mind as a blank slate, waiting to be written upon (Locke, 2003, p. 1). According to Fisher and Moody (2000), this assumption encouraged educators to believe that students receive instruction as if they were empty vessels, devoid of any prior ideas of their own. The findings of research suggest that students come to classrooms with many ideas and experiences; it is through these ideas and experiences that they attempt to make sense of the world around them. The problem arises when the student’s understandings are erroneous from the scientific point of view (Fisher & Moody, 2000).

The pre-instructional conceptions that students hold are often in direct contrast to the science concepts taught in school. Within the research community, several names have been developed to refer to such conception from “naïve ideas” to “limited or inappropriate prepositional hierarchies” (LIPHS), introduced by Helm and Novak (1983). Many investigators prefer the designation of “alternative conceptions” rather than “misconceptions,” since it is a value-neutral term and demonstrates respect for student ideas (Wandersee, Mintzes, & Novak, 1994).

Often, preinstructional concepts are embedded in learners’ understandings of a concept and are difficult to change (Mintzes, Wandersee, & Novak, 2001; Treagust, Duit, Fraser, 1996). Alternative conceptions are common across the sciences, as evidenced in many research studies. Mintzes, Wandersee, & Novak (1998) have recognized just under 3,500 studies that have addressed learner alternative conceptions.

Wandersee (1983) has illustrated numerous student alternative conceptions in a nationwide biology study conducted to investigate learner understandings of how plants make food. The study probed learners from grades 5, 8, and 11, as well as college sophomores, to determine their understanding of soil and photosynthesis. Learners at all levels displayed alternative conceptions that included “soil loses weight as the plant grows, the function of leaves is to capture rain, and plants get their food from the roots and store it in the leaves.” These ideas made sense to the learner, although they were scientifically incorrect. Glasersfeld (1989) states that learners construct their own meaning of knowledge, based upon meanings assigned to words, and the visual images attached to them.

Wandersee, Mintzes, and Novak (1994) have identified eight propositions that explain how learners develop alternative conceptions: (a) learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events, (b) the alternative conceptions that learners bring to formal science instruction cut
across age, ability, gender and cultural boundaries, (c) alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers, (d) alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture, and language as well as in teachers’ explanations and instructional materials, (e) alternative conceptions are tenacious and resistant to extinction especially by conventional strategies, (f) teachers often subscribe to the same alternative conceptions as their students, (g) learners’ prior knowledge interacts in profound ways with knowledge presented in informal instruction, resulting in a diverse set of unintended outcomes, and (h) instructional approaches that facilitate conceptual change are usually essential for replacing a resistant misconception with a scientific idea” (pp. 177-210).

Some of the meanings that students maintain were initiated in their early years but often were subsequently reinforced by the teacher and/or the textbook. It is possible for students to develop parallel but mutually inconsistent explanations of scientific concepts—one for use at school and one for use in the “real-world” (Trowbridge & Mintzes, 1985). Research findings have suggested that misconceptions can be classified as: (a) preconceived notions—popular conceptions rooted in everyday experiences, (b) nonscientific beliefs---ideas learned from other sources other than scientific education, (c) conceptual understandings—students are taught information that does not confront paradoxes and conflicts in their own preconceived notions, (d) vernacular misconceptions—arise from the use of words that mean one thing in everyday life and another in scientific content, and (e) factual misconceptions—falsities often learned at an early age and retained unchallenged into adulthood. (Dykstra, 1995, p. 1).”

The cohesive sets of concepts taught in the classroom often support alternative conceptions by requiring the student to resort to recitation or rote memorization as a means of ‘learning” facts and principles, instead of solidifying understanding. These alternative conceptions have been constructed over an extended period of time and form complex frameworks; one or two classroom activities are not going to change those ideas (Driver, 1983; Fisher & Moody, 2000b; Gunstone & Mitchell, 1998).

Lawrenz (1986), in his study of student misconceptions, surveyed a group of elementary teachers using physical science questions given to 17 year-olds as part of the National Assessment of Educational Progress studies (NCES, 2003). The results of the test revealed that 11 of the 31 questions were answered correctly by 50% or fewer of the 333 teachers surveyed. Considering current science education reform, which focuses on the content knowledge of the teacher as a means of improving student achievement, the question then becomes: What happens to the student of the teacher who does not understand elementary physical science concepts or any other area of science?

Fisher and Moody (2000b) suggest that one positive aspect of the alternative conceptions research is the attention that it has brought regarding the absolute necessity for teachers and researchers to be well-grounded in both content knowledge and pedagogical content knowledge. Dykstra (1995) further suggests that alternative conceptions can only be dismantled when teachers can identify them and then help their students in confronting them.
Cooperative Learning

The Standards (NRC, 1996) distinguishes the type of learning environment needed to promote scientific literacy by noting that learning science is an active process. Science learning is described as process where learners are acting, instead of being acted upon. Cooperative learning is an instructional strategy that engages students in the learning process through group activities and discussions (Johnson & Johnson, 1994).

The classroom that emphasizes active science learning, with a teacher that is willing to change her/his practice of “presenting information” or “covering science content” to one where students are engaged in problem solving, discussion, and interactive activities is more likely to create an environment of active learning. John Dewey advocated that children need an environment where they are free to communicate ideas within a social context (Dewey, 1997). Cooperative learning can do this.

Johnson and Johnson (1994) have conducted extensive research on cooperative learning since the early 1970s. They have identified three basic ways students interact with each other as they learn: they can compete to see who is “best;” they can work individualistically toward a goal without paying attention to other students: or they can work cooperatively, with a vested interest in each other’s learning, as well as their own (Johnson and Johnson, 1994, p.1).

Johnson and Johnson (1994) propose that competition is the predominant form of interaction that occurs among students, and it increases as they progress through school. Researchers have conducted over 375 studies comparing cooperative and competitive learning environments. Results of this research indicates that cooperative learning groups produce (a) higher student achievement, (b) increased critical thinking skills, (c) greater interest in the subject, (d) lower student attrition, and (e) higher self esteem (Brightman, 2003).

The cooperative learning model, according to Brown and Palinscar (1989), is a means to promote positive social and communication skills while providing students with an environment to engage in various cognitive processes. Sharan (cited in Brown and Palinscar, 1989) suggests that the products or learning outcomes that encourage rote learning of the content hinders the practice of higher level thinking. He concluded that, according to the research, there were significant differences in outcome measures of students who were engaged in group activities. Furthermore, the results of the TIMSS study (1999) and NAEP reports (2000) suggested that students who were engaged in hands-on-activities had the tendency to perform better than their cohorts who were exposed to more didactic forms of instruction which supports a competitive environment.

An interpersonal, competitive situation is characterized by negative goals and limits, where one student’s achievement maybe at the cost of another student’s failure. Cooperative learning promotes an environment of positive communication, where students are encouraged to develop oral language skills and other benefits from relationships that develop within groups. Johnson and Johnson (1994) suggest that cooperative learning supports students’ abilities to celebrate each other’s successes, encourage each other to succeed, and their learning to work together, regardless of ethnic background, gender, academic ability, or special needs.
Von Glassersfeld (1993) posits that when a peer leads a student to understanding, not only does the one receiving the information gain knowledge, the tutor also receives valuable feedback to “spot inconsistencies” (p. 31) in her/his own thought processes. When solutions are found, group work also “generates motivation to face a new problem” (p. 31) encouraging the learner to explore further.

Learning is a social process (Vygotsky, 1978); our learning is associated with our connections with other human beings, teachers, peers, family and even casual acquaintances. The role of the teacher is to provide an atmosphere where cooperation becomes a natural way of acting and interacting.

**Multiple Intelligences**

In 1904, Alfred Binet and a group of his colleagues was summoned by the French Minister of Public Instruction to develop an instrument that would assess children in primary grades to determine which students may be at risk for failure, so that they could receive remediation. Out of their efforts, the team developed what became known as the first intelligence test (Armstrong, 1994, p. 1). Intelligence testing became popular in the 20th century a means for measuring intelligence. This practice of administering intelligence tests was viewed as a solution to school systems’ problems of determining the academic levels of their students; it reduced intelligence to a single, “IQ” score.

Howard Gardner was one person who challenged this idea of intelligence with the publication of his book, *Frames of Mind* (Gardner, 1983), arguing that society’s view of intelligence was too narrow. Gardner proposed that there is both a biological and a cultural basis for the existence of multiple intelligences. Gardner described intelligence as “the capacity to solve problems or to fashion products that are valued in one or more cultural settings” (Gardner & Hatch, 1989 cited in Brauldi, 2003). Brain research also indicates that learning is the result of modification in the synaptic connections between cells. Learning occurs when synaptic connections between brain cells grow and existing connections are intact. The synaptic connections in the brain occur when there is a stimulus, the stimulus is sorted and processed, and, finally, a synaptic connection is formed in a level of memory.

Gardner (1983) posits that culture also plays an important role in the development of the intelligences. All societies value different types of intelligences. The cultural value that is placed on a given ability provides the motivation (stimulus) for the learner to become skilled in those areas.

Gardner proposes that each individual has at least seven intelligences. In 1997, Gardner added an eighth intelligence, with the understanding that, as research develops on how individuals learn, more intelligences may become evident. According to Gardner, each individual has a unique blend of the intelligences and rarely do they operate independently. Gardner’s descriptions of the intelligences have provided a functional perspective of the human range of capabilities (Appendix F).

Multiple Intelligence (MI) theory has strong implications for learning. It provides eight different potential pathways to teach (Armstrong, 2003). If a learner is having difficulty understanding a concept in one way, the teacher has numerous options to facilitate meaningful learning. Multiple Intelligence theory suggests that individuals possess all of the intelligences; but that each learner has, her/his own preferred learning style. The teacher who is aware of each learner’s dominant learning style may be able to provide an environment that supports the learner’s needs.
Inquiry-Based Learning

According to the Standards, teaching in an inquiry-based setting promotes understanding of science subject matter and the ability to conduct a scientific inquiry. The National Science Education Standards (NRC, 1986) suggest that inquiry helps the student to become engaged in the process of understanding the natural world.

Inquiry, a pedagogical method that combines hands-on activities with student-centered questioning, discussion, and discovery has a long history. In contemporary times, it can be traced to John Dewey. Dewey, in an address to the education section of the American Association for the Advancement of Science in 1909, argued that science teaching gave too much emphasis to the accumulation of information and not enough to science as a method of thinking and an attitude of mind. He further stated that, as taught, science was too much a subject matter of fact and law, rather than an effective method of inquiry (Bybee, 2000).

During the 1950s and 1960s, Joseph Schwab published articles on inquiry, establishing inquiry as a prominent theme in the curriculum reform of that era. Schwab warned that teachers and textbooks were presenting science in a way that was inconsistent with modern science (Bybee, 2000). Schwab suggested that teachers look to laboratories for experiences to promote student inquiry. Additionally, he advocated that students participate in research projects utilizing the techniques of inquiry used by scientists.

Haury (1993) suggests that caution must be used when interpreting reported findings that support inquiry-based instruction. He further suggests, by citing Lock (1990), that there is evidence of interactions among investigative approaches and teaching styles and that the effects of inquiry may vary by level of cognitive development as suggested in Germann (1989).

In the late 1970s and 1980s, the National Science Foundation supported a study, Project Synthesis, which reviewed the state of science education in the United States (Bybee, 2000). The results suggested that the science community was using the term “inquiry” in a variety of ways. The study found that although teachers recognized the importance of using the inquiry method in the classroom, they were also concerned about teaching students facts for science tests.

Currently, inquiry is the major topic of reform conversation. Gerald Wheeler (2000) contends that one threat to reform is the ambiguity surrounding inquiry. Wheeler posits that there are three faces to inquiry that should be addressed in the classroom. The first occurs when the students are engaged in hands-on activities. He states that “doing” does not have an impact on students unless they can make connections to what is being done and how it is being done. Uno (1990), states that doing or completing tasks does not always validate that the learner knows why they are engaged in the activity. The Benchmarks (AAAS, 1993) concur with this perspective by stating; “Hands-on experience is important but does not guarantee meaningfulness” (p.319).

Wheeler’s second face of inquiry occurs when a student interacts with materials. He suggests that inquiry implies that the materials and questioning (which often stems from curiosity) should be intertwined. It is through the questioning phase of a lesson that students are led to “Why did it happen?”
Last, Wheeler contends that in the third face of inquiry, student engagement, does not necessarily guarantee that content is being learned. The key is that, as students conduct inquiry-based activities, they stay focused on the purpose of the activity, the point of the inquiry, and what conclusions can be drawn.

Inquiry mimics everyday life in that, when the learner is exposed to multiple examples, they began to categorize these experiences and form generalizations (Fisher, 2000). Although there are different approaches to inquiry-based learning such as guided inquiry, open-ended inquiry, project-based inquiry or inquiry in collaboration with the teacher, all of these approaches’ primary purpose should be to engage the student in the learning process.

Learning occurs when the learner is actively engaged in the learning process. Purposeful inquiry, that is, inquiry that is planned with a particular goal in mind, supports learning by action and reflection. By actually doing, the learner applies concepts to life, which promotes higher order thinking. The reflection component allows the learner to “think and feel” about the actions they have taken, thus seeking meaning and making connections (Baird & White, 1996).

Inquiry-based learning, because of its interactive nature, provides the opportunity for the teacher to elicit prior knowledge in order to determine any gaps in student learning, or more importantly, any alternative conceptions. Engagement with a phenomenon, event, or simulation that illustrates the scientific principle being studied draws students into the problem and generates interest; additionally, it provides a process to anchor knowledge construction (Fisher, 2000).

Research indicates that inquiry-based lessons require teachers to also become involved in the metacognitive process, questioning their personal beliefs, perceptions, and attitudes. However, more importantly, they must examine their understanding of the teaching and learning that has taken place, and their role in the classroom activities (Baird & White, 1996). Barnes and Foley (1999) posit that to sustain ongoing inquiry at all educational levels, preservice elementary teachers should be exposed to methods courses that are designed to explore inquiry in their teaching and learning of science. Providing preservice elementary teachers with opportunities to experience inquiry-based activities in their methods classes helps them to learn that science is a dynamic process, not just a collection of information to be memorized.

**Concept Mapping**

Visual images are an important part of how humans communicate information, ideas, stories and feelings in every day life. Most learning during the early stages of child’s life takes place primarily through the ears and eyes. In recent decades, researchers have emphasized the need to understand how information is stored and processed in memory. Research suggests, that to promote meaningful learning, the use of multiple representations for the same knowledge and having students translate between representations, can help student to inter-relate knowledge (Dufresne, Leonard & Gerace, 1995).
“Visual imagery has always been a powerful element of communication. In prehistoric times, people carved images on the sides of vases and on rocks. The early Greeks drew pictures on vases to tell the stories of their myth” (Knoell, 2003, p. 3). Today, in our visually oriented world, science and technology education rely heavily on the use of images to present information (Lowe, 2000). There are various visual construction tools to help students to visualize how major ideas are connected to each other and how ideas are related to prior knowledge.

Several graphic tools were reviewed by Hamner and associates (1998). Each tool was shown to have its individual strengths and weaknesses. Moreover, the concept map developed by Novak (1998) was the one most positively reviewed. According to Kinchin (2000), concept mapping is a tool that can be used by any learner.

In the 1970s, Joseph Novak (1998) began to study the unique graphic representation termed concept mapping. This graphic technique is grounded in Ausubel’s theory of meaningful learning. In this process, the student is required to make a conscious effort to identify key concepts and relate them to her or his existing knowledge (Kinchin, 2000).

According to Novak (1998), a concept is a regularity in events or objects designated by some label. Concepts do not exist in isolation; they exist in relation to other concepts. The linking of two or more concepts by a word or words is called a proposition. Concept maps are two-dimensional graphic displays of concepts and their related propositions, as shown in Figure 2, which is a concept map of plant tissue.

![Figure 2. Concept Map. Illustrating concepts about plant tissue.](image)

The concept map is useful as both a learning tool and an assessment tool. It is a learning tool because it stimulates the process of integrating new knowledge with existing structures, as advocated by the constructivists. It is an assessment tool, as discovered by Novak (1998), in that it identifies the learner’s alternative conceptions.
The use of concept maps with preservice elementary teachers allows them to actively engage in the learning process while offering them a learning tool to use in their own classrooms. Research studies indicate that concept maps can be used to assess cognitive structures or conceptual understanding. Two of these studies (Markham et al., 1994; Wallace & Mintzes, 1990) were used to study biology concepts and found to support the claim that concept maps are vehicles for documenting and exploring conceptual change in biology.

Mintzes, Wandersee, and Novak (1997) maintain that in order to learn meaningfully, the student needs to focus on concepts, the patterns they encode, and the relationships among them. The concept map has been found to be the basic tool to help students learn how to learn and to assess their learning.

**Plant Science Concepts and Principles**

The goal of biology instruction, as identified by the American Association for the Advancement of Science (1998), is to produce biologically literate learners. Biologically literate individuals are capable of valid biological thinking as citizens, as personal and public decision makers, and as employees in the global economic network (Wandersee, Fisher, & Moody, 2000).

Plants are considered as an important area of study in biology because of their relatedness to other areas of science and their place in negotiating the understanding of the natural world. The American Society of Plant Biologists (ASPB, 2001), published the *Principles of Plant Biology* establishing the goal of plant science instruction to develop an understanding of the world and our relations to it through the knowledge of plant diversity, plants as organisms, and plants as the dominant biotic features of our environment. Another important document in establishing the plant science curriculum is *Botany for the Next Millennium* (1995), published by the Botanical Society of America (BSA). This report’s primary focus is to promote the integrative approach to the study of plants. The *Principles of Plant Biology* are aligned with the *Standards* (NRC, 1996) to assure that the content and process standards are addressed in the classroom.

In their document, *Botany for the Next Millennium*, the BSA identified the whole-plant approach as a unique conceptual strategy to understand the relatedness of plants. A whole-plant approach allows the learner to view plants as integrated systems. The BSA outlines the importance of plant studies within three areas: the evolution and diversity of life; the development of organisms, and the structure and function of ecosystems. The whole-plant approach allows the learner to explore plant diversity while studying the plant as the “dominant biotic feature of our environment” (BSA, 1995). According to the National Research Council (1996), the study of plants as a system provides a perspective of other life processes. It also provides an understanding of how to solve problems in related areas such as agriculture, health and the environment.

The amount of research that is available in the study of preservice teachers understanding of science concepts are numerous (DeJong & Brinkman, 1997; Hewson & Hewson, 1989; Lawrenz, 1986); however, there has been little research on preservice elementary teachers’ understanding of plant science concepts and principles. The gravity of this situation lies in the fact that plants are such an important part of the elementary curriculum. Therefore, it is important to produce biologically literate teachers who understand plants and use them to teach about the life sciences.
One question is: Why is there such little emphasis on the study of plants? Wandersee and Schussler (1999) conducted research to explore why people in the United States tend to be less interested in plants than in animals, and why they fail to “see” plants in their environment. They have described the condition of being unable to notice or see plants in one’s own environment as *plant blindness*.

In further explanation of the term, plant *blindness*, Wandersee and Schussler (2001, p. 3) state that the inability to see or notice the plants in one’s environment may lead to: “(a) the inability to recognize the importance of plants in the biosphere, and in human affairs; (b) the inability to appreciate the aesthetic and unique biological features of the life forms belonging to the Plant Kingdom; and (c) the misguided, anthropocentric ranking of plants as inferior to animals and thus, unworthy of human consideration.” Wandersee and Schussler (2001) suggest that the term *plant blindness* is appropriate to describe this condition because it uses linguistically familiar words. Plant is a term that is generally associated with most flowering plants (Ryman, 1994) and which is common in everyday science; blind, in metaphorical terms, refers to the absence of visual information, such as in blind spot and blind date.

Wandersee and Schussler (2001, p. 3) have proposed that persons afflicted with plant blindness may display the following symptoms: “(a) failing to see or take notice of plants in their daily life, (b) thinking plants are merely the backdrop for animal life, (c) misunderstanding what kinds of matter and energy plants require to stay alive, (d) overlooking the importance of plants in everyday life, (e) failing to distinguish between the differing time scales of plant and animal activity, (f) lacking hands-on experiences in growing, observing and identifying plants in their own environment, (g) lacking awareness of plant diversity, (h) being insensitive to the aesthetic qualities of plants and their structure, and (i) lacking awareness that plants are central to a key biogeochemical cycle—the carbon cycle.”

The condition of *plant blindness* has been attributed to the following causes: “(a) humans can only “see” what they already know; (b) plants generally offer fewer time based, spacing-based, color-based visual cues for humans; (c) plants tend to grow in close proximity, thus individual plants are not recognized; and (d) plants are typically non-threatening elements of an ecosystem, and thus incidental contact can be ignored without consequences” (Wandersee & Schussler, 2001, pp. 5-6).

Research has shown that several people can view the same event and each have different interpretation of that event. Rugg emphasizes that “all events are not equal; they differ in how they are initially encoded into memory” (Rugg, 1998, p. 215 cited in Wandersee & Schussler, 2001). According to Rugg, the two factors that affect whether or not we will remember an event depends on the degree of attention we pay to it and the meaning or importance we assign to it. Wandersee & Schussler (2001) suggest that appropriate plant experiences can enhance the equality of both conditions.

Because plants grow in close proximity, people tend to minimize the emphasis on the individual plant. Humans tend to group multiple small objects into large groups according to Zakia (1997), which is called static proximity. The process is analogous to the chunking process in which humans process information in large blocks.
A culture is more likely to reduce the prevalence of plant blindness when it places a greater emphasis on the value of plants and the majority members of the culture work directly with plants or plant products (Balick & Cox as cited in Wandersee & Schussler, 2001). Through literature such as the children’s science picture book *Lost Plant* (Schussler & Wandersee, 1999) and hands-on experiences with plants, elementary teachers not only can increase their students’ knowledge base, but also their awareness of plants—thus, reducing plant blindness.

Research Methodology

There has been a debate that has been going on for over 30 years in the social and behavioral sciences, concerning the issue of superiority of qualitative versus quantitative research methods (Guba & Lincoln, 1994; Patton, 1990; Tashakkori & Teddlie, 1998). Researchers often differ about the respective approaches largely because they differ in their views about the nature of knowledge and how knowledge is acquired.

Qualitative methods of research are derived from a naturalist/constructivist paradigm, and quantitative are derived from a positivist research paradigm (Patton, 1990). The former uses an approach that is inductive and holistic to understand human experience in context-specific settings, whereas the latter uses an experimental approach to test hypothetical-deductive generalizations. Further distinctions between qualitative and quantitative paradigms include their view of reality and the relationship of the knower to the nature of knowledge. The qualitative paradigm considers the nature of reality to be multiple and holistic. In such a research design, the researcher does not attempt to manipulate the research setting. In the naturalist environment, the purpose is to understand naturally occurring phenomena in their naturally occurring state (Patton, 1990). In contrast, the experimental research of the quantitative paradigm seeks to control the situation being studied through manipulating, changing, or holding constant external factors in order to measure the outcomes of a set of variables.

The question of which research methodology offers a better way to approach the study of social and behavioral sciences, as addressed by pragmatists, has been a futile argument. The use of both qualitative and quantitative approaches to research adds to the body of knowledge attained in a study by providing both inductive and deductive perspectives. Patton (1990) states that the method that is employed can be separated from the paradigm of which it originated. Therefore, a researcher does not have to adopt or defend a particular paradigm in order to apply its respective methodology. The question should not be of which methodology is superior, but which is appropriate for the research question being posed and the stage of the research cycle that is occurring (Patton, 1990; Tashakkori and Teddlie, 1998). Tashakkori and Teddlie further state, “Study what interests and is of value to you, study it in the different ways that you deem appropriate, and utilize the results in ways that bring about positive consequences within your value system” (p. 21, cited in Tashakkori and Teddlie, 2003).

The use of both a qualitative and quantitative approach to research is complementary in nature, and adds to the body of knowledge attained in a study by providing both inductive and deductive perspectives. Theory derived from this type of research often overlaps. From the qualitative perspective, the motivating purpose is theory building; while the quantitative intent is theory testing. Both are needed to conceptualize a research study holistically.
The continuous process of self-checking and feedback that this type of research provides, strengthens the qualitative-quantitative continuum (Gall, Borg, & Gall, 1996; Newman & Benz, 1998). In further support of the complementary nature of mixed methodology, Tashakkori and Teddlie (1998) recommend its use to answer practically any research question in the social sciences, regardless of whether that question is exploratory or confirmatory.
METHODS

Overview of Research

As past reform efforts are reviewed, it is evident that an understanding of the nature of science continues to be a major goal of science curriculum and instruction (AAAS, 1993; NRC, 1996). In becoming scientifically literate, an understanding of science as a way of knowing becomes an important prerequisite for the future development of science knowledge. Research suggests that the success in developing scientifically literate individuals depends not only on what science is taught, but on also how it is taught.

Further educational research indicates that there are effective ways to teach biology for deep understanding and lifelong learning (Morse, 2003). The teaching strategies advocated by learned societies in the sciences endorses recognizing that learners may have misconceptions about the nature of science especially those concepts related to biology, and therefore, addresses them. Biology study from a holistic perspective is viewed as the study of organisms and their total environment, including both internal and external responses, as well as their interrelationships (Hurd, 1997).

The constructivist perspective supports a deeper learning of science by advocating an emphasis on the context in which learning takes place, which is suggested as the most important aspect of determining if learning will take place. The constructivist perspective takes into account the learner’s prior experiences to provide the anchor for new learning and the altering of misconceptions. Biology reform efforts call for opportunities for the learner to interact with the science in order for connections among concepts and principles to occur.

Appleton and Kindt (1999) state that the literature about elementary science education has revealed many elementary teachers do not teach science, or when it is taught, they resort to a transmissionist approach. Science teaching becomes a series of lectures, videos, library research activities, and teacher demonstrations. In order for changes in teaching to occur, teachers must learn science content in an environment that is non-traditional, or in a pedagogical context with strong focus on misconceptions, a constructivist view of learning, and attention to gender equity (Napper & Crawford, 1990 cited in Appleton & Kindt, 1999). Through her own experiences, the preservice teacher is able to make connections between the science content and pedagogy required for effective science teaching.

Research Design

The purpose of this study was to determine the impact of an inquiry-based, whole-plant instruction intervention on preservice elementary teachers’ prior knowledge of plant science concepts and principles, as they participated in six carefully designed instructional activities that formed a unit on the topic of plants. A pilot study conducted the semester prior to this research revealed that preservice teachers indeed had misconceptions related to plant science concepts and principles; moreover, the study revealed that a whole-plant approach was a possible instructional strategy to teaching these plant science concepts and principles (Appendix X). Research questions in the study were addressed using a mixed-models design. Tashakkori and Teddlie (1998) define “mixed-model” studies as mixed method studies that combine the qualitative and quantitative approaches within different phases of the research process” (p.19).
Hurd (1993) describes the changing research in biological science as one that involves understanding the interactions, relationships, and interdependence among biological systems, as well as the physical systems in which the biological systems are found. This type of research according to Gall, Borg and Gall (1996), requires the use of both qualitative and quantitative methods. Patton (1990) states that when investigating human behaviors and attitudes, it is most fruitful to use a variety of data collection methods. Through the mixed-models design, various sources and methods of data collection are possible, and the evaluation of data can be improved, based upon strengths and weaknesses of each method.

Description of Research Site

The setting for the study was a comprehensive, regional, state-supported university in the Deep South, with a student population of approximately 7,500 undergraduate and graduate students, of which 1,400 are students in the College of Education. Located in a rural community, the university is positioned between two large metropolitan cities, with each located a distance 60 miles southeast and southwest of the university, respectively. The University is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools (SACS) and is comprised of four colleges (Colleges of Arts and Sciences, College of Business, College of Life Sciences and College of Education) plus the Culinary Institute. The University serves a seven-county region, with the majority of the communities being within 45 minutes driving time from the university. The College of Education is comprised of the departments of Teacher Education, Psychology, and Counselor Education. It offers programs in both elementary and secondary education with several certification options.

The composition of the student body reflects the communities it serves; the ethnic structure of the seven-county region, as indicated in the U.S. 2000 Census (U.S. Census Bureau, 2003) reports, along with a comparison of the University enrollment as of Fall 2002 is cited in Table 1. In the College of Education has a large population of Caucasian students which is consistent with the region and the University’s ethnic composition.

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Region Percentage of Population</th>
<th>University Percentage of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>66%</td>
<td>78%</td>
</tr>
<tr>
<td>African American</td>
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<td>16%</td>
</tr>
<tr>
<td>Hispanic</td>
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<td>Asian</td>
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<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>2.5%</td>
<td>2%</td>
</tr>
</tbody>
</table>
The College of Education does have a significant population of preservice teachers identified as non-traditional students by the University. A non-traditional student is one who may possess any of the following characteristics: non-recent high school graduate, person returning to the university after several years of absence, and/or one having a degree in another discipline.

The sample for this study was a sample of convenience; the participants were enrolled in a course sections that were assigned to the researcher, who serves as instructor for the course. This relationship enhanced the administration and the data collection of the study. The participants were members of a six-credit hour elementary education methods course that addresses the content, pedagogy, and methodology of science, mathematics, and social studies. The course is considered as a major methods course in the elementary program. This is the first course that requires the preservice elementary teacher to teach a series of micro-lessons to public school children.

**Research Participants**

The target population of interest in this study was the preservice elementary teachers who have reached professional status (third or fourth year of their undergraduate degree) in their program. The study’s preservice elementary teachers were enrolled in two sections of an elementary methods course, with one section meeting on Monday, Wednesday, and Friday and the other section meeting on Tuesday and Thursday. Participants were enrolled in the class after meeting the following criteria: having a 2.5 grade point average or better on a 4.0 scale, successfully completing a general methods course, and having completed six credit hours of college science coursework. A rigorous curriculum is prescribed for preservice elementary teachers as they seek teacher certification in this southern state. The sections were designated as the treatment and comparison groups before the first day of class, with only the number of students being enrolled revealed to the researcher.

The sample was quite homogenous in nature, consisting of 95% Caucasian female preservice elementary teachers; ethnic delineation of the participants found 38 Caucasians, 1 African American, and 1 Native American participant. The age range of the sample was 20-25 years of age, with a mean grade point average of 3.2 on a 4.0 scale. All of these preservice elementary teachers were natives to the area, having familial, social, and economic ties to the community, and having graduated from high schools within the university’s service region. Most participants expressed a desire to remain in the area after completing their program when acquiring teaching positions.

A purposive sample (Tashakkori & Teddlie, 1998) of four preservice teachers from the treatment group was selected to participate in co-construction concept map sessions. The sample represented the class by including participants at a range of achievement levels and ages. The selection criteria include current grade point average, minimum of six hours of course work completed in science, and willingness to participate in concept mapping sessions. The four preservice elementary teachers included in the sample are referred to in the study as P1, P2, P3, and P4; with the number designation ranking the participants in order of increasing grade point average.

**Data Collection**

The IRB-approved research process used a variety of data collection methods to provide a comprehensive approach for identifying and documenting changes in the
preservice elementary teachers’ conceptual understanding of plant science concepts and principles. Two class sections of an elementary methods course were used to create a treatment and comparison group to determine if the intervention influenced the participants’ understanding of the concepts and principles. The prior pilot study employed methods of data collection and activities that were successful; therefore, they were implemented into the study. Adjustments were made to the pretest and posttest to include graphics that were printed in color to assist with identification of particulars in the graphic.

Primary Units of analysis for the study were the preservice teachers who participated in the study, and the six instructional activities. The subordinate units of analysis that influenced the units of analysis were: instruction, learning habits/skills, prior knowledge, and participant artifacts. Quantitative data were obtained through an equivalent 20-question pre-and postinstruction test; whereas, qualitative data were comprised of participants’ co-constructed concept maps, participant artifacts from activities, and field notes.

Pre-and Postinstruction tests
Quantitative data provided the researcher with a numerical value of difference in the variable. In this study, a pre-and postinstruction test was administered to determine the difference in the participants’ understanding of plant science concepts and principles, before and after an instructional intervention. The pretest (Appendix G) was administered on the first session of the study and the posttest (Appendix H) on the last day of the study. Content of the tests was based upon Principles of Plant Biology (ASPB, 2001); National Science Standards (Appendix I) (NRC, 1996); and Botany for the Next Millennium (BSA, 1995). Wandersee’s 20-Q model (Appendix J) was used as a model in designing the test items. Members of this researcher’s doctoral committee established the content validity of this test.

Co-Constructed Concept Maps
Members of the focus group participated in two hour-long sessions for co-constructing concept maps. During the concept map co-construction the researcher acted as facilitator, guiding each participant in the construction of a map that demonstrated her current understanding of concepts and principles (Wandersee & Abrams, 1993). There have been several variations of the construction process including the approach by Abrams (1994), where the participant constructed maps using only those concepts and propositions that were established in an earlier interview session; Trowbridge (1995), on the other hand provided only the superordinate term, and students supplied the remaining terms; and, Griffard (1999) provided students with a list of concepts they classified as recognizable and unrecognizable. In this study, the researcher provided the preservice elementary teachers with the superordinate concept (plants) along with several key concepts, then allowed them to construct maps supplying any additional terms needed. The process of co-constructed concept maps allows the researcher to probe for deeper understandings that may not have been obvious during instruction.

The first mapping session occurred at the three-week mark of the study and the second session at the end of the study. Each session began with a discussion of the activities that were implemented prior to mapping sessions to establish a basis for beginning the mapping process. Concept maps were constructed using paper and pencil, since the participants had only been introduced to concept mapping in this class a week before the
study. Preservice teachers were in the early stages of learning how to use computer software to construct maps; therefore, a technology-based strategy of mapping was avoided to alleviate anxiety. The maps for the co-constructed sessions were redrawn by the researcher (Appendix K) to allow for clearer reproduction in this document.

Field Notes
During activities, the researcher made general observations of the preservice elementary teachers’ performances and recorded them in the field notes. Description of situations, events, and dialogues that occurred during activities were also documented. Patton (1990) describes field notes as the most important task of an observer to preserve the details of an event. Photographs of scenes taking place during interventions augmented the field notes of this study. Appendix L provides a representative sample of pictures taken during the study.

Participant Artifacts
The participant artifacts for the study included activity sheets, reflections, concept webs, and concept maps. Participant artifacts were collected during the course of the study and maintained. Activities that required the preservice elementary teachers to continue them at home were turned-in as the tasks were completed. Artifacts developed by the preservice elementary teachers can be found in Appendix M.

Protection of Human Subjects
Fraenkel and Wallen (1996) stated that the “most important ethical consideration …is the fundamental responsibility of every researcher to do all in his/her power to ensure that participants in a research study are protected from physical or psychological harm, discomfort, or danger that may arise due to research procedures” (p. 39). An application for exemption was submitted to Institutional Review Board (IRB) for oversight in the early stages of the research process and was subsequently approved, as evident in Appendix N.

The preservice elementary teachers were given a consent form (Appendix O) that outlined the purpose of the study, a verbal explanation of the purpose, correlation to the pedagogical concepts and skills to be acquired during the course, and the nature of the treatment. A questionnaire (Appendix P) was administered to each participant to establish the demographic composition of the class, as well as prior science experiences.

Data Analysis
The ultimate purpose of conducting any research study is that it may contribute to the field of study. Two research issues that contribute to the success of a study are the validity and reliability of the data collection, and the analysis to determine plausible conclusions. The use of a mixed-models approach for this research provides for multiple methods of data collection and analysis, thus contributing to the validity and reliability of the study through triangulation (Lincoln & Guba, 1985; Patton, 1990), Tashakkori & Teddlie, 1998).

The nonequivalent group design is susceptible to a posttest threat because the participants are not randomly assigned (Trochim, 2001). In this study, the participants were all preservice elementary teachers who had attained professional status in their program. Preservice elementary teachers receive a prescribed set of prerequisites to follow before registering for this course; thereby, reducing the threat of selection. The maturation threat that often occurs with post-test differences for the treatment group is addressed by the use of a comparison group similar in composition to the treatment
Mortality threat was low in this study since the participants were generally juniors and seniors in their course of study who were enrolled in a required course to complete their program of study. Introducing activities related to a common topic and using similar types of activities assured consistency of the environment during the study and reduced location threat. Moreover, during the delivery of interventions an abbreviated script (Appendix Q) was employed to assure consistency. The reliability of the study was established by a consistent structure of pre- and postinstruction tests, a single collector of data, and an outline of procedures.

The quantitative data (pre- and postinstruction tests) and qualitative data (concept maps, concept webs, reflections, and activity sheets) underwent a quantitative analysis using the Milestones in Understanding Plant Science Scale (MUPSS) (Appendix R). The scale’s six levels indicate the stages resulting from assessing the preservice elementary teachers understanding of the structure of plants from the smallest component, the seed, to the largest component, the whole plant.

Patton (1990) writes that the challenge of qualitative analysis is “to make sense of massive amounts of data, reduce the volume of information, identify significant patterns, and construct a framework for communication the essence of what the data reveal” (pp. 371-372). The significant patterns of the research were analyzed and coded for biological concepts; facilitated by applying a simple valence analysis procedure described by Tashakkori and Teddlie (1998). The researcher chose to use an “a priori” approach to establishing the coding system; in this structure, a small number of coding schemes or categories are developed to aid in search for patterns in the data, specifically in concept webs, concept maps, activity sheets, and reflections. The concepts to code were based upon the four tenets in which the researcher categorized the Biology principles to assure activities developed whole-plant understanding. They included: structure and diversity characteristics (STRUC-CHAR), biological processes (BIOL-CHAR), ecosystems (ECO-CHAR), and role of plants (ROLE-CHAR).

The co-constructed concept maps were scored according to the scoring criteria developed by Novak and Gowin (1984). Three levels of criteria are established in this analysis: (a) hierarchal organization, (b) progressive differentiation, and (c) integrative reconciliation. Hierarchal organization requires that the map has a broad concept, then inclusive concepts leading to less inclusive concepts. Hierarchy develops relationship between the concept and its subordinate concepts. Progressive differentiation refers to the process where new concepts gain meaning, as they are linked to other concepts, forming propositions. Integrative reconciliation occurs when the learner can identify the relationships between related concepts or propositions (Novak & Gowin, 1984). Results of the qualitative analysis of the co-constructed concept maps are found in Appendix S.

The quantitative data (pre- and postinstruction tests) also underwent statistical analysis using descriptive and inferential statistics. Participants’ responses on the pre- and postinstruction tests were calculated and reported comparing participant performance on the pre- and postinstruction instruments. The data were also analyzed to calculate gain scores for each participant, in both the treatment and comparison groups. Further analyses were applied to determine the magnitude of difference between the treatment and comparison groups using effect size. Tables indicating the results of the statistical analysis are provided in Appendix T.
The Whole-Plant Unit of Study

The whole-plant unit of study was comprised of six different activities. It was conducted with one section of a science methods course for preservice elementary teachers; the second section of the course was assigned as the comparison group and was instructed using didactic methods on the same science content. The study took place over a six-week period. Each activity was based upon four central tenets: structure and diversity; biological processes; ecosystems; and the role of plants. Activities were analyzed to determine if they provided for inquiry-based learning using a set of guiding questions (Appendix U) and to assure that they met the four central tenets for studying the whole plant (Appendix V).

Activity One: Interdependence of life forms. This activity began by brainstorming for foods that the preservice teachers had consumed the night before the session to establish relationships between different organisms and to establish the vital role of plants. In the next phase, the preservice teachers were introduced to the interdependence of life forms. The participants analyzed a small plot of earth to determine what types of organisms cohabited in that “one-square foot” of area. The results were provided in a pictorial graph, since this is the type of graph often used in elementary grades to introduce the skill of graphing. Preservice teachers reflected on their results and discussed them in class. Later in the semester, after the study had been concluded, the preservice teachers teamed with children from the local school system so that they could apply their new pedagogical skills using the activity they had experienced in Activity One (Appendix W).

Activity Two: Analyzing plant structures. This activity was designed to help preservice teachers understand the function of plant parts in relation to the whole plant. In the first phase, the participants examined the inside of a seed, predicting the eventual function of the parts, in terms of the mature plant. Phase two provided the preservice elementary teachers with the opportunity to examine different types of seeds using a hand lens to compare their structures. The participants were then asked to predict the effect of seed structure on seed dispersal and survival of the plant form. In the third phase, live plants were provided for the preservice teachers to examine leaves and flowers. The flowers were taken apart so all the parts could be identified, and inferences were made as to their function. During this phase, the participants also went to sites near the campus to compare the diversity of land plants and those that lived in water habitats.

Activity Three: Growth and Development. This activity was designed for participants to identify the requirements of plants for growth and development; additionally, this activity examined the phenomena of plants being affected by external signals such as light, touch, and gravity. In the first phase of the activity, the preservice elementary teachers were given several seeds enclosed in a plastic bag that contained a moistened paper towel. They were told to hang the bag upside down and observe the seed for a period of 3-4 days. Through this activity, the preservice teachers observed that gravity plays an important role in the development of plants. In the second phase, the preservice teachers planted seeds. For many this was their first experience planting. Each participant was given several growth medium pellets and a variety of seeds to choose to plant. During the next few weeks, the participants were told to observe their plants and record any changes that occurred. In the third phase, they were given seedlings to remove from pots and examine for differing root systems. In groups, the participants...
discussed the role of the roots and the importance to the whole plant. A second seedling was provided to serve as a comparison to the first plant. The preservice teachers were charged with monitoring the plants and comparing their growth.

Activity Four: Habitats. In this activity, the preservice elementary teachers were asked to examine and create a habitat. Before creating a habitat, the participants explored different habitats close to the nearby bayou and around the campus. During their explorations, they were charged to look for details of interdependency, essential factors to the plants’ survival, and smaller webs of life that contribute to the whole system. The second phase prepared the participants to explore the concepts of transpiration and photosynthesis. The researcher provided an example of a plant in a bag and probed as to how the plant is surviving and why there was moisture on the bag. After discussion in their groups and with the whole class, the participants were provided with a host of materials to create their own habitat for a seedling. In the third phase, plants were provided given to be sowed in alternative conditions (besides soil) and monitored for growth and development.

Activity Five: Plants as dominant biotic feature. The focus of this activity was to confront the issue of the awareness of plants and plant blindness. A plant was placed strategically around the building in a place that is heavily trafficked by preservice teachers. Upon entering class, they were asked if they saw anything different as they reported to class. A tally was taken of how many preservice teachers were able to recognize the presence of the “planted” plants. Data were collected and written on the board to demonstrate which plants were more visible to the participants. The discussion of plant blindness then ensued. In the second phase, the preservice teachers were given cameras and told to take pictures of plants representing concepts they had learned about the important role of plants. The results of their explorations were reported to the class.

Activity Six: Historical View. The historical impact of plants was explored in this component of the unit. The first phase provided the preservice teachers with a setting in which they conducted a simulated dig to determine the history of the area. During this phase of the activity, the participants collected small relics to further assess the area. The participants in the second phase created a mold of their replicas such as a paleontologist might do. This phase was followed with an exploration of natural forms of preservation. The role of plants was discussed, with comparison of pictures of the Glossopteris and present day ferns. Participants discussed the impact of plants on history. The official state fossil of this state is a fossil palm.

Development of the Milestones in Understanding Plant Science Scale (MUPSS)

The Milestones in Understanding Plant Science Scale (MUPSS) (Appendix R) was developed to assess preservice elementary teachers’ understanding of plant science concepts and principles as they progressed through the six activities of the whole-plant unit. The MUPSS was developed based upon the Principles of Plant Biology (ASPB, 2001), the National Science Education Standards (NRC, 1996), and Botany for the Next Millennium (BSA, 1995). The instrument was developed as a result of the pilot study. It became apparent that a means to determine the participants’ progress during the study was needed. The following discussion provides an explanation of the rationale for the level of literacy for each level of the rubric:
• **LEVEL 0—Absence of Understanding**
  This level indicates that the learner has virtually no scientific understanding of plants; the basic structures of plant (stem, leaf, root, flower) cannot be identified.

• **LEVEL 1-- Seeds**—This level illustrates the plant at its earliest stages; that the seed contains the entire structure of the plant before it is germinated. The learner at this level, like the seed, has a basic understanding of plant structures and function. The National Science Standards (NRC, 1996) state that students should understand that each plant has various structures that serve different functions in growth, survival, and reproduction.

• **LEVEL 2--Germination**—This level demonstrates the plant that is developing, taking toward the first steps toward becoming a mature whole plant. During germination, humans began to recognize the organism as a plant. The plant begins to resemble the parent, with varied potential uses. At this level, the learner understands the role of plants in food chains and identifies some uses of plants.

• **LEVEL 3--Stems and Roots**—This level recognizes that as plants develop there are characteristics that make each plant unique. It acknowledges that the stem and roots are important to the plant as transporter of nutrients it needs to survive and as an anchor. The learner who has achieved this level understands that plants have specific needs in order to grow and develop, and that there are external factors that affect plant growth and development. At this level of achievement, the learner also recognizes the diversity of plants in size, appearance, reproduction, and life span.

• **LEVEL 4--Flowers**—During the life cycle of a plant, the flower carries the essential components for its continued existence. At this level the learner recognizes the important processes that are essential to plant survival, that the processes of respiration and photosynthesis support life and its reproduction. The learner at this level recognizes the processes that sustain the life of a plant and the role each plant organ plays to support the life of the plant.

• **LEVEL 5—Whole Plant**—The whole plant is a system with parts that together contribute to the functioning of the complete organism. At this point, the learner understands that each stage of the life cycle of a plant is essential to its becoming a mature plant. The learner who has achieved this level understands the interdependency and importance of each plant part to the functioning of the whole plant. The learner at this level is also able to describe the interdependency that exists between plants, other organisms, and the environment, with plants being the dominant biotic feature.
RESULTS AND DISCUSSION

The instructional interventions comprising the whole-plant model consisted of participant investigations/activities from an inquiry-based approach. The activities allowed the preservice elementary teachers, as learners, to construct ideas about plants and their relationship with other life forms.

The campus sites of the study provided the opportunity to study diverse environments while still being in close proximity to the classroom. Although the preservice teachers did not express any regrets when working in the classroom, they seemed to experience the most pleasure when they conducted plant science activities outdoors. Examples of the diversity of the campus sites include: a pond with goldfish and other life forms, an agriculture center that grows different species of plants, and a park across from the campus situated near a slow moving body of water (bayou). The preservice teachers were able to choose from these sites (and several others on the campus) to observe different species of plants and other life forms.

Materials used to conduct activities were purposely inexpensive. Many of the items used were able to be purchased at discount stores for minimal costs or were common household items. During the beginning of the study, several participants commented that teaching science was expensive and school systems did not always have the funding to support science instruction. After working with the everyday materials in the study, the preservice elementary teachers began to realize that teaching science does not have to be expensive. In reaction to their newly found discovery, several of the preservice teachers began making a materials list for their future classrooms as activities were conducted.

The Preservice Elementary Teacher

The preservice elementary teachers were a little apprehensive at the beginning of the study responding that they had taken biology, but failed to remember very much about plants besides the basics. During the early stages of the study the participants had the tendency to seek assistance to determine if their conclusions were correct. However, as their involvement expanded so did their sense of confidence to probe and seek answers to their questions independently. The preservice teachers in the treatment group eagerly participated in activities and showed camaraderie; however, this was not evident in the traditional didactic comparison group. A contributing factor in the differences in class climate could have been that the treatment group had more informal opportunities to interact and develop relationships than the comparison group. This observation supports the claim that learners perform more effectively when they are in an environment that allows for social interaction (Huitt & Hummel, 2003; Vygotsky, 1978).

Pre- and Postinstruction Tests

The results of the pre- and postinstruction tests were analyzed to determine the differences, if any, in the preservice elementary teachers’ understanding of plant science concepts. Gain scores were calculated for each group with the following results. The treatment group indicated a mean gain of .9 points; whereas, the treatment group performance revealed a mean gain of 2.6 points. When comparing the quantitative scores of two or more groups, researchers suggest calculating the effect size. In comparing the pre-and post- mean scores of the two groups, the effect size was determined to be .53. This score is considered significant, in that most researchers consider that an effect size...
score of .50 to be an important finding of difference (Fraenkel and Wallen, 1996). The researcher therefore surmises that the whole-plant interventions had an impact on participant understanding of plant science concepts and principles.

Performance on MUPSS

Throughout the study, at the conclusion of an activity, participant artifacts were analyzed using MUPSS. Table 2 indicates the result summary of those analyses.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
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</tr>
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</tr>
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<td>5%</td>
<td>0%</td>
<td>10%</td>
<td>80%</td>
<td>5%</td>
</tr>
</tbody>
</table>

The results suggest that the treatment group demonstrated levels of improvement in understanding plant science concepts according to MUPSS. It can also be inferred that, because their growth was scaffolded, that each experience became a part of a building process as the participants developed their own knowledge structure of plant science concepts and principles. Since the comparison group were involved in a more didactic setting there were fewer artifacts to analyze their performance on the MUPSS. It can be estimated that the comparison group’s understanding did improve, but at a much smaller rate as supported by the difference in post test scores between the comparison and treatment groups.

Activity One Participant Results

The preservice teachers were skeptical about finding anything living or dead in such a small, 1 square-foot area. However, what they found as organisms considered as living were those that were large enough to see; anything that was miniscule was difficult to comprehend as a contributor to the ecosystem. Wandersee and Schussler (2001) cite Zakia (1997), stating that humans have the tendency to group multiple, close objects into bulk visual categories. This is known as static proximity. Because, as humans, we often see plants as a group of ten, hundreds, or thousands, we fail to see the uniqueness of a species and its contributions to the ecosystem. Participants who were not a part of the focus group (E1, E2, E3) reflected on the activity with the following statements:

E1: I never realized how organisms live together and rely on each other.
E2: I learned how plants and animals are relevant to each other’s survival.
E3: Organisms are dependent upon each other even in death.

Activity Two Participant Results

Before class, the researcher placed leaves, seeds, and plants in the science classroom for participants to examine. Each group of participants chose a set of materials to assist them in developing an understanding of characteristics and to eventually classify the items. The leaves were quickly organized through obvious factors such as venation and structure. However, most had difficulty with moving to simple and compound leaf
classifications. Exploring the seeds allowed the participants to examine the differences and infer as to the type of covering of the seeds and the possible purposes. The whole plant was examined to assure the identification of basic parts (organs), but also the function of these parts. Participants were able to identify the basic parts without difficulty. Participant comments on Activity Two include:

E10: I never really looked at differences in leaves.
E20: Plant identification goes beyond looking at the structure; you can also look at individual parts.
E6: I never thought of a tree as a plant.

Activity Three Participant Results

During the initial stage, the preservice teachers were comfortable with examining the roots of the plant, based upon the results of their activity sheet. Through oral responses, 60% were able to compare the types of roots successfully. When asked why fibrous roots have a less organized arrangement, there was no response. The participants brainstormed as to why some plants have this structural arrangement, until a defensible response was acquired. The next phase of planting seedlings allowed the participants to choose a plant, and then plant it to be monitored at home. While planting their seedling, the researcher observed that some of the preservice teachers were uncomfortable with the planting process (by their facial expressions and their reluctance to get involved with the activity). When asked about their reluctance, they replied it was messy to plant the seedlings. Further discussion revealed they had never manipulated a plant before and were unsure about the probability of success. One of the members of the focus group (P1) had difficulty with arranging the roots of her seedling in the cup; she then decided to cut off some of the roots. The researcher asked her how the action might in her opinion would affect her plant. Confidently she responded it did not need that many roots and there were plenty more if needed. Comments concerning Activity Three included:

E11: I never planted anything before; this is fun.
E20: My seedling is very tall. Has it grown up to its full size?
P2 (diary entry): New leaves are forming on my plant.
   The plant is rapidly growing, I think I watered it too much.
   I used bug spray to get rid of those white bugs. What happens in nature where there is no spray?

Activity Four Participant Results

Participants went on an exploration of different campus habitats and took notes of the biotic and abiotic components that supported that habitat. Upon returning to class, the participants created a habitat in a bottle. During this process, they decided what materials would support their living plant and the amount of each material to use. Each preservice teacher created her own miniature environment, and then in groups all discussed what they thought would support their plant without any further intervention from them. The terms photosynthesis, respiration, and transpiration became a dominant part of the conversation indicating the preservice teachers’ growing awareness of the importance these process have for plants, but also for other life forms. Participant comments concerning activity four included:

E18: I didn’t think you could grow a plant in the bottle until I saw the model.
E14: I am not sure my plant will survive.
E9: My bottled plant is doing well, but I am going to try it in a different environment
Activity Five Participant Results

Plants were placed strategically around the building to determine if preservice teachers would notice these plants. Data were collected and the results indicated that the plants that were most noticed were located where the participants had to pass by on their way to class such as the stairway, elevator, central lobby and near corners of hallways. The preservice teachers were unaware of plants near bulletin boards, chairs, or near hall corners.

Preservice teachers were then given the opportunity, in this activity, to act as reporters on nature. The researcher distributed Polaroid cameras to each cooperative group to take pictures of plant environments. The participants’ task was to provide evidence of differing plant habitats and relationships among organisms. The participants were surprised and excited that they had “free-rein” to take pictures. Since the group members shared the cameras, they were responsible to create a learning group of sharing and consensus, skills they will have to eventually teach to their own students. Participant responses to the activities included:

E14: The cameras made us look at the environments carefully to find habitats.
E 5: A habitat is where an organism lives. Now I know that habitats provide for the organism in some way.
E8: Pictures are great; I can see how I can use them in my class.

Activity Six Participant Results

Participants were surprised at the amount of data they could collect from what seemed like an insignificant area during the earth digs. Creating molds and casts helped participants understand the importance of learning from the past and that the inquiry and research process is very tedious. The comparison of the Glossopteris and the house fern helped them to make connections with the past and present. The participants’ reflections indicated that they were familiar with the term plate tectonics, but less than 20% made the connection between plants and the establishment of that theory. Participant comments included:

E12: I understand better the ties between the past and the future.
E5: I used to think some things were new to this time period, but that is not true.

Purposive Group Results

The members of the purposive group met individually with the researcher on two occasions. Before the concept mapping session began, there was a brief discussion activity to assess the participants’ attitude toward this approach to learning science. Each participant in the group constructed two maps: one map was completed after the three-week mark of the study and the second, at the end of the study. Appendix K shows the two maps for each member of the group. The areas that are in light blue indicate the participants’ initial connections after the superordinate concept was given. Analyzing the maps according to Novak and Gowin’s rubric (1984), the results indicate that the preservice teachers were able to make some appropriate links on the initial maps. However it is important to note even though there were some levels of hierarchy, it was not always evident throughout the maps. The group was not proficient with the concept mapping process and tended to revert to a skill they had mastered earlier which was webbing. The second maps, especially P1’s indicate more complex links were being attempted, with crosslinks and multilinks being applied.
P1 Results
In Appendix K.1, the first map for P1 indicates that she has an understanding of the basic parts of the plants was able to develop specific functions of each of the basic parts. The links that lead from flowers indicates that the participant has some ideas about fertilization, but limits the process to insects. The link between chlorophyll and leaves is important in understanding the food making process, although there is no mention of the function of this process. Map 2 (Appendix K.2) demonstrates a growth in P1’s understanding of plants and has branched to include examples of the use of plants. New concepts that are developed indicate higher levels of thinking are being developed. When asked about the crosslink, the participant said that she knew about photosynthesis, but could now see a bigger picture of its importance.

P2 Results
The first map (Appendix K.3) has two levels of hierarchy present, but it is concentrated on stems. Photosynthesis is correctly addressed as a higher level concept than the leaves in which it takes place. This preservice teacher was able to make the connection between photosynthesis as a source of life support. Map 2 (K.4) demonstrates a definite growth in understanding of plant concepts and processes. The idea of the web of life is present in the link from food. Examples are provided in the identification of plant types, indicating the participant is making connections between plants and everyday life.

P3 Results
The first concept map (Appendix K.5) indicates the participant has developed two levels of hierarchy. The leading concepts (branches, roots, stems, and flowers) are considered as an indicator of understanding the basic parts (organs) of a plant; although, branches (modified stems) are not viewed as a basic part of plants by botanists. Also, the fact there are no links leading from this concept indicates an area of uncertainty, along with leaves. Map 2 (Appendix K.6) indicates that this preservice teacher has developed a broader understanding of plants and their functions and is able to make connections with some items from everyday life.

P4 Results
The first map (K.7) represents a hierarchy that relates plants to their uses. The organization of this map focuses on the plant parts, but no connections are made with the uses (industry and food). In the second map, (K.8) the participant adds a few links that further explain the uses of plants, but also she provides several crosslinks. The basic understanding of plants that was established by the time of the first mapping session remained the same at the time of the second map. There is little evidence of growth.

According to the MUPSS, the purposive sample group is reflective of the whole class in that there was an increase in understanding of plant science concepts and principles. Appendix S provides further statistical analysis of the concept maps in terms of connections to the four tenets that organizes the plant science principles.

Research Questions
Research Question 1: How does a whole-plant approach to meaningful instruction impact preservice elementary teachers’ understandings of plant science concepts and principles?
Curiosity is typically the starting place for science learning. However, this natural curiosity is often diminished by instructional methods that do not support the natural tendencies of learning. James Ellis (2002), posits that commonly used teaching strategies perceive students as black boxes in which instructional input leads to predictable outcomes (normally performance on achievement tests) (p. 6). These types of instructional techniques result in students who appear to know basic science concepts, but are unable to make connections with the real world.

The inquiry-based activities in this study allowed the preservice teachers to interact with plants during each session. To support their curiosity, the preservice teachers were exposed to plants that were both common and uncommon to them, they participated in activities in several settings, and then followed-up with discussions and reflections. John Dewey suggested that the most effective learning is based on a three pronged-approach: doing, observing the doing, and reflecting on the observations (cited in Swain, 1998, p. 28)

As a result of their experiences during the study, the data indicate a significant impact on the preservice teachers’ understanding of plant science concepts and principles. Initial analysis of the preservice teachers’ understanding occurred during the activity sessions. The researcher observed the participants to determine if there were any questions concerning the purpose of the activity and the level of participation. During these observations as demonstrated in Appendix L, the participants were usually actively engaged in the task, but also conversed with their group members. During their small group discussions, the participants were constantly reaffirming their own learning by assisting and verifying each other’s tasks. This form of interaction may be perceived as insignificant, but the discussions became a vehicle for the preservice teachers to confront their misconceptions without feeling uncomfortable. The researcher’s field notes revealed that often the misconceptions were directly correlated to the task at hand as the participant attempted to meaningfully construct an understanding of the concept.

The MUPSS provided a means to analyze the purposive group’s co-constructed concept maps. The results of this analysis in Appendix S show that there was an increase of the preservice teacher’s understanding of plant science concepts. 75% of the members of the purposive group increased two levels on the MUPSS after the intervention had taken place.

Further analysis of the artifacts indicated that initially the preservice teachers had a broad understanding of some plant concepts, but those understandings became more specific in nature as the study progressed. The concept webs that were drawn during the study showed the connections that were being developed. This strengthening of links identified in the co-constructed concept maps, artifacts, and observations support Ausubel’s (1968) claim, that when a learner begins to recognize relationships between concepts and form propositions, it indicates integrative reconciliation is taking place.

The pre- and postinstruction test provided quantitative data of the participants’ understanding of plant concepts and principles. The posttest scores of the treatment group (Appendix T.3) indicate that over 85% of the participants showed a positive gain score, with 40% of that group was within the range of 3-5 test points. In contrast, the level of gain for the comparison group was maximum 2-point difference, with 25% of the participants in that group showing no gain. Further analysis of the tests scores revealed the effect size of .53, indicating that the whole-plant intervention had a significant impact.
on the preservice teachers’ understanding of plant science concepts and principles. The chart in Appendix T.1 and T.2 compares the pre and postinstruction test scores of the participants to further illustrate the growth in their understanding.

Considering that the tests used in the study to assess preservice teachers’ understanding of plant science concepts is fact-oriented, consideration should be given to the ability of the participants to perform on tests. Therefore, the application of various data sources provided multiple means of assessing the preservice teachers understanding of plant science concepts and principles. The analyses of these various resources support the claim that the whole plant instructional strategy does impact participant understanding of plant science concepts and principles. Based on the results of multiple data sources the dramatic differences in the levels of understanding of between the treatment and comparison groups is significant.

Research Question 2: What do preservice elementary teachers know about basic concepts and principles of plant science before and after a methods class unit on teaching and learning about plants?

For many preservice elementary teachers their memory of science and specifically biology is a series of lectures, memorized facts, and lab activities (often with little focus on content purpose). Course content is a series of “parts”—parts of a cell, parts of the body, parts of the classification system, and parts of the plant. The result is a curricula that often leaves the student with detached pieces of content, deprived of an integrated understanding of the biological sciences.

The results of the preinstruction test indicates that the participants in both the treatment and comparison groups were able to respond to questions related to plant structure with little difficulty. Table 3 illustrates the participants’ responses to questions from the preinstruction test. For example, question 3 asks the participants to respond to what are the needs of plant roots; 100% of the treatment group and 95% of the control group answered the question correctly.

The trend is the same for the other questions related to structure such as questions 8, 11, and 20. The participants in both groups had small numbers responding incorrectly. This supports the claim that most elementary teachers have a basic understanding of plant structure. However, the pretest and posttest both revealed that the preservice teachers did have difficulty with questions related to biological processes and ecosystems.

As a result of instruction the response results indicate that the questions related to the structure and role of the plant both showed marked improvement. However, those questions such as question 9 that assessed biological processes both groups displayed difficulty although the number of incorrect answers was fewer on the posttest. The areas of biological processes and ecosystems required that the preservice teacher make connections among the areas of plant science. These types of questions require not only a basic understanding of facts, but also more importantly an understanding among the biological sciences. In Botany for the Next Millennium (BSA, 1995), scientists call for an infusion of botany from a whole-plant perspective. This form of instruction allows the learner to create links between prior knowledge and new knowledge. It also allows the learner to develop an understanding of the interrelatedness of the sciences.

In the posttest results for question 6 in Table 4, which is related to the ecosystem, 10 participants in the comparison group answered incorrectly where 5 in the treatment group
answered incorrectly. Although the pretest scores for both the treatment and comparison groups were similar, 12 and 13 respectively on the pretest, the treatment groups’ posttest scores showed a marked improvement. This indicates that the activities in the study did have an impact on the students understanding of the ecosystem.

The co-constructed concept maps support the claim that preservice teachers’ basic understanding of plant structure and the role of plants was present prior to instruction; however, there is an indication that the participants’ understanding of plants was enhanced as a result of instruction. For example, Map 2 of P1 (K.2) map had a significant increase in links related to role of plants and its structure. Additionally, the treatment group was able to respond positively to a larger number of questions related to with average of 2 incorrect questions related to structure and average of 3 for questions related to role. Further evidence of the preservice teachers’ learning about plant science in the co-constructed concept maps indicates that the early maps of the focus groups had the tendency to rely on higher level terms with few links; however, the post instruction maps show the participants’ ability to make connections within a particular area, but also to make crosslinks.

Furthermore, Appendix S demonstrates the number of links according to the basic tenets for each member of the purposive group. These results indicate that structure characteristics had the highest number of links with role of the plant as the second highest.

Table 3 Preservice Elementary Teachers’ Incorrect Responses to Preinstruction Test Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Tenet</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How are plants identified?</td>
<td>BIOL</td>
<td>C 5 T 1</td>
</tr>
<tr>
<td>2. Root survival depends upon…</td>
<td>STRUC</td>
<td>C 0 T 1</td>
</tr>
<tr>
<td>3. Which of the following is true about respiration?</td>
<td>BIOL</td>
<td>C 1 T 9</td>
</tr>
<tr>
<td>4. How would you describe the function of the stigma?</td>
<td>ROLE</td>
<td>C 3 T 3</td>
</tr>
<tr>
<td>5. Water performs all of the following functions, except</td>
<td>BIOL</td>
<td>C 0 T 1</td>
</tr>
<tr>
<td>6 Plants are a dominant force in the ecosystem due to…</td>
<td>ECO</td>
<td>C 12 T 13</td>
</tr>
<tr>
<td>7. Compare the seedlings in the picture, why do they grow toward the window?</td>
<td>STRUC</td>
<td>C 7 T 5</td>
</tr>
<tr>
<td>8. Reproductive organs in some plants are</td>
<td>STRUC</td>
<td>C 3 T 4</td>
</tr>
<tr>
<td>9. What is the concept a biologist would use to explain the reason for a plant wilting?</td>
<td>BIOL</td>
<td>C 12 T 13</td>
</tr>
<tr>
<td>10. Which of the following is not essential for plants to survive?</td>
<td>BIOL</td>
<td>C 10 T 10</td>
</tr>
<tr>
<td>11. This seed is an example of a seed from a flowering plant, it is called a</td>
<td>STRUC</td>
<td>C 4 T 0</td>
</tr>
<tr>
<td>12. What is the original source of energy in a food web?</td>
<td>ECO</td>
<td>C 7 T 7</td>
</tr>
<tr>
<td>13. What is the connection between a tree that forms root nodules with soil bacteria and the soil that is enriched by the bacteria…</td>
<td>ECO</td>
<td>C 8 T 16</td>
</tr>
</tbody>
</table>
14. A chimpanzee eats several plants in the jungle, how would biologists describe how the energy that flows through the biosphere and affects the animal?  

| 15. The green layer of algae often found in ponds… | STRUC 10 11 |
| 16 Which of the following is not the role of fruits? | ROLE 5 6 |
| 17 How does the amount of sunlight affect organisms in different habitats? | BIOL 10 11 |
| 18 Limiting factors in the survival of plant species are | ECO 14 14 |
| 19 A plant is placed in a bottle Why are there droplets of water in the bottle? | BIOL 5 9 |
| 20 Plants differ in size. Which of the following is not a plant? | STRUC 2 3 |

| Table 4 Preservice Elementary Teachers’ Incorrect Responses to Postinstruction Test Questions |
|---|---|---|---|
| **Question** | **Tenet** | **Participant Responses** |
| 1. What factors does the biologist use to make an initial identification of the plant? | BIOL | 1 1 |
| 2. Plants receive nutrients through the process of… | STRUC | 0 1 |
| 3. Cellular respiration is a series of chemical reactions that break down organic materials and releases energy. If the temperature increases, we would expect… | BIOL | 1 2 |
| 4. The flower has brown structures in the center, this structure produces pollen it is the… | ROLE | 3 1 |
| 5. The main tissue involved in transporting water from roots to leaves is the… | BIOL | 1 0 |
| 6. How could the following members of the ecosystem (short grasses, rabbits, and hawks) be affected by a drastic change in the intensity of sunlight? | ECO | 10 5 |
| 7. The plant is growing toward the light it is demonstrating a plant’s response to the light source this is called | STRUC | 5 0 |
| 8. In flowering plants, the process that enables the sperm to approach the egg is…? | STRUC | 5 4 |
| 9. Which one of the following pairing of plant structures/functions does not match? | BIOL | 15 13 |
| 10. Plant survival depend on all of the following except… | BIOL | 11 4 |
| 11. At what point does the plant begin to manufacture its own food? | STRUC | 2 1 |
| 12. Climate change will have the least effect on… | ECO | 3 2 |
| 13. Monocots and dicots have which one of the following in common? | STRUC | 12 6 |
14. Plants and animals have a symbiotic (interdependent) relationship with respect to …

<table>
<thead>
<tr>
<th>Question</th>
<th>Subject</th>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. A bromeliad (flower) that grows from the side of a tree is an example of what type of relationship?</td>
<td>ECO</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>16. The oxygen that is involved in photosynthesis …</td>
<td>STRUC</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17. Photosynthesis includes all of the following processes, except</td>
<td>BIOL</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>18. Roughly two-thirds of all vascular plants are found in the tropics, which of the following is not a factor that affects the abundance of plant life in this area?</td>
<td>ECO</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>19. A plant is placed in a dark room, the stem of the plant becomes weak and the plant begins to fall to the side, the plant is measured and has not grown since its placement in the dark room. How would a biologists explain the condition of the plant?</td>
<td>BIOL</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>20 “Plants are the center of our existence.” Which of the following facts do not support this statement?</td>
<td>ROLE</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Research Question 3: How well do preservice elementary teachers understand the interrelatedness of plant parts with the plant’s environment (whole-plant perspective)?

At the beginning of the study, the preservice teachers were asked what did they eat for dinner on last evening. After listing the items from their meal, they were asked to classify the source of those items as animal or plant (Appendix M.1-M.7). As they discussed their meals among themselves, several instances occurred where there was an uncertainty as to classify the item as plant or animal. The discussions finally evolved with the preservice teachers realizing the interrelatedness of the items they had eaten last evening and the many plant types.

As the study progressed, each activity was scripted (Appendix Q) to assure consistent themes were addressed in both the treatment and comparison groups. However, the lesson presentation in the comparison group was not scaffolded to allow the preservice teachers to make connections with the concepts that were being presented. The participants were expected to make those connections on their own as in most traditional classrooms. The treatment group was placed in cooperative groups to conduct all activities. In the groups, they were provided the opportunity to interact with the materials to form links, but also with their peers to reinforce their understandings.

Lord (2001) conducted a study with biology students and found the mean scores were significantly higher with the cooperative learning group. He further claimed that the environment allowed for the team members of the groups to discuss biology and make any connections or changes in their understanding (p. 31). Patricia Morse (2003) states that learning biology concepts occurs best when the learner is asking questions, experimenting, gathering data and communicating with their peers (p. 9).

During the study, the initial artifacts had the tendency to focus narrowly on single concepts. For example, in the 1 foot-square activity, when given the assignment one participant asked if she should count the tiny organisms, at this point she did not perceive this tiny life form as a contributor to the environment. However, the opportunity to work
with plants allowed the preservice teachers to make connections within each component that they were studying. The fact that the plants were easy to handle provided a comfortable environment for the participants to explore and make connections in their understanding.

After several sessions the preservice elementary teachers began to integrate terminology into their reflections, an indicator they were beginning to form connections between the parts and the whole. The co-constructed maps (Appendix K) illustrate the very basic ideas of the purposive group on their initial maps and the second maps illustrate their growth in understanding where the participants begin to make crosslinks. An example of this type of growth is in Appendix K.4, the second map of P2 illustrates the understanding of plants playing a role in humans by providing food, shelter, and life through photosynthesis.

The participant’s understanding of the interrelatedness of plants with their environment was reinforced with the investigative activity. There the participants were able to see many different plant forms and their connections to their environment.

Research Question 4: How does the process of growing their own plant affect preservice teachers’ understanding of scientific inquiry, and of plant science concepts and principles?

For many of the participants this was their first experience “growing” a plant. Therefore, they learned through inquiry what conditions were favorable for supporting their plant. Questions raised by the participants included: Do you think you can put too much soil in the container? What happens if I place my plant in a bottle that is not clear; would that affect photosynthesis? How do plants in water habitats differ from land plants?

In the instance of planting the seed, the activity allowed the participants to trace the life cycle of a plant. For many participants this closed gaps they had in their understanding concerning the mysterious origin of plants. One participant commented that she only saw seedlings at a discount store, but never thought about most plants beginning from a seed.

The idea of conceptual learning refers to a level of understanding which is typically deeper that the results usually achieved in didactic presentation of facts and memorization. The constructivists’ perspective supports an environment that allows the student to learn science as a scientist would by interacting with the materials, reflecting the views and practicing as a scientist. For the preservice elementary teachers this meant moving from their traditional ideas of learning and teaching science to one in which the teacher is the facilitator of learning.

During the process of monitoring their plants, the participants collected data on the progress of their plant’s growth, made inferences as to why changes were occurring with their plants and finally came to conclusions as to what factors contributed to the success or demise of their plant. By maintaining a diary (Appendix M.14- M.18) it helped the participants to understand the changes that can occur in a short period of time, but also to look for patterns, a problem solving strategy, when seeking solutions. All of these phases are common to the skills that a scientist would display as she/he investigate any phenomena.

Discussing each component of the plant in isolation contributes to the tendency to memorize without understanding. However, being forced to look at the soil, water, light,
and external factors that may affect the plant helped the preservice teacher realize the interconnectedness of all parts of the plant. In the reflections (Appendix M.44-M.26) the participants discussed the significant findings of this experience as it contributed to their own learning, but also the implications it would have for them as a classroom teacher.

Some of the participants made reference to that the inquiry approach allowed them to make connections between what they had been learning in class and the application to the real world. Several participants also commented that if learning was interesting for them in this format that surely it would capture their future students’ attention.

**Research Question 5:** Which activities, if any, within the activity-rich plant studies enhance preservice elementary teachers’ understanding?

During the course of the study, the researcher observed activities that engaged the participants to think at higher levels. The activities that seemed to have the greatest impact were those that allowed the participants to study plants in their natural habitats. These settings allowed them to explore, but also generated questions for further exploration.

In rank order, the activity that seemed to have the most impact on the preservice teachers’ understanding of plant science concepts and principles, but also of the interrelatedness of plants is Activity One, the 1-foot square activity. During this activity, the participants had to look at different life forms, at different stages of the life cycle. For many of the participants it was the first time they realized that a dead organism is still an important component of the ecosystem. They were engrossed in the activity in that it took place in a place that was familiar to them (the university campus) yet they were unaware of the many life forms that were present. The impact of this activity was evident throughout the study; the researcher observed on several occasions that another organism or even activity was referenced to 1 foot-square.

The participants were so impressed with this activity, that when given a choice of science activity to participate with a K-12 class, they chose this activity as the one they wanted to implement, as evidenced in Appendix W. The substantial amount of time they were exposed to the plant environment and were able to manipulate plants provided a comfort zone for the preservice teachers, but also provided an awareness of plants. Thus, one of the goals of this study was met: to bring about an awareness of plant blindness.

Activity Five had an impact on the preservice teacher’s learning where they explored the campus for different plant forms and the habitats in which they existed and took pictures. The cameras provided the preservice teachers with a different medium to collect data, but it was also used as means to demonstrate alternative forms of assessment. Through this activity the preservice teachers were provided with a tool to verify student learning as well as to assess their learning.

Activity Two’s focus was to explore the structure of the plant. The preservice teachers were provided with different plant forms to examine. However, the most impressionable part of this activity on the participants’ understanding was the fact that they pulled weeds. During this phase of the activity the participants were told to go near the study site building and pull any weeds that they might find, compare them to the plants they were given earlier, and classify them as dicot or monocot. The preservice teachers were flabbergasted since, “weeds could not possibly be a plant.” As they pulled weeds, many
were in awe that some of the characteristics of the beautiful plants were the same as the weeds that were often ignored. Through this activity, the preservice teachers learned that any form of a plant can be used to teach plants, but they also learned that weeds were a plant.

Activity Three allowed many of the preservice teachers to actually plant a seedling and a seed; therefore, it became an all consuming tasks for some of the participants just to plant the seedling without crushing it. Many of the preservice participants commented on their reflection sheet that they felt the process helped them to make connections with all of the parts they were learning.

Activity Four allowed the preservice teachers to develop higher order thinking by creating an environment for a seedling in a bottle. The first phase of this activity the preservice teachers explored different habitats on campus, observing which types of habitats were conducive to certain types of plants. Based upon their findings they were to create a habitat for a plant in a 2-liter bottle. The activity went well in that the researcher could see that the habitats being considered for the plant choices were appropriate.

Activity Five provided the preservice teachers with the opportunity to experience the integration of science and social studies. In the preparation for the dig and the actual process of digging the preservice teachers were able to experience the tasks of a paleontologist; therefore, providing them with the opportunity to broaden their own understanding of the roles of researchers. The creating of a mold and cast made a connection with the arts, but again with history in terms of preservation. The participants seemed to enjoy the dig, but were less enthused about the mold and casts.

The findings of this research are in harmony with the Human Constructivist theory of meaningful learning. Each activity in the research probed and incorporated prior learning, on which new knowledge was developed. Through a scaffolding process during the activities, participants were able to develop the cognitive framework necessary to incorporate their new knowledge of plants, a critical process for meaningful learning.

This study also supported the findings of the NAEP (NCES, 2000) results that indicated learners perform better in an environment in which they are allowed to work in groups and interact with their peers. It further reinforces the premise that teacher learning is similar to student learning. Through this experience the preservice elementary teachers were able to observe and participate in the type of environment that is advocated in science reform.

Preservice elementary teachers were exposed to plant concepts during the study, which allowed them to expand their understanding of plants beyond identifying basic parts and functions. Through this experience the participants began to develop an understanding of the importance of plants to the essence of other life forms. As the participants understanding became more refined they were able to develop links between plants and other areas of science. As one preservice teacher stated, “Participating in the science activities has been cotyledon for the brain, an organ with the resemblance of dicot venation. (I love my new vocabulary).”
SUMMARY AND CONCLUSIONS

According to *Botany for the Next Millennium* (BSA, 1995), humans’ study of plants was spurred by human need and practical interests. Biology is also considered as the cornerstone course in most high school curriculums, a determinant of student success in college according to the NSTA (2003). Yet, students fail to meet the expectations of the curriculum or see the importance of subjects such as plants. Science reform efforts, especially in the biological sciences call for a change in the way that science teaching is conducted if there is to be a change in student performance.

In this study, many of the preservice teachers in the treatment group were apprehensive to learn in an environment that did not involve in lectures and that required extensive notetaking. In their fears about the setting, they suggested that they could not possibly learn science without the traditional instructional setting. Presenting preservice teachers with an environment in which they can successfully learn science is the first step toward the type of systemic change advocated by science education reformers.

Dana, Campbell and Lunetta (1997) posits that teacher learning is analogous to student learning in that they construct new knowledge based upon prior experiences. Factors that have delayed the changes in science instruction can be related to the fact that teachers are often tenacious in holding on to their own misconceptions, and also about the way they provide science instruction. Research, such as the TIMSS (NCES, 2003) study, establishes the effects of good instruction on student learning. For teacher preparation programs, the course is obvious. Preservice teachers have to be trained not only in pedagogical skills, but also in content knowledge and pedagogical content knowledge. But more importantly the environment in which this learning takes place has to simulate the type of environment in which the preservice teacher is expected to implement in her/his own teaching.

Instructors in teacher education programs who espouse reform-based instruction, yet continue to teach in traditional methods develop an environment where knowledge construction or pedagogical content knowledge cannot be easily developed. Preservice teachers often resort to teaching as they see their instructors or cooperating teachers teach. Although they may have been exposed to constructivist theories of learning, authentic-based assessment, and cooperative teaching strategies, they often resort to their own experiences as a resource. According to Dewey (1994), the gap between theory and practice has been the critical gap in teacher preparation that has gone unattended.

This study was an attempt to understand how a whole-plant approach to understanding plant science concepts and principles impact preservice teachers. Implementing a constructivist approach appeared to allow the participants to actively participate in the inquiry learning process. Constructivists view learning as a process where the individual actively constructs the knowledge they wish to possess. This construction means that the sense-making process is strictly completed by the learner, but this learning environment has to be established by the teacher. NAEP (NCES, 2000) results indicate that students in the K-12 setting learned best when working in groups, this study support this theory in that the participants in the treatment group interacted with their classmates, but also were able to develop more complex ideas because of the reinforcement that occurred during their interaction.
The participant’s reflections in the study indicated they were able to develop their own understanding of concepts and principles by engaging with the information through their experiences. Although both groups improved in their understanding of plant science concepts and principles, there was a significant difference between the two groups. It favored the whole-plant approach. Many of the participants were handling plants for the first time, providing them with an opportunity to reduce the fear of teaching content which they may not have been well-versed. The fact that the participants conducted all of their activities on the campus site, from examining plants, to photographing different plant forms to the pulling weeds to make comparisons, helped them to understand the importance of providing the opportunity for meaningful learning, but in can be done within the local ecology. Through this study, they experienced activities that can be implemented in their own classrooms, but were also modeled to assure understanding.

Researchers recommend that science should be taught in meaningful ways by teachers who are well-versed in their content, have an understanding of constructivism and have the ability to establish an environment of inquiry where instruction promotes and monitor student conceptual understanding.

Limitations of the Study

This research study had limited generalizability due to the small number of participants in the treatment and comparison groups. Although the classes were comparable in composition and taught by the same instructor, the fact that the classes were held at different times of the day, one at 7:30 a.m. and the other at 10:30 a.m. could have an impact on some participants.

The study is limited by assumptions built into the design of the study. These assumptions were (a) that differences in understanding can be analyzed in a mixed methods approach, (b) that the researcher’s own knowledge of plants is as scientifically correct as an instructor of preservice elementary teachers should be, (c) that conceptual change will occur, and (d) that the conceptual change will be systemic.

Additionally, the participants of this study were a majority Caucasian females which limits the results to a homogenous setting. The population of this course is similar to the composition of many teacher education programs in the United States, thus limiting the varied types of feedback that is desired in this type of research.

Implications for Future Research

The potential for using the whole-plant approach as a strategy for conceptual change requires further study at different academic levels from K-16 and in actual K-16 classrooms as well as science methods courses. The findings of this study indicate that the whole-plant instructional strategy can be an effective way to teach preservice teachers about plant science concepts and principles. The plants provide a natural vehicle for teaching not only botany concepts, but also concepts in other sciences. As the study indicates, there is a need to explore the area of teacher learning. Research has found that teachers who possess content knowledge and pedagogical knowledge have a significant impact on student learning. The study has the potential of informing science educators, elementary teachers, and preservice teachers and the science community about the types of conceptual understandings preservice teachers have about plant science principles so that further study of this area can occur. Further research should be conducted to determine the impact of this approach as instructional strategy that preservice teachers implement in their own instructional style as they begin to teach their own classes.
Further research should be conducted to determine the lack of minority representation in the teaching of science. The teachers that are in the classrooms are role models; therefore, it is important that the K-12 students are exposed to science educators that mirror their image. According to Clark (2003), minorities are underrepresented at every level of science education from elementary to the university level. As the demographics of the world change so do the needs for the classroom.

In considering the factors that have affected minority enrollment in the sciences, attitudes toward science are considered as a contributory factor. Some minority groups may possess a strong cultural value of group and community that may be in direct contrast to competitiveness that is often associated with the sciences. The implications of this study are that more research is needed to determine how to encourage women and minorities in the sciences. This study indicated that the collaborative approach to study whole-plants allowed the preservice teachers to become comfortable with the concepts being taught, but also to develop a cooperative work environment in which to learn. This may mean further study of the type of environment that the whole-plant approach provides which allows for the less competitive environment.

Lastly, the research has implications that relate to Human Constructivism based on the premise that prior knowledge is a limiting factor in the construction of new knowledge. In the instances where the preservice teachers had not constructed a sufficient knowledge base, such as for biological process and ecosystems, they had difficulty making connections to create the whole system. This college science departments need to be part of the science education reform. Additional research is needed in how to provide the preservice teacher with the skills for metacognition as well as investigative skills. On the other hand, further investigation is needed in teacher preparation programs to identify those types of preservice science education learning environments that allow for the linking of theory and practice.

The purpose of any body of research is to provide insight and to make improvements for the future. The results of this study support the reform efforts that teachers should be taught as they will be expected to teach. Therefore, it behooves researchers to continue to researching for the best environment to create highly qualified teachers.

“The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards.” Anatole France
REFERENCES


Fratt, L. (2002). Less is more: Trimming the overstuffed curriculum. District Administration, 38, 56-60.


APPENDIX A

NATIONAL COUNCIL FOR ACCREDITATION OF
TEACHER EDUCATION
(NCATE)

Standard 1: Candidates’ Knowledge, Skills and Dispositions

Candidates preparing to work in schools as teachers or other professional school personnel know and demonstrate the content, pedagogical, and professional knowledge, skills, and dispositions necessary to help all students learn. Assessments indicate that candidates meet professional, state, and institutional standards.

Content Knowledge for Teacher Candidates.

Acceptable Performance - Teacher candidates know the subject matter that they plan to teach and can explain important principles and concepts delineated in professional, state, and institutional standards.

Pedagogical Content Knowledge for Teacher Candidates.

Acceptable Performance - Teacher candidates have a broad knowledge of instructional strategies that draws upon content and pedagogical knowledge and skills delineated in professional, state, and institutional standards to help all students learn. They facilitate student learning of the subject matter through presentation of the content in clear and meaningful ways and through the integration of content knowledge.

Professional and Pedagogical Knowledge and Skills for Teacher Candidates.

Acceptable Performance - Teacher candidates can apply their professional knowledge and skills delineated in professional, state, and institutional standards to facilitate learning. They consider the school, family, and community contexts in which they work and the prior experience of student to develop meaningful learning experiences.
Acceptable Performance-Teacher candidates focus on student learning as shown in their assessment of student learning, use of assessments in instruction, and development of meaningful learning experiences for students based on their developmental levels and prior experiences (NCATE, 2002, pp.14-16).

## APPENDIX B

### UNIFYING BIOLOGICAL PRINCIPLES

<table>
<thead>
<tr>
<th>Principle</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Evolution: Patterns and products of change</td>
<td>Living systems change through time.</td>
</tr>
<tr>
<td>2. Interaction and Interdependence</td>
<td>Living systems interact with their environment and are interdependent with other systems.</td>
</tr>
<tr>
<td>3. Continuity (reproduction and inheritance)</td>
<td>Through reproduction living systems are liked to other generations by genetic information passed onto the next generation.</td>
</tr>
<tr>
<td>4. Development: Growth and Differentiation</td>
<td>Living system grows, develops, and distinguishes itself by the changes that occurs during its lifetime based upon a genetic arrangement.</td>
</tr>
<tr>
<td>5. Energy, matter, and organization</td>
<td>Matter and energy are required by living systems in order to maintain a highly organized and complex organization.</td>
</tr>
<tr>
<td>6. Maintenance of dynamic equilibrium</td>
<td>Through various regulatory mechanisms and behavior living systems maintain a relatively stable internal environment.</td>
</tr>
</tbody>
</table>

APPENDIX C

PRINCIPLES OF PLANT BIOLOGY

developed by the American Society of Plant Biologists
http://www.aspp.org/education/foundation/principles.efm

The following principles were developed to provide basic plant biology concepts for science education in grades K-12 and to assist students gain an understanding of plant biology.

1. Plants contain the same biological processes and biochemistry as microbes and animals. However, plants are unique in that they have the ability to use energy from sunlight along with other chemical elements for growth. This process of photosynthesis provides the world’s supply of food and energy.

2. Plants require certain inorganic elements for growth and play an essential role in the circulation of these nutrients within the biosphere.

3. Land plants evolved from ocean-dwelling, algal-like ancestors, and plants have played a role in the evolution of life, including the addition of oxygen and ozone to the atmosphere.

4. Reproduction in flowering plants take place sexually, resulting in the production of a seed. Reproduction can also occur via asexual propagation.

5. Plants, like animals and many microbes, respire and utilize energy to grow and reproduce.

6. Cell walls provide structural support for the plant and also provide fibers and building materials for humans, insects, birds, and many other organisms.

7. Plants exhibit diversity in size and shape ranging from single cells to gigantic trees.

8. Plants are a primary source of fiber, medicines, and countless other important products in everyday use.

9. Plants, like animals, are subject to injury and death due to infectious diseases caused by microorganisms. Plants have unique ways to defend themselves against pests and diseases.
10. Water is the major molecule present in plant cells and organs. In addition to an essential role in plant structure, development and growth, water can be important for the internal circulation of organic molecules and salts.

11. Plant growth and development is under the control of hormones and can be affected by external signals such as light, gravity, touch, or environmental stresses.

12. Plants live and adapt to a wide variety of environments. Plants provide diverse habitats for birds, beneficial insects, and other wildlife in ecosystems.

# APPENDIX D

**NATIONAL SCIENCE EDUCATION STANDARD**

Life Science Content Standard C

<table>
<thead>
<tr>
<th>Grades K-4</th>
<th>Grades 5-8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics of Plant Organisms:</strong></td>
<td><strong>Structure and Function in Living Systems</strong></td>
</tr>
<tr>
<td>• Organisms have basic needs. Plants require air, water, nutrients, and light. They can survive only in environments in which their basic needs are met.</td>
<td>• Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization and function begin with the smallest level--the cell to whole organisms.</td>
</tr>
<tr>
<td>• Each plant has different structures that serve different functions in growth, survival, and reproduction.</td>
<td></td>
</tr>
<tr>
<td>• The behavior of a plant is influenced by internal cues (such hormonal changes which influences growth) and external cues (such as light, gravity and temperature).</td>
<td></td>
</tr>
<tr>
<td><strong>Life Cycles of Organisms</strong></td>
<td><strong>Reproduction and Heredity</strong></td>
</tr>
<tr>
<td>• Plants have life cycles that begin with germination, seedlings, and developing into mature plants, reproduce and eventually die.</td>
<td>• Reproduction is a characteristic of all living systems. Plants may reproduce either sexually or asexually.</td>
</tr>
<tr>
<td>• Plants closely resemble the parent plant.</td>
<td>• The egg and sperm are produced in the flower of sexually reproducing plants.</td>
</tr>
<tr>
<td>• Many characteristics of plants are inherited from the parent plant, but other characteristics result from interaction with the environment.</td>
<td>• The characteristics of an organism can be described in terms of a combination of traits (leaf venation, flower petals, types of seeds).</td>
</tr>
<tr>
<td>Organisms and Their Environments</td>
<td>Regulation and Behavior</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>• All animals depend on plants for food.</td>
<td>• All plants must be able to obtain and use resource, grow, reproduce, and maintain stable internal conditions while living in a changing environment.</td>
</tr>
<tr>
<td>• A plants’ pattern of behavior is related to its environment. When the environment changes some plants survive and reproduce, and other die.</td>
<td>• Plants respond to internal or external stimulus. A behavioral response requires coordination and communication at many levels, including cells, systems and whole plant.</td>
</tr>
<tr>
<td>• Plants cause changes in the environment in which they exist.</td>
<td>• An organism’s behavior evolves through adaptation to its environment.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Populations and Ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Populations of organisms can be categorized by the function they serve in an ecosystem. Plants and some microorganisms are producers—they make their own food. Food webs identify relationships between producers and consumers.</td>
</tr>
<tr>
<td>• For ecosystems, the major source of energy is sunlight.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diversity and Adaptations of Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Millions of species of animals, plants and microorganisms are alive today. The unity among organisms is apparent from analysis of their structure, similarity of their chemical processes, and the evidence to their ancestry.</td>
</tr>
</tbody>
</table>

APPENDIX E

GOWIN’S VEE DIAGRAM OF RESEARCH

World Views
AUSUBEL (1968) - Knowledge is constructed within the context of prior knowledge.
VYGOTSKY (1934) - Knowledge construction is social.
NOVAK (1964) - Language development is the largest achievement of cognitive development.

Motto of the ROYAL BOTANIC GARDENS - KEW - “All life depends on plants.”

Theories
- Concept mapping as a metacognitive tool (Novak & Gowin)
- Human Constructivism (Ausubel-Novak-Gowin)
- Botany for the Next Millennium - Vision for plant education and the field of botany (Botanical Society of America)
- Mapping as a tool for knowledge construction and supporting meaningful learning. (Fisher, Wandersee, Moody)
- Inquiry and the National Science Education Standards - Inquiry to do science, learn about the nature of science, and learn science content (National Academy of Sciences)
- Mindful learning (Ellen Langer)
- Principles of Plant Biology (American Society of Plant Biologists)

Concepts
- biosphere
- habitats
- concept maps
- systems
- diversity
- plants
- ecology
- ecosystem
- human constructivism
- inquiry learning
- meaningful learning
- mindful learning
- multidisciplinary
- plant kingdom
- whole-plant

The growth in knowledge of preservice teachers

Research Question
How does a whole-plant approach to meaningful science instruction impact preservice teachers’ prior knowledge of plants?

Sub-questions
1. What do preservice elementary teachers know about basic concepts and principles of plant biology before and after a methods class unit on teaching and learning plants?
2. How well do preservice elementary teachers understand the interrelatedness of plant parts with the plant’s environment (whole-plant perspective)?
3. How does the process of growing their own plant affect preservice elementary teachers’ understanding of scientific inquiry, and of plants science concepts and principles?
4. Which activities within the activity-rich plant unit being studied affect preservice elementary teacher’s understanding?

Objects and Events
1. Preservice elementary teacher participants from Education methods classes are identified to take part in the study.
2. Preservice teacher participants consider and write responses to items on a pre-instructional survey.
3. Preservice elementary teacher participants engage in a series of inquiry-based, whole-plant instructional activities while learning science pedagogical skills.
4. Selected participants and the researcher periodically co-construct and validate a series of concept maps within a focus group setting as the unit unfolds.
5. The researcher records field notes, takes classroom photographs, and collect participants’ artifacts.
6. Preservice elementary teacher participants consider and respond to items on a post-instructional survey.

Value Claims
- Studying the preservice elementary teacher’s understanding of the whole plant, provides teacher educators with the opportunity to improve science methods instruction.
- A whole-plant approach to plant science instruction improves cross-curricular integration.
- Preservice elementary teachers who experience the whole-plant approach come to view themselves as understanding and applying the whole-plant approach in their class.
- Periodic classroom photographs can help the researcher monitor and assess time on task, unobtrusively, validly, and reliably.

Knowledge Claims
- Whole-plant approach leads to increased meaningful understanding of plants.
- The whole-plant approach allows preservice elementary teachers to view themselves as teachers of science.
- The whole-plant approach, through inquiry-based experiences, effectively promotes preservice teachers to plant for inquiry-based lessons and model inquiry-based learning.

Transformations
- Content analysis of the series of concept maps constructed by focus group.
- Calculation of effect size for differences between pre-and post-instructional survey scores.
- Content analysis or researcher’s field notes.
- Content analysis of photographic images.
- Triangulation of sources’ data

Records
- Researcher’s field notes and classroom photographs
- All participants classroom performance products
- All participant’s pre-and post-instructional surveys
- Focus groups’ co-constructed concept maps
## APPENDIX F

### HOWARD GARDNER’S MULTIPLE INTELLIGENCES

<table>
<thead>
<tr>
<th>Intelligence</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistic</td>
<td>Sensitivity to sounds, structure, meanings, and functions of words and languages</td>
</tr>
<tr>
<td>Logical-mathematical</td>
<td>Sensitivity to, and capacity to discern, logical or numerical patterns; ability to handle long chains of reasoning</td>
</tr>
<tr>
<td>Spatial</td>
<td>Capacity to perceive the visual-spatial world accurately and to perform transformations on one’s initial perceptions</td>
</tr>
<tr>
<td>Bodily-Kinesthetic</td>
<td>Ability to control one’s body movements and to handle objects skillfully</td>
</tr>
<tr>
<td>Musical</td>
<td>Ability to produce and appreciate rhythm, pitch, and timbre; appreciation of the forms of musical expressiveness</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>Capacity to discern and respond appropriately to the moods, temperaments, motivations, and desires of other people</td>
</tr>
<tr>
<td>Intrapersonal</td>
<td>Access to one’s own feeling life and the ability to discriminate among one’s emotions; knowledge of one’s own weaknesses and strengths</td>
</tr>
<tr>
<td>Naturalist</td>
<td>Allows people to distinguish among, classify, and use features of the environment</td>
</tr>
</tbody>
</table>

APPENDIX G

PRE-INSTRUCTIONAL TEST

CODE: ____________

Directions: Circle the letter of the term or phrase that completes the statement or answers the question.

1. More than 500,000 different species of plants have been identified and named. The plants are identified by
   A. developmental adaptations       B. reproductive processes
   C. structural development         D. biomes in which they are found

2. Roots are vital to a plant, the survival of a plant’s roots depend upon
   A. sugar manufactured in leaves   B. water from leaves
   C. deposition of soils            D. natural defense system

3. Which of the following statements is not true about respiration?
   A. respiration produces carbon dioxide and water
   B. uses food for plant energy
   C. respirations occurs only in sunlight
   D. ATP is produced

4. The flower has a bright yellow organ located in the center. This plant structure is called a stigma, on what basis would you describe its function?
   A. It may be used to attract insects because of the color.
   B. Due to the small open tip it creates pollen and drop it.
   C. The pronged edge would make it likely to receive pollen.
   D. Because of the length it receives sperm cells.

5. Water performs all of the following vital functions in plants, except
   A. act as a chemical reactant
   B. provide support to leaves and new tissue
   C. buffer temperature changes
   D. attract insects

6. Plants play an important role in the support of all living matter, they are a dominant force in our ecosystem partially due to
   A. transforming light energy from the sun into chemical energy
   B. producing oxygen
   C. conducting a process called carbon fixation
   D. producing glucose
7. Comparing the seedlings in the picture, some plants are growing toward the window, the plant behavior is called
   A. gravitropism  B. photoperiodism
   C. phototropism  D. phytochrome

8. Reproductive organs in some plants are
   A. flowers  B. cones  C. fruits  D. petioles

9. What is the concept a biologist would use to explain the reason for a plant wilting?
   A. the plant needs nutrients (plant food)
   B. plants tend to wilt during the dormancy stage
   C. the plant lacks water to maintain rigid
   D. the plant needs light

10. Which of the following is not essential for plants to survive?
    A. water  B. light  C. room for growth  D. carbon dioxide

11. This seed is an example of a seed from a flowering plant it is called a
    A. monocot  B. flowering seed
    C. dicot  D. cotyledon

12. In a food chain involving green plants, insects, birds, and mammals, the original source of energy is
    A. sunlight  B. water and glucose
    C. chlorophyll  D. water and carbon dioxide

13. What is the connection between a tree that form root nodules with soil bacteria and the soil that is enriched by the bacteria, changing poor soil to enriched soil?
    A. both parties benefit from the relationship
    B. one party benefits and the other is harmed
    C. one party benefits an the other is not affected
    D. both parties are harmed

14. A chimpanzee eats bamboo shoots, fruits and other plants in the jungle, how would a biologist describe how the energy that flows through the biosphere affect the animal?
    A. most photosynthetic organism store excess sugars which become food and energy sources for animals when they eat the organisms.
    B. the animal receives natural energy from being in the sun.
    C. chimpanzees store sugars naturally providing them with energy?
    D. chimpanzees are not affected by this process because they eat fruit.
15. The green layer of algae that is often found floating on the tops of ponds,
   A. are photosynthetic organisms that provide food for other organisms
   B. harms other forms of life near the pond
   C. have no role in the flow of energy in the biosphere
   D. is a form of glucose

16. Which of the following is not the role of fruits in the plant cycle process?
   A. manufacture sugars
   B. disperse seeds
   C. protect seeds
   D. house seeds

17. The amount of sunlight that reaches the floor of a tropical rainforest is considerably lower than that of a grassland. How does this difference affect the organism found in the areas?
   A. the size of the plants may differ
   B. the structure of the plants will differ
   C. animals that can use those plants will be present
   D. all of these

18. Limiting factors in the survival of plant species is
   A. disease
   B. ability to reproduce
   C. supply of energy for life processes
   D. all of these

19. A plant is placed in a bottle with only tiny air holes at the top. The plant is not watered, yet droplets of moisture is observed on the inside of the bottle, this is due to
   A. respiration        B. pollination       C. transpiration   D. evaporation

20. Plants differ in size, which of the following is not a plant?
   A. blade of grass
   B. algae
   C. cycad
   D. shrew
APPENDIX H

POST-INSTRUCTIONAL TEST

CODE: __________

Directions: Please circle the letter of the term or phrase that best answers the statement or answers the question.

1. A biologist discovers this flower on a plant hunt. What factors could he use to make an initial identification?
   A. petals                   B. color
   C. biomes in which it is found               D. root arrangement

2. Plants receive nutrients through the process of
   A. consuming the soil                           B. attaching their roots to the soil
   C. photosynthesis and respiration       D. absorbing water

3. Cellular respiration is a series of chemical reactions that break down organic materials and releases energy. If the temperature increases, we would expect
   A. the rate of cellular respiration to increase.
   B. less energy production.
   C. the formation of more enzymes.
   D. no change in cellular respiration or energy production.

4. The flower has brown structures in the center. This structure is a part of the stamen that produces pollen, it is the
   A. pistil   B. anther
   C. ovule     D. sepal

5. The main tissue involved in transporting water from roots to leaves is the
   A. xylem            B. phloem          C. meristem         D. vascular

6. Suppose the intensity of sunlight was drastically reduced for several months due to the volcanic ash from an erupting volcano. How could the following members of the ecosystem be affected: short grasses, rabbits, and hawks? Which of the following is not an effect?
   A. less plant growth                           B. rabbits and other herbivores would starve
   C. rabbits would hibernate               D. hawk would be in danger of starving
7. The plant that is growing toward light is demonstrating a plant’s response to the light source called
A. gravitropism  B. photoperiodism
C. phototropism  D. phytochrome

8. In flowering plants, the process that enables the sperm to approach the egg is
A. fertilization  B. seed germination
C. pollination  D. dormancy

9. Which one of the following pairings of plant structures/functions does NOT match?
A. leaves- nitrogen uptake  B. anther- hold pollen
C. roots- nutrient storage  D. stems- transport

10. Plant survival depends on all of the following except
A. carbon dioxide  B. water
C. light  D. direct nutrients

11. At what point does the plant begin to manufacture its own food?
A. Point A  B. Point B
C. Point C  D. Point D

12. Climate change will have the least effect on

<table>
<thead>
<tr>
<th>I. plant germination</th>
<th>II. plant flowering</th>
<th>III. deciduous trees losing leaves in the fall</th>
</tr>
</thead>
</table>
| A. I only            | B. II only          | C. III only                                   | D. I and II  | E. II and III.

13. Monocots and dicots have which one of the following in common?
A. network of veins in leaves  B. one cotyledon
C. well-developed xylem  D. petals of lowers occurring in threes of multiples of four
14. Plants and animals have a symbiotic (interdependent) relationship with respect to
   A. nitrogen and carbon dioxide   B. nitrogen and oxygen
   C. hydrogen and oxygen          D. oxygen and carbon dioxide

15. A bromeliad (flower) that grows from the side of a tree is an example of what type
    of relationship?
   A. predator-prey               B. independent
   C. symbiotic                   D. stimulus-response

16. The oxygen that is involved in photosynthesis
   A. is an end product           B. is used to make ATP
   C. captures sunlight          D. is a raw material for glucose

17. Photosynthesis includes all of the following processes, except
   A. chemical changes             B. extracting waste
   C. collecting light             D. creating chlorophyll

18. Roughly two-thirds of all vascular plants are found in the tropics, which of the
    following is not a factor that affects the abundance of plant life in this area?
   A. available water              B. intensity of sunlight received
   C. reduction of waste           D. variety of organisms to support life

19. A plant is placed in a dark room, the stem of the plant becomes weak and the plant
    begins to fall to the side, the plant is measured and has not grown since its placement
    in the dark room. How would a biologist explain the condition of the plant?
   A. the plant’s basic need for water is not being met
   B. the plant has not received light to generate photosynthesis
   C. the plant lacks the basic nutrients and water needed for growth
   D. all of these

20. “Plants are the center of our existence.” Which of the following facts do not support
    this statement?
   A. Plants provide practical support to humans in food, fuel, medicines, and
      materials.
   B. Plants provide energy to all forms of life through food webs and chains.
   C. Plants are the largest items on earth.
   D. Plants provide a habitat for certain species.
APPENDIX I

CORRELATION OF PRINCIPLES OF PLANT BIOLOGY WITH SCIENCE STANDARDS

The National Research Council published the *National Science Education Standards* to provide a guide to science education with the goal of producing scientifically literate citizens. The Life Science Standards may be located at [http://www.nap.edu/reading_room/books/nses/html/contents.html](http://www.nap.edu/reading_room/books/nses/html/contents.html)

American Society of Plant Physiologists recommend the following correlation of *Standards* and *Principles*.

<table>
<thead>
<tr>
<th>Life Science Standard</th>
<th>Principle of Plant Biology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEVELS K –4</strong></td>
<td></td>
</tr>
<tr>
<td>Characteristic of organisms</td>
<td>1, 2, 4, 5, 7, 11</td>
</tr>
<tr>
<td>Life cycles of organisms</td>
<td>4</td>
</tr>
<tr>
<td>Organisms and environments</td>
<td>1, 2, 9 -12</td>
</tr>
<tr>
<td><strong>LEVELS 5-8</strong></td>
<td></td>
</tr>
<tr>
<td>Structure and function of living systems</td>
<td>1, 4 - 6, 10</td>
</tr>
<tr>
<td>Reproduction and heredity</td>
<td>4</td>
</tr>
<tr>
<td>Regulation and behavior</td>
<td>11, 12</td>
</tr>
<tr>
<td>Populations and ecosystems</td>
<td>1, 2, 6, 9, 12</td>
</tr>
<tr>
<td>Diversity and adaptations of organisms</td>
<td>5 – 12</td>
</tr>
<tr>
<td><strong>LEVELS 9-12</strong></td>
<td></td>
</tr>
<tr>
<td>The cell</td>
<td>1, 5, 6, 10</td>
</tr>
<tr>
<td>Molecular basis of heredity</td>
<td>1, 4</td>
</tr>
<tr>
<td>Biological evolution</td>
<td>3, 4, 7, 12</td>
</tr>
<tr>
<td>Interdependence of organisms</td>
<td>1 –3, 6, 8, 12</td>
</tr>
<tr>
<td>Matter, energy, and organization in living systems</td>
<td>1 – 3, 5, 10</td>
</tr>
<tr>
<td>Behavior of organisms</td>
<td>11</td>
</tr>
</tbody>
</table>
# APPENDIX J

WANDERSEE’S 20-Q MODEL OF IMAGE-BASED BIOLOGY TEST ITEMS

<table>
<thead>
<tr>
<th>Question</th>
<th>Code Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Describe this event biology</td>
<td>describe event</td>
</tr>
<tr>
<td>2. Give the function (s) of this/these structures…</td>
<td>give functional</td>
</tr>
<tr>
<td>3. Provide the next stop in this process…</td>
<td>give next step</td>
</tr>
<tr>
<td>4. How else could this event be explained biologically…</td>
<td>give alternative explanation</td>
</tr>
<tr>
<td>5. Predict what will happen next…</td>
<td>predict results</td>
</tr>
<tr>
<td>6. What evidence do you see that suggests…</td>
<td>tell what evidence suggests</td>
</tr>
<tr>
<td>7. What is the limiting factor in this process…</td>
<td>give limiting factor (s)</td>
</tr>
<tr>
<td>8. What biological principle is operating here …</td>
<td>specify principle operating</td>
</tr>
<tr>
<td>9. If we didn’t have or couldn’t use…</td>
<td>suggest could use—instead of</td>
</tr>
<tr>
<td>10. What if the connection between…</td>
<td>give connection between</td>
</tr>
<tr>
<td>11. In the past, how was this event explained by scientists …</td>
<td>supply past scientific</td>
</tr>
<tr>
<td>explanations</td>
<td></td>
</tr>
<tr>
<td>12. On what basis do you suspect this organism is a…</td>
<td>give connection between</td>
</tr>
<tr>
<td>13. Biologically, this organism is most closely related to…</td>
<td>what most closely related to</td>
</tr>
<tr>
<td>14. How would you do about measuring…</td>
<td>tell how you’d measure</td>
</tr>
<tr>
<td>15. Make a biological estimation how long it would take for…</td>
<td>make time estimates</td>
</tr>
<tr>
<td>16. What is the concept a biologist would use here…</td>
<td>suggest valid concept</td>
</tr>
<tr>
<td>17. Ask an important biological question about this photograph…</td>
<td>ask important question</td>
</tr>
<tr>
<td>18. What could a …graph of this event look like…</td>
<td>sketch graph of event</td>
</tr>
<tr>
<td>19. Design a device to monitor an important variable in this environment…</td>
<td>designing monitoring device</td>
</tr>
<tr>
<td>20. Apply what you read in your last assignment to this photo…</td>
<td>apply reading to photo</td>
</tr>
</tbody>
</table>

APPENDIX K

CO-CONSTRUCTED CONCEPT

Coding
Blue – Initial map entry
Coding
Blue – Initial map entry
Lavender- Second map entry
Coding
Blue- Initial map entry
Coding:
Blue- Initial map entry
Lavender- Second map entry
Coding:
Blue- Initial map entry
Coding:
Blue- Initial map entry
Coding:
Blue- Initial map entry
Coding:
Blue- Initial map entry
Lavender- Second map entry
Examining leaves and flowers.

Examining site for plant diversity
Investigating habitats.
Taking photographs of habitats.
APPENDIX M

PARTICIPANT ARTIFACTS

M.1

What is your role in the web?

Task:
- List all the foods that you ate yesterday.
- If your food was made from several ingredients—list each one separately. Then determine if the source was plant or animal.
- Draw a picture of the web that occurred in your diet.
- What does the song "Circle of Life" mean (from the Lion King)?

- peach — plant
- bagel, cream cheese — plant
- cheeseburger — animal
- french fries — plant
- turkey sandwich — animal

The circle of life means that we are all connected on this Earth. Plants and animals could not survive without one another.
What is your role in the web?

Task:
- List all the foods that you ate yesterday.
  If your food was made from several ingredients---
  list each one separately. Then determine if the source was plant or animal.
- Draw a picture of the web that occurred in your diet.
- What does the song- "Circle of Life" mean (from the Lion King)?

1. Shrimp-animal
   French fries - flour (plant)

2. Chicken spaghetti
   Chicken-animal
   Spaghetti - flour (plant)
   Tomato sauce (plant)

The circle of life means that animals and plants both provide and take from each other to sustain life.
What is your role in the web?

**Task:**
- List all the foods that you ate yesterday. If your food was made from several ingredients—list each one separately. Then determine if the source was plant or animal.
- Draw a picture of the web that occurred in your diet.
- What does the song- "Circle of Life" mean (from the Lion King)?

spaghetti, sauce, meatballs, pasta, salad, bread, rice, eggroll, shrimp, vegetables (broccoli), egg drop soup

The 'Circle of Life' means that all living things are dependent on one another—the continuous cycle from birth to death.
What is your role in the web?

Task:
- List all the foods that you ate yesterday. If your food was made from several ingredients—list each one separately. Then determine if the source was plant or animal.
- Draw a picture of the web that occurred in your diet.
- What does the song-"Circle of Life" mean (from the Lion King)?

- granola bar - plant
- turkey sandwich - animal/plant
- turkey bread
- orange - plant
- apple - plant
- pork roast - animal
- rice - plant
- butter beans - plant
- sausage - animal

The circle of life means that we all depend on one another to survive in nature.
What is your role in the web?

Chicken Salad Sandwich and a Glass of Milk
- Bread-plant
- Chicken-animal
- Mayo- eggs and oil-animal
- Milk-animal

Corn Chips and Cheese Dip
- Chips-plant
- Cheese-animal
- Milk-animal

The Circle of life means that in order for everything to survive we all depend on each other.
Lesson: ONE SQUARE FOOT

Purpose: Identify, describe, count, tally and graph life that exists near plants in one square foot of land.

Materials: String in four foot lengths, for each square foot marked off.

Procedures:
1. Mark off one square foot of area near a plant.
2. Fill your chart with the species found in the one square foot. Make sure to sketch your finding as well count them.

<table>
<thead>
<tr>
<th>What I found</th>
<th>How Many</th>
<th>My Sketches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ants</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

3. Create a graph to display your data.

Conclusion:
1. Are there any materials that might support the life of the plant?

2. Why does the main plant survive in this environment?

3. How would you classify this plant? Monocotyledon or Dicotyledon?

Dicot, has leaves have branding veins
<table>
<thead>
<tr>
<th>Item Found</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ants</td>
<td>4</td>
</tr>
<tr>
<td>Pill Bugs</td>
<td>2</td>
</tr>
<tr>
<td>Leaves</td>
<td>8</td>
</tr>
<tr>
<td>Grubs</td>
<td>6</td>
</tr>
<tr>
<td>Acorns</td>
<td>3</td>
</tr>
</tbody>
</table>
Can You Fool A Plant?

A plant's roots grow down and its stems grow up.

What happens if you turn the plant upside down? Will its roots grow up? Do the experiment to find out?

Purpose:

Hypothesis: Will a plant's roots still grow down and its stem grow up if the plant is turned upside down? They would turn and grow down.

Materials: small plastic zippered bag, lima bean, paper towel, water

Procedure:

1. Wet the paper towel and then place in the plastic bag.
2. Put the seeds between the paper towel and the bag so they can be seen. Zip the bag closed and hang it with the zipper part to the top.
3. Check the bag each day to see if the towels are damp. Add water if needed.
4. After several days look for a stem and look for a stem and a root, one from each end of the plant. When this happens draw a picture showing how the sprouting seed looks in the left-hand box.
5. Turn your bag upside down and hang it in place. Be sure the roots are pointing upward and the stem downward.
6. Draw a picture of what happened in the right-hand box.

First drawing

Second drawing

Compare the roots and stems in both pictures in which direction are they pointing?

Conclusions: Based on your observations, what can you say about the direction that a plant's stem and roots grow when the plant is turned upside down? The roots grow the same way until they hit a boundary.
Date 1-28-03  First day of my plant. It had no flowers on it. On the way home, the plant fell over in the car, spilling everywhere. It was about 4 inches tall.

Date 2-5-03  I watered my plant because it was looking kind of brown. There are still no flowers on my plant. It is now about 5 1/2 inches.

Date 2-10-03  My plant started to look healthier today. I watered it and put it outside to get some direct sunlight. It stayed about the same size. It had one bud growing.

Date 2-22-03  My plant looked very dry. Half of the leaves are brown and wilted. I gave my plant some water. It is not growing. I think my plant might be dying.

Today my plant died!
The flowers and leaves are droopy. The soil is really dry so water was added. Plant also placed in sunlight.

The flowers and leaves have perks up some. Addition of water seemed to help. The sunlight seems to have benefitted the plant.

One of leaves is drooping and beginning to turn yellow. Water added to the soil although it was already moist.

The flowers and leaves are starting to droop some. Water added just in case it is lacking water.

The plant is dead. The soil is moist, yet the flowers and leaves are dry.
PLANT DIARY

Date __________
Brought plant home, watered plant. Put plant by window.

Date __________
Measured plant - 6½" tall. Slightly yellowish tinge on brown leaf.
2 buds. Plant is by window.

Date __________
One bud is opening up, watered plant. Just slightly open. New leaves are forming. Plant is by window.

Date __________
Plant is still 6½" tall. Aphids are present. The plant is limp. The plant is getting water + sunlight.

Date __________
The plant is perking back up. The bud is opening more. Still 6½ inches tall.
Watered plant. Plant is by window.
The plant is not as yellow.
Date: My plant is lump. It is almost dead. My plant need rewaterment. I will take care of it. I named my plant Panpy.

Date: My plant is doing better. I gave it water and sunlight. It needed it.

Date: My plant is fine. I normally keep it on my dresser by the window. Today I opened my window because it was a nice day. I put my plant on the window seal.

Date: Today I examined my plant and found little white bugs. I put them outside.

Date: I found out the bugs can be caused by the plant being too moist. I gave it too much water.
PLANT DIARY

Date: My plant was droopy today. We planted them this morning, it was drizzly and sickly-looking. After having some water it perked right up. It is now 14 days old and one open flower stands 2 inches tall.

Date: My cats knocked the plant out of the windowsill. It is killed of flowering in the cup now. The flower is cracked in the middle and the bud is unopened. Some of the leaves are dying.

Date: My plant has gotten droopy again. It gets enough water and sunlight. I don't understand. It has been cut off of reach of the cats so it's not them. It may need to be repotted.

Date: My plant is a drier. I put it into a larger cup, and it just didn't adapt. I've put it outside in an extra sunny area to see if that helps. The original flower is hanging on, and the bud is still unopened.

Date: No change. The original flower is still alive, but finally starting to wilt. The bud is still unopened. It is still changing and thirsy, but worse. It won't be much longer, I am going to move it in the ground. protein
BOTTLE BIOLOGY

Materials:
1 or 2 liter bottle
Tool for cutting
Hole puncher
Plant
Gravel
Soil
Sand

Procedure:
1. Cut the bottle in half; poking holes in the top.
2. Place a level of gravel & sand
3. Dampen the gravel,
4. Place the plant in the soil and then cover with soil, dampen the soil
5. Close the top of the bottle with the half with holes.
6. Seal the container with tape.
7. Place where plant can receive sunlight.
   Large leaf Green Goddess Ivy.

Discussion
1. How do you think the plant will receive water that it needs? By transpiration

2. How does the plant receive its nutrients?
   From sunlight, the nutrients already in the potting soil, and as old leaves die and fall off they will decompose returning their nutrients back to the soil.
FOSSIL HUNT

Look at the fossil. Examine it carefully.

1. Describe your fossil.
   It is long and slender. The top can be squeezed to open the bottom. It has a pivot in the middle for the pieces to use to open up.

2. Identify your fossil. What evidence justifies your answer?
   It is a clothespin. The mechanisms and appearance are the same.

3. How does fossil help us learn about plants?
   Fossils are exact copies. They are very detailed to look at. We can learn what they are, where they're from, and if they exist today.
FOSSIL HUNT

Look at the fossil. Examine it carefully.

1. Describe your fossil.
   - Smaller round section
   - Larger, flat, shaped section with many small branches
   - Small section at the end, small flat shapes

2. Identify your fossil. What evidence justifies your answer? It appears to be from a tree. (Magnolia tree possibly the seed pod? Can I)

3. How does fossil help us learn about plants? It helps us by giving us a good idea what it may have looked like.
During the past two weeks you have been learning about plants and their interrelations with other forms of life and their impact on the world. Think about each of the activities you have done (they’re listed for you) and reflect on your experiences.

Activities:
A. One Foot Square
B. Examining leaves and seeds Monday/Friday
C. Planting seeds in pellets
D. Transplanting a potted plant/examining parts
E. Examining an ivy plant and placing in water
F. Creating Fossils/relating how plants provided information about the earth

1. For each activity describe the most important learning experience for each experience.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shows what and how many animals and plants live in a one foot square.</td>
<td>Takes the differences between Monday and Friday.</td>
<td>Prove how soil is able to expand when water added.</td>
<td>Plants need water, soil, and sunshine to survive.</td>
<td>Show that plants can grow from a stem by burying it off.</td>
<td>Determine age of something.</td>
</tr>
</tbody>
</table>

2. How could these experiences be relevant to children?

It helps students to be able to grasp the concept more because it's hands on activities that the students are able to complete.
During the past two weeks you have been learning about plants and their interactions with other forms of life and their impact on the world. Think about each of the activities you have done (they’re listed for you) and reflect on your experiences.

Activities:
A. One Foot Square
B. Examining leaves and seeds
C. Planting seeds in pellets
D. Transplanting a potted plant/examining parts
E. Examining an ivy plant and placing in water
F. Creating Fossils/releting how plants provided information about the earth

1. For each activity describe the most important learning experience for each experience.

<table>
<thead>
<tr>
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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   | The activity helped us learn about photosynthesis and how living things depend on each other. |
   | The activity helped us learn how to plant seeds. Plants can grow from seeds. |
   | The activity helped us learn how to transplant a potted plant. Plants need water and sunlight. |
   | The activity helped us learn how to create fossils. Fossils provide information about the earth's history. |
   | The activity helped us learn how to relate plants and fossils. Fossils provide information about the earth's history. |

2. How could these experiences be relevant to children?

   These activities could be relevant to children as they provide them with something they can do and handle to learn about plants and how they grow, the soil, and how they can live in the world.
APPENDIX N
IRB FORM

Application for Exemption from IRB (Institutional Review Board)
Oversight for Studies Conducted in Educational Settings
LSU COLLEGE OF EDUCATION

Title of Study: **A Study of the impact of a whole-plant approach on preservice elementary teachers' understanding of plant biology principles**

Principal Investigator: **Christine Colline-Hypolite**

Faculty Supervisor: **Dr. James H. Mandresen**

Date of proposed project period: From **October 2001** To **December 2001**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. This study will be conducted in an established or commonly accepted educational setting (schools, universities, summer programs, etc.)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>2. This study will involve children under the age of 18.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>3. This study will involve educational practices such as instrumental strategies or comparison among educational techniques, curricula, or classroom management strategies.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4. This study will involve educational testing (cognitive, diagnostic, aptitude, achievement)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>5. This study will use data, documents, or records that existed prior to the study.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>6. This study will use surveys or interviews concerning content that is not related to instructional practices.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>7. This study will involve procedures other than those described in numbers 1, 4, 5, or 6. If yes, describe:</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>8. This study will deal with sensitive subjects and/or subjects' families, lives, such as sexual behavior or use of alcohol or other drugs.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>9. Data will be recorded so that the subjects cannot be identified by anyone other than the researcher.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>10. Informed consent of the subject cannot be identified by anyone other than the researcher.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>11. Assent of minors (under age 18) will be obtained. (Answer if #2 is above is Yes)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>12. Approval for this study will be obtained from the appropriate authority in the educational setting.</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Attach an abstract of the study and a copy of the consent form(s) to be used. If your answer(s) to numbers 6 and/or 7 is (are) YES, attach a copy of any surveys, interview protocols, or other procedures to be used.

--- OVER ---

121
ASSURANCES

As the principal investigator for the proposed research study, I assure that the following conditions will be met:

1. The human subjects are volunteers.
2. Subjects know that they have the freedom to withdraw at any time.
3. The data collected will not be used for any purpose not approved by the subjects.
4. The subjects are guaranteed confidentiality.
5. The subjects will be informed beforehand as to the nature of their activity.
6. The nature of the activity will not cause any physical or psychological harm to the subjects.
7. Individual performances will not be disclosed to persons other than those involved in the research and authorized by the subject.
8. If minors are to participate in this research, valid consent will be obtained beforehand from parents or guardians.
9. All questions will be answered to the satisfaction of the subjects.
10. Volunteers will consent by signature if over the age of 6.

Investigator Statement:

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will advise the Office of the Dean and the University’s Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature: [Signature]
Date: 9-18-01

Faculty Supervisor Statement (required for student research projects):

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will supervise the conduct of the proposed project in accordance with federal guidelines for Human Protection. I will advise the Office of the Dean and the University’s Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature: [Signature]
Date: 9-19-01

Reviewer recommendation:

✔ exemption from IRB oversight. (File this signed application in the Dean’s Office.)

Name of Authorized Reviewer: [Name]
Print name: [Print name]
Signature: [Signature]
Date: 10/5/2001
Title of Research Study
The impact of whole-plant instruction on preservice elementary teachers' understanding of plant science principles.

Project Director
Principal Investigator: Christine Collins Hypolite, Doctoral Candidate, LSU
P.O.Box 2035, Thibodaux, Louisiana 70301
(985) 448- 4342
Faculty Advisor: Dr. James H. Wandersee, Wm. LeBlanc Alumni Professor of Biology Education
Louisiana State University
(225) 578-2348

Purpose of Research
The purpose of the study is to investigate how inquiry-based, whole-plant instructional strategies affect preservice elementary teachers’ understanding of plant science concepts and principles.

Procedures for this Research
During a six-week period participants will continue with their methods coursework while participating in activities related to plants. Each of the two sections of the methods class will be identified as either the experimental or the comparison group. All preservice elementary teacher participants will be administered a pre-instructional survey related to plant science concepts and principles and a questionnaire to establish the science background of the participants. Participants in the experimental group will participate in a series of inquiry-based instructional activities using a whole-plant approach. An equivalent post-instructional survey will be administered to all participants.
Selected preservice elementary teacher participants will participate in co-constructing concept maps with the researcher to determine their changing understanding of plant science concepts and principles.

**Potential Risks of Discomfort**
There are no medical, personal, social, or academic risks anticipated in this study. Participation in the study will have no effect on grades. If participants should have concerns of any type, they are encouraged to discuss them with the principal investigator.

**Potential Benefits to You or Others**
The study has the potential to benefit preservice elementary teachers and elementary science educators by developing a rationale and providing evidence for using whole-plant approach to plant science instruction. The preservice elementary teacher may gain an increased understanding of plant science content and of systematic science teaching methods.

**Alternative Procedures**
There are no alternative procedures in this research. Participants’ role in the study is strictly voluntary; participants may withdraw and terminate participation at any time without consequences.

**Protection of Confidentiality**
The data collected in this study will be numerically coded for anonymity and confidentiality. All data will be treated equitably and held in the strictest of confidence. Results of the study will be made available in the campus library for all interested participants to review.

I have been fully informed of the above-described procedure with its possible benefits and risks, and I give my permission for participation in this study.

<table>
<thead>
<tr>
<th>Signature of Subject</th>
<th>Name of Subject (Print)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Christine C. Hypolite</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signature of Person Obtaining Consent</th>
<th>Name of Person Obtaining Consent (Print)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX P

QUESTIONNAIRE

CODE: ____   ___   ___   ___(last four digits of social security number)
(This coding will subsequently be recoded by the researcher for purposes of the study)

Please check and/or answer the following questions. Your answers are completely confidential.

1. Your age is 20-25____ 26-30____ 31-35____ 36-40____ 41-45____ Other, please state ____

2. Your gender is Female______ Male______

3. Your ethnicity is__________________________

4. Your current college GPA____

5. How many hours of courses in college science have you completed? Please name each college science course completed and give the grade.

6. Check the education methods classes or related courses you have completed. General methods____ Reading methods____ Science methods____ Math methods____ Other? ________________________________

7. Please list the names of science courses, if any in which you are enrolled this semester.

8. Do you have any teaching experience? ____ If so, please explain.
### APPENDIX Q

#### ABBREVIATED SCRIPT

**Q.1 Activity 1- Interdependence**

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The lesson begins with participants brainstorming about foods they had consumed the night before in groups, then classifying them as individuals.</td>
<td>a. The lesson begins with a picture of a bird, fox, rabbit in a meadow, the instructor asks if there is a relationship between these different organisms.</td>
</tr>
<tr>
<td>b. The Circle of Life (from the movie “Lion King”) is played for the participants to listen then interpret.</td>
<td>b. The instructor writes the term interdependence on the board and solicits the meaning from the participants. After a definition is established the instructor asks for examples of interdependence in nature.</td>
</tr>
<tr>
<td>c. Instructions are provided for the “One Foot Square “ activity and materials distributed. Preservice teachers are told that they need to complete a frequency chart, then convert it to a pictorial graph.</td>
<td>c. The instructor lectures about relationships of living organisms. The following key concepts are dictated in notes with an explanation: life processes, characteristics of living things, and systems.</td>
</tr>
<tr>
<td>d. At the conclusion of the activity the participants discuss their findings in their groups and draw a picture of how they think the organisms are interdependent. Question for research -how do you distinguish living from nonliving things? Further discussion asks for other examples of interdependence and then related to the food activity in the first step.</td>
<td></td>
</tr>
</tbody>
</table>
Q.2 Activity Two-Analyzing Plant Structures

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Preservice teachers examine a seed and predict what the parts may become as a mature plant.</td>
<td>a. The instructor will provide a picture on the overhead projector of a dicot seed and a monocot seed. Students are asked to compare the structures.</td>
</tr>
<tr>
<td>b. The participants receive several types of seed are asked to compare and contrast the seeds. After characteristics have been established the term monocot and dicot will be introduced.</td>
<td>b. The instructor will provide a worksheet with the two seed types on it for students to identify the seed parts and compare the seeds.</td>
</tr>
<tr>
<td>c. The preservice teachers will reenact the seed dispersal process by going outside and throwing the seeds, then discuss the survival of the plant.</td>
<td>c. Preservice teachers will review diagrams on seeds and their characteristics. The instructor will lecture on seed dispersal.</td>
</tr>
<tr>
<td>d. Flowers will be given to each participants to take apart and identify the function of as many parts as they can; the class will discuss the flowers drawing conclusions about the function of parts.</td>
<td></td>
</tr>
<tr>
<td>e. Preservice teachers will go out on campus to compare the diversity of land and water habitats in which plants exist.</td>
<td></td>
</tr>
</tbody>
</table>
## Q.3 – Activity Three- Growth and Development

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The instructor asks if there is a relationship between how plants grow and gravity.</td>
<td>a. The instructor asks what happens to places with no gravity. The instructor shows pictures from NASA of research with plants and discusses the force of gravity on plants.</td>
</tr>
<tr>
<td>b. The preservice teachers are encouraged to respond during discussion. They are given a bag with seeds and told to hang if upside down to determine if it grows.</td>
<td>b. The instructor lectures about the growth and development of plants.</td>
</tr>
<tr>
<td>c. Seeds and plant pellets are used by preservice teachers to sow a plant. They are then given seedlings to examine the roots and then take home to monitor the growth. They are asked to describe the stages of the plant they have examined.</td>
<td></td>
</tr>
<tr>
<td>d. A second seedling is provided to the participants to care for and compare to their initial plant.</td>
<td></td>
</tr>
<tr>
<td>e. A brief discussion takes place about the needs of the whole plant.</td>
<td></td>
</tr>
</tbody>
</table>
Q.4- Activity Four- Habitats

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The preservice teachers explore the habitats of different plants on the campus. They are to examine different webs and their contribution to the whole plant.</td>
<td>a. The preservice teachers will discuss the different habitats plants can be found in and why they differ structurally.</td>
</tr>
<tr>
<td>b. The researcher will bring a bag to class with a plant inside and ask questions concerning the moisture on the bag, and the needs of plants.</td>
<td>b. The instructor will bring in A model of the plant in the bottle and asks how does it exist with human intervention.</td>
</tr>
<tr>
<td>c. The preservice teachers are provided with materials to create a habitat in a bottle. They will monitor for growth and development.</td>
<td>c. A lecture will follow on the processes of photosynthesis and respiration.</td>
</tr>
</tbody>
</table>

Q.5- Activity Five – Plants as a dominant biotic feature

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The instructor place plants strategically to determine if preservice teachers recognize them. The term plant blindness is discussed.</td>
<td>a. The instructor place plants strategically to determine if preservice teachers recognize them. The term plant blindness is discussed.</td>
</tr>
<tr>
<td>b. The preservice teachers are given Polaroid cameras and told to take pictures of habitats and the role of plants in the ecosystem.</td>
<td>b. Using the pictures in a magazine, the instructor discusses the role of plants and asks the preservice teachers to find evidence of the role of plants. The class will report their findings.</td>
</tr>
<tr>
<td>c. Preservice teachers discussed their findings and shared pictures to develop a list of features that contribute to the ecosystem</td>
<td>c. The instructor will lecture about the role of the whole plants in the ecosystem;</td>
</tr>
</tbody>
</table>
### Q.6. – Historical View

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Comparison group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. The instructor will ask the preservice teachers what is the role of paleontologists. Why is it important to learn what occurred in the past?</td>
<td>a. The instructor will ask the preservice teachers what is the role of paleontologists. Why is it important to learn what occurred in the past.</td>
</tr>
<tr>
<td>b. Given instructions and a site the preservice teachers go on a simulated dig. They are instructed to find a relic to bring back as evidence of the dig.</td>
<td>b. The teacher will lecture about plate tectonics and how scientists use evidence to support theory; how this process is a link to past.</td>
</tr>
<tr>
<td>c. A class discussion will ensue about the relics and what type of information could they give of former life forms in the area. The participants will be given pictures of the Glossopteris and asked what plant of today does it resemble a discussion will take place about plate tectonics and how scientists discovered the plant and its importance</td>
<td>c. Participants will examine pictures of preserved plant specimens and describe their role on earth.</td>
</tr>
<tr>
<td>d. Each participant will make a mold and cast of their relic to demonstrate one techniques to preserve specimens. They will then go on a treasure hunt for nature means of preservation.</td>
<td></td>
</tr>
</tbody>
</table>
MILESTONES IN UNDERSTANDING PLANT SCIENCE SCALE (MUPSS)

Level 0—Absence of Understanding

Virtually no scientific understanding of plants, the basic structures of plants (leaf, root, stem, flower) cannot be identified.

Level 1 --Seeds

Has a basic understanding of plant structures and functions.

Level 2--Germination

Understands the role of plants in food chains and identifies some of its uses.

Level 3--Stems and Roots

Recognizes that plants have unique characteristics. Acknowledges that the stem and roots are important to the plant for transporting nutrients and anchoring the plant. Understands plants have specific needs to grow and develop, and that there are external factors that affect plant growth and development. Recognize plant diversity in size, appearance, reproduction, and life span.

Level 4--Flowers

Recognizes the important processes that are essential to plant survival, that the Processes of respiration and photosynthesis support life and its reproduction. Recognizes the processes that sustain the life of a plant and the role each plant organ plays to support the life of the plant.

Level 5--Whole-Plant

Understands the interdependency of plant parts to the functioning of the whole plant.

Can describe the interdependency that exists between plants, other organisms, and the environment, with plants being the dominant biotic feature.
APPENDIX S

MILESTONES IN UNDERSTANDING PLANT SCIENCE SCALE RESULTS

<table>
<thead>
<tr>
<th>Level of Achievement on MUPSS</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map 1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Map 2</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Map 1 was constructed after the group participated in three activities. Map 2 was constructed at the end of the study.

Assessment of Maps according to Tenets
Percentage of Connections to the Tenet on Map 1 and Map 2

N=4

<table>
<thead>
<tr>
<th>Tenet</th>
<th>P1 No. of links</th>
<th>P1 %</th>
<th>P2 No. of links</th>
<th>P2 %</th>
<th>P3 No. of links</th>
<th>P3 %</th>
<th>P4 No. of links</th>
<th>P4 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRU-CHAR</td>
<td>4</td>
<td>29</td>
<td>8</td>
<td>47</td>
<td>11</td>
<td>92</td>
<td>4</td>
<td>26</td>
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<tr>
<td>BIOL-CHAR</td>
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<td>21</td>
<td>3</td>
<td>18</td>
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<td>0</td>
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<td>26</td>
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<td>ECO-CHAR</td>
<td>1</td>
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<td>12</td>
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<td>0</td>
<td>3</td>
<td>25</td>
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<tr>
<td>ROLE-CHAR</td>
<td>6</td>
<td>43</td>
<td>4</td>
<td>24</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>26</td>
</tr>
</tbody>
</table>
APPENDIX T

STATISTICAL ANALYSIS

Pre- and Postinstruction Test
Performance - Treatment Group

Performance on Test

Participants

Pretest
Postest
Pre- and PostinSTRUCTION Test
Performance - Comparison Group

Performance on Tests

Participants

Pretest
Posttest
Gain Scores for Treatment Group

<table>
<thead>
<tr>
<th>Comparison Participant (code no)</th>
<th>Pretest Score</th>
<th>Posttest Score</th>
<th>Gain Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>165</td>
<td>12</td>
<td>16</td>
<td>+4</td>
</tr>
<tr>
<td>243</td>
<td>9</td>
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<tr>
<td>983</td>
<td>12</td>
<td>15</td>
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<tr>
<td>1141</td>
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<td>9</td>
<td>+2</td>
</tr>
<tr>
<td>1532</td>
<td>12</td>
<td>14</td>
<td>+2</td>
</tr>
<tr>
<td>2030</td>
<td>11</td>
<td>15</td>
<td>+4</td>
</tr>
<tr>
<td>2896</td>
<td>10</td>
<td>15</td>
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<td>3574</td>
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<tr>
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Summary:

<table>
<thead>
<tr>
<th>Percentage of Participants</th>
<th>Number of Participants N=20</th>
<th>Amount of Gain (By point difference)</th>
<th>Mean Gain: 2.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>1</td>
<td>+5</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>2</td>
<td>+4</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>5</td>
<td>+3</td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td>6</td>
<td>+2</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td>4</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>1</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>5%</td>
<td>1</td>
<td>-2</td>
<td></td>
</tr>
</tbody>
</table>
### Gain Scores for Comparison Group

<table>
<thead>
<tr>
<th>Comparison Participant (code no)</th>
<th>Pretest Score</th>
<th>Posttest Score</th>
<th>Gain Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>118</td>
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<td>9</td>
<td>-1</td>
</tr>
<tr>
<td>436</td>
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<td>15</td>
<td>+2</td>
</tr>
<tr>
<td>824</td>
<td>13</td>
<td>15</td>
<td>+2</td>
</tr>
<tr>
<td>1105</td>
<td>11</td>
<td>13</td>
<td>+2</td>
</tr>
<tr>
<td>1641</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
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<td>14</td>
<td>15</td>
<td>+1</td>
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<td>9</td>
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</tr>
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<tr>
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<tr>
<td>4451</td>
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<td>5300</td>
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<td>10</td>
<td>+1</td>
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</tr>
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</tr>
<tr>
<td>8917</td>
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<td>11</td>
<td>+1</td>
</tr>
<tr>
<td>9408</td>
<td>13</td>
<td>14</td>
<td>+1</td>
</tr>
</tbody>
</table>

### Summary:

<table>
<thead>
<tr>
<th>Percentage of Participants</th>
<th>Number of Participants N=20</th>
<th>Amount of Gain (By point difference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>6</td>
<td>+2</td>
</tr>
<tr>
<td>45%</td>
<td>9</td>
<td>+1</td>
</tr>
<tr>
<td>10%</td>
<td>2</td>
<td>0 (no change)</td>
</tr>
<tr>
<td>15%</td>
<td>3</td>
<td>-1 (score declined)</td>
</tr>
</tbody>
</table>

Mean gain: .9
### APPENDIX U

#### ANALYSIS OF INQUIRY-BASED ACTIVITIES

<table>
<thead>
<tr>
<th>Question</th>
<th>Activity 1</th>
<th>Activity 2</th>
<th>Activity 3</th>
<th>Activity 4</th>
<th>Activity 5</th>
<th>Activity 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the activity provide the opportunity to develop an understanding of plant science concepts?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. How does the activity engage the learner in the use of investigative and analytical skills?</td>
<td>Field work; discussion</td>
<td>Manipulate Seeds, leaves, flowers</td>
<td>Sow plants, examine roots, discussions</td>
<td>Explore Habitats; Bottle plants</td>
<td>Take pictures of different habitats; discussions</td>
<td>Simulated dig; create fossils; infers as to history of site</td>
</tr>
<tr>
<td>3. Does the activity contribute to the understanding of the connectiveness of plants?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Does the activity provide for the learner to link explanations with scientific knowledge?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### APPENDIX V

**INSTRUCTIONAL ACTIVITIES ALIGNED WITH FOUR CENTRAL TENETS**

<table>
<thead>
<tr>
<th>Instructional Activity</th>
<th>Structure/Diversity</th>
<th>Biological Processes</th>
<th>Ecosystem</th>
<th>Role of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interdependence</td>
<td>Identify different life forms in a square foot area</td>
<td>Decomposition Germination</td>
<td>Relationships among living things</td>
<td>Habitat for life forms Provides oxygen Aesthetics</td>
</tr>
<tr>
<td>2. Analyzing plant structures Comparing seeds Classifying leaves and flowers</td>
<td>Describing and comparing seeds; flowers</td>
<td>Life cycle of plants Pollination Fertilization</td>
<td>Seed dispersal Habitats of plants</td>
<td>Role of plant parts in relation to the whole</td>
</tr>
<tr>
<td>3. Growth and development</td>
<td>Discovering roots</td>
<td>Reaction to external factors Growth needs Adaptations</td>
<td>Plants to reduce soil erosion</td>
<td>Provide for human growth and development</td>
</tr>
<tr>
<td>4. Habitats</td>
<td>Investigating different types of habitats</td>
<td>Respiration Transpiration Photosynthesis</td>
<td>Animals and plants coexisting in a habitat</td>
<td>Plants provide habitats for all levels of animals</td>
</tr>
<tr>
<td>5. Dominant biotic feature</td>
<td>Plants provide according to their structure</td>
<td>Relationships among living organisms;</td>
<td>Dependency on plants</td>
<td>Provided nutrients for survival Habitats</td>
</tr>
<tr>
<td>6. Historical View</td>
<td>Comparing fossilized specimens with actual item</td>
<td>Life cycle of plants</td>
<td>Contributions to earth</td>
<td>Plants as a key to understanding the past</td>
</tr>
</tbody>
</table>
APPENDIX W

PRESERVICE TEACHERS WORKING WITH PUBLIC SCHOOL STUDENTS
APPENDIX X

PILOT STUDY

Research Purpose

The purpose of this study was to determine if an inquiry-based approach to plant science concepts would impact preservice elementary teachers’ understanding of plant science concepts and principles.

Description of the Study

In the fall of 2001, a pilot study was conducted with two groups of preservice elementary teachers at a university in a small rural town in the Deep South. The university is located 65 miles southeast and southwest from two major metropolitan cities, thus situating the university in the middle of sites of two larger universities. The size of the classes in the teacher education program at this university have the tendency to remain small, between 10-25 students, due to the location of the university and the regional population it serves.

Participants in the study were enrolled in two sections of a six-credit hour elementary methods class that addressed the disciplines of science, mathematics and social studies. This course is a required course of all elementary majors and can be considered as a transition point into professional coursework. Students in this course are instructed in methodological and pedagogical practices as related to the three disciplines for elementary grades 1 through 8.

The elementary preservice teachers that participated in the study were all female Caucasians ranging in the ages of 20-25 years. All of the students had completed coursework in the first level biology classes required in their program at the university level and completed biology in high school. The average grade point average of the participants was 3.3 on a 4.0 scale. Each section of the course had 25 participants in the class.

At the onset of the study, the participants were given a copy of the consent-form and an explanation of the study was provided. Further explanation was provided
concerning how the participants’ anonymity would be protected through a coding system; all of the artifacts would be coded with no referral to the individual’s name. Each participant was given the opportunity to ask questions and express any concerns they had about participating in the study. After several of the preservice elementary teachers asked if they would be assessed in their final grading based upon performances during activities, they were reassured that their participation in the study would not be reflected in any assessment of their performance in the course. According to Fraenkel and Wallen (1996), the most important ethical issue in research is the responsibility of the researcher to ensure participants they are protected from harm or discomfort during the research procedure. The process of providing full disclosure to the participants was an attempt to meet the ethical responsibility of the researcher in assuring their comfort and the confidentiality of the research data that was to be collected.

The study, a quasi-experimental design, began with establishing a control group and an experimental group. The process of establishing a control and experimental group reduces the threat to the internal validity of the study (Trochim, 2001). Since both classes were composed of the same number of students and the same basic types of students based upon age, ethnicity and mean grade point average, there was a reduction of the threat of validity due to selection. Both groups were administered a pre-instructional survey to assess their understanding of plant science concepts and principles based upon the Principles of Plant Biology (ASPB, 1999).

The structural content of the study was based upon the Principles of Plant Biology (ASPB, 1999). The delivery of the content to the control group was traditional in nature in that it consisted of lectures that were enhanced with transparencies, pictures, or models. However, the activities for the experimental group were inquiry-based, meaning that they focused on the participants becoming actively involved in the learning process through hands-on activities. Inquiry, as defined in the Standards (NRC, 1996) should be an environment where students ask questions, use their questions to plan and conduct a scientific investigation, use appropriate science tools and scientific techniques, evaluate evidence and use it logically to construct several alternative explanations and communicate their findings scientifically.
During the six weeks of the study, the groups focused on their understanding of the characteristics of plants, basic needs of plants, plants as producers, diversity of plant life and inter-connectedness of plants and their environment through activities for the experimental group and through lectures for the control group. The activities that the experimental groups conducted were arranged in cooperative groups with extension activities that could be conducted individually. The elementary preservice teachers reflected upon each activity at its conclusion to make connections with prior concepts learned and to connect the activities to strategies for teaching children.

As the study progressed, it became obvious that in the experimental group many participants were cautious about conducting tasks, making sure they did not “mess-up.” Several times they had to be reassured that their results may not all be the same and to extend their experiences to find solutions to questions that had surfaced during the activities. One of the activities required that the participants plant seedlings in an alternate medium and track its growth. They were given several choices, but insisted that they needed to be guided to the “right” medium to assure the growth of their plant. They were concerned, ‘what would happen if the plant died’?

The uncertainty that surfaced in the experimental group’s activities also became prominent in the control group. They were concerned about getting the correct notes and how much they needed to write down. One of the participants in the experimental group alluded that she felt ‘naked’ without having a text or writing notes. Their understanding of the concepts became secondary to memorization and the quantity of facts they received. Understanding was “concretized” as described by Bereiter and Scardamalia (1989), meaning that understanding was reduced to tasks to be accomplished. Apple (1979) describes this perception of learning environment as a means of preserving capitalist structures and preparing students to their future roles as workers. Thomas Lord (1998) posits that in order for learning to occur that the student must actively pursue thinking by interacting with the new knowledge.

As the study continued, the experimental group was observed taking ‘risks’ during the activities and interacting more with the concepts.
The participants created concept maps to monitor their growth in understanding the plant biology concepts and principles. As the participants began to visually see the connections in their learning they were excited to discuss varying perspectives of concepts and even hypothesize concerning other issues related to plants.

At the end of study, the participants of both groups were given a post-instructional survey. Although they had been reassured several times concerning the role of assessment in the study, they were still steadfast in their uncertainties; therefore, it was necessary once again to reassure them that their performance would not affect the grade for the course. The concern of the researcher in the students’ anxiety was confirmed in the results of the course evaluations that were generated by the university’s Office of Institutional Research. The comments from the experimental group members included: “enjoyed the activities,” “learned more about plants then they thought,” and “never thought about the importance of plants to the earth.” However, both groups indicated they were concerned about grades and would have preferred to have that issue out the process.

The results of this pilot provided the following insights for the proposed study: (a) the intervention should take place in the latter part of the semester to assure that all assignments for the course have been completed to reduce anxiety, (b) activities were appropriate for the study, but cooperative learning skills need to be carefully developed, and (c) it is necessary to include more constructivist techniques in discussion and developing the concept.

Conclusion

One of the biggest fallacies in education today is the belief that content recitation or memorization confirms comprehension and understanding. Constructivists believe that in the acquisition of knowledge, mental energies are expended by both the deliver and the receiver (Lord, 1998). Prospective teachers’ understanding of the nature of knowledge and of science is a critical factor in their teaching. Paul Baker of the Wisconsin Center for Research in Education suggests that, prospective teachers would benefit from methods courses that offered more comprehensive perspectives on how students learn and how teachers teach science.
Continued research in the use of inquiry-based approaches to learning is important. Teachers must experience active learning if they are to teach their students through active learning.
VITA

Christine Collins Hypolite is a native of New Orleans, Louisiana and is currently a resident of Thibodaux, Louisiana. Having attended Nicholls State University in Thibodaux, Louisiana, she completed a Bachelor of Arts degree, cum laude, in elementary education in 1978. She taught 7th and 8th grade science for 14 years in the Lafourche Parish Public School System. During her tenure in Lafourche Parish she was named Outstanding Teacher of Thibodaux. She completed her master’s degree at Nicholls State University in 1980 in the area of curriculum and instruction.

Returning to Nicholls in 1992, she pursued certification in administration and supervision. In 1994, she secured a position at Nicholls State University, as an Assistant Professor in the undergraduate elementary program, teaching elementary science methods courses as well as several foundation courses. Meanwhile, she completed her certification in administration and supervision and then began pursuing her doctorate degree.

She has presented at numerous conferences locally, regionally, and nationally; as well as served as a consultant on the topics of science education, interdisciplinary instruction, and classroom management. Her research interests include: science education, middle school education, teacher preparation, multicultural education, and the integration of disciplines.