ꟷ
6
2007

This is to certify that the
thesis entitled

STIMULATING SCIENCE WONDERMENT AND
DEVELOPING SCIENTIFIC KNOWLEDGE THROUGH
MULTI-DAY FIELD TRIPS AND POST-FIELD TRIP
FOLLOW UP

presented by

KELLI JO BERRYHILL

has been accepted towards fulfillment
of the requirements for the

M.S. degree in HORTICULTURE

Norman Lownds
Major Professor's Signature

6-21-05
Date

STIMULATING SCIENCE WONDERMENT AND DEVELOPING SCIENTIFIC KNOWLEDGE THROUGH MULTI-DAY FIELD TRIPS AND POST-FIELD TRIP FOLLOW UP

By

Kelli Jo Berryhill

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Horticulture

2005

ABSTRACT

STIMULATING SCIENCE WONDERMENT AND DEVELOPING SCIENTIFIC KNOWLEDGE THROUGH MULTI-DAY FIELD TRIPS AND POST-FIELD TRIP FOLLOW UP

By

Kelli Jo Berryhill

Seeds of Science is a program offered at Michigan State University's 4-H Children's Garden in which classes participate in multi-day field trips. The 4-H Children's garden offers students many opportunities for exploration and discovery. Seeds of Science field trips encourage student wonderment and science learning, and are closely tied to the curricular needs of schools. Through hands-on activities and authentic experimentation students ask questions based on their observations and ultimately gain knowledge of plant science.

Students expressed their wonderment through questioning, during and after field trips. Students demonstrated a gain and re-structuring of knowledge about science process, plant and flower parts, and plant problems. Analysis of data indicates that students' knowledge increased and their knowledge structures more closely resembled those of experts after Seeds of Science. Post-field trip activities provided continued opportunities to wonder and reinforced content learned at the 4-H Children's Garden. Post-field trip activities differed between schools, but included data collection, a lab report, use of the on-line Wonder Wall, and inquiry-based, student designed experiments.

ACKNOWLEDGMENTS

I would like to thank Dr. Norm Lownds for his interest and passion in science education, his willingness to offer guidance, and his ability to make children wonder. I am grateful for this entire experience.

To my committee, Dr. Ken Poff and Dr. Christina Schwarz, thank you for your sound advice and direction.

Thank you to my fabulous family and friends who always manage to make me laugh and never allow me to forget that life is good.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The 4-H Children's Garden, located on the campus of Michigan State University, is one of five parts of the Horticultural Demonstration Gardens. The garden, about two-thirds of an acre in size, is divided into over 60 different theme gardens, including the pizza and perfume gardens. The mission of the 4-H Children's Garden is "To promote an understanding of plants and the role they play in our environment and daily lives; To nurture the sense of wonder in a child's imagination and curiosity; To provide a place for the enrichment and delight for all children." It is a place where plants, children and imaginations grow (4hgarden.msu.edu).

In addition to the outdoor 4-H Children's Garden, there is also an indoor 4-H Children's Garden. Within the indoor children's garden there are theme gardens including the Michigan garden, which has important horticultural crops of Michigan growing in it. Michigan's lower and upper peninsulas are connected by a miniature, suspension bridge like the Mackinac Bridge. The great lakes are represented as ponds and fish swim about, which delight and fascinate children. The indoor 4-H Children's Garden gives children a year round opportunity to explore, discover, and wonder.

Various educational programs are offered throughout the year at the 4-H Children's Gardens, one of which is Seeds of Science. Local school groups have been involved with this program, visiting the gardens on multiple field trips, spaced about one week apart. Seeds of Science abides by the mission of the children's garden, promoting wonderment and emphasizing plant science education. Teachers work closely with the individuals involved in organizing and running the field trips, and play a vital role in shaping the field trip curriculum.

THE STUDY

The purpose of this study is to assess how Seeds of Science field trips and subsequent post-visit activities influence students learning, knowledge structure, and wonderment. Three research questions were explored:

1. What impact do Seeds of Science field trips have on students' learning and knowledge structure?
2. How do Seeds of Science field trips influence the questions students ask?
3. How do post-field trip activities influence students' wonderment and learning?

Hypotheses include the following:

- H1: Students' post-visit knowledge of plant science will be greater than students' pre-visit plant science knowledge. This is expected since the Seeds of Science curriculum offers students many opportunities to experience plant science first hand.
- H2: Students post-visit concept maps will be more similar to the expert map, in terms of concept organization and number of valid links, compared to students' pre-visit maps. As students gain knowledge, they add the new information to their prior knowledge and organize the concepts in a way that allows for easy recall of information. Organization of concepts is an indication of expertise.
- H3: Students will express basic information questions and wonderment questions relatively equally during the Seeds of Science field trips. This is based off of

research done on immersion field trips at the 4-H Children's Garden where second and third grade students asked wonderment and basic information questions equally (Driscoll, 2004).

- H4: Students engaged in post-field trip activities will have a greater change in science process knowledge compared to those students who did no follow up. Post-field trip activities focused on completing a scientific investigation, which provided students with the opportunity to experience the science process in its entirety.
- H5: Students will express more wonderment questions in post-visit activities than during the course of the Seeds of Science field trips. It is expected that the majority of basic information questions will be raised and addressed during the field trips; therefore, it is likely that post-field trip activities will elicit more wonderment questions.

CHAPTER 1

REVIEW OF THE LITERATURE

WONDER AND CURIOSITY

Martin, an 8 year old student eloquently defined science: "Science is all the wonder things – all the things you wonder about. A scientist studies everything almost, like all the wonder things. Like you wonder, 'Is there an end to space?' It's probably a scientist who discovered there's no end to space" (McNay, 1985). Wonder and curiosity are the precursors to student questioning, which educators must nurture. In fact, Bjorkvold (1992) claimed that wonder was responsible for forming the very basis of children's culture. Children love asking questions, inquiring into topics that normally are taken for granted, such as "How do birds fly? What are freckles? How many stars are there?" (McNay, 1985). Wondering is an innate behavior that human beings experience upon birth (Britton, 1970). Educators need to embrace children's natural inquisitive nature and use it to guide student learning. Children, if allowed and encouraged, "remain active and curious philosophers and scientists throughout their lives" (Latham, 1996). Even centuries ago Plato clearly highlighted the importance of wonder: "Look for the genesis of knowledge in the child's emerging sense of wonder" (cited in Nikola-Lisa, 1988). It is through wonder and curiosity that children come to know the world at large (Cobb, 1977).

Wonder and curiosity go hand in hand. Curiosity is an energizing factor, a motive, that arouses exploratory behavior (Jenkins, 1969). It is the root of scientific questioning. To confront and question the novel and unfamiliar is to be curious. It is the force behind much of what human beings do within daily life, especially in science, and should be encouraged within education (Opdal, 2001). Opdal (2001) views curiosity as a confident, focused interest with the goal of finding something out. Wonder on the other hand, is a state of mind where one is struck by peculiarity or strangeness, which may lead to an experience of awe (Opdal, 2001). Wonder and curiosity have shaped science by providing the motive to question the unknown. The scientific community views scientific progress as the result of discipline and curiosity: "The curiosity of creative minds, asking continuously How? and Why?, and the discipline to realize that science is part of the world, that it is shaping it, for better and for worse" (Groen, et al., 1990).

Many classrooms are unfortunately, curriculum driven and create a fact-based rather than curiosity-based learning environment. Children easily fall into the "correct way" - the "getting it right" syndrome. Rarely, are students given the opportunity to wade around in the unknown (Latham, 1996). Concept development is a primary objective of elementary school science and curiosity has been identified as a motivational force in children to form concepts (Jenkins, 1969). In a society that is moving toward increasing scientific literacy, providing opportunities for wonder and curiosity are crucial. Stern (1971) identified intellectual curiosity as "the very source of science" and as a driving force in child development (Stern, 1973). Curiosity has also been noted as being "one of the most important spurs to educational attainment" (Day, 1982). Wonder has its place too: "To be surprised, to wonder, is to begin to understand" (Yolen, 1981). It is via wonder and curiosity that children begin to make sense of concepts.

National and State standards require teachers to cover specific curricula, which often leaves little time for inquiry-based or discovery learning. The initial wonder that children experience in a science activity is quite important for leaning: "while wonder is passive, the new light in which it reveals the world can be a potent stimulus for learning. Wonder, in fact, gives things their meaning and reveals their significance" (Hove, 1996). There are close connections between stimulating curiosity and learning: "Learning is largely due to the curiosity held by the children" (Maw and Maw, 1961). Furthermore, Hadzigeouruiou (1999) pointed out that curiosity stimulates conceptual development and heightened curiosity facilitated the retention of facts (Berlyne, 1954). Thus, a relationship between curiosity and learning has been empirically documented. Curiosity has also been known to lead to exploratory behavior causing individuals to seek information about the environment. Additionally there is evidence that curiosity is a factor that motivates individuals toward the acquisition of knowledge (Jenkins, 1969). McNay (1985) points out that "we teach children something immensely valuable when we set them the example of a curious person seeking to understand."

The role of the educator is to provide inquiry opportunities for students. To allow them time to question, formulate, and refine ideas about scientific phenomena they have observed. As Socrates stated, educators need to "move children in the direction of the answers by fostering exploration" (cited in Hamilton, 1961), yet educators fail to provide opportunities for wondering. Children's questions are often times simplistically answered by adults, leaving them with no desire to make further inquiries so the wondering ceases. Unfortunately "for many children wondering about the world stops when they start school," which is largely the result of the content driven classroom (Latham, 1996). The educational system is known for quelling curiosity in the classroom (Torrance, 1965), yet pedagogical literature strongly supports and advocates teachers to stimulate curiosity in the classroom (McNay, 1985). Educators need to keep young children's wondering and discovering alive through exploration and reflection (Latham, 1996).

Wonder and curiosity must be cultivated and encouraged in order for students to expand their existing scientific theories. Gardner (1993) suggested that children as young as four years old are capable of formulating theories and are also very eager to share their ideas. Encouraging children to wonder and be curious can be done in a number of ways: valuing children's ideas, creating a wonder filled environment, exposing children to new experiences, and giving time for exploration, discovery, and reflection (Latham, 1996). Children can make connections with the natural world if given the chance. Such a richly stimulating environment allows for play, wonder, ecstasy, and time to dream (Nikola-Lisa, 1988). Students build scientific understanding through observations and making sense of the world around them (Bransford, et al., 2000). Before anyone can establish a long-term "relationship" with a new idea or concept, the subject must first "come alive and become stimulated" (Whitehead, 1929). Wonder, curiosity, and mystery all play a vital role in what Whitehead (1929) deemed 'the stage of romance.' Children in particular should begin their engagement "in a 'romantic' way, in a way that makes them feel the excitement inherent in the subject" (Hadzigeorgiou, 2001).

SCIENCE INQUIRY

Schwab (1962) interpreted inquiry as referring to both pedagogy and content: teaching and learning of science as inquiry, or the act of inquiring; and instruction in which the production of scientific knowledge is viewed as the process of inquiry. Much more recently the National Resource Council (NRC, 2000) defined scientific inquiry as:

> The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as understanding of how scientists study the natural world.

Inquiry gives students the opportunity to participate in active investigations, instead of rote memorization of facts. In short, inquiry allows students to behave as "real" scientists by "observing, describing, questioning, and searching for answers" (Doris, 1991). As Cobb (1977) advises, children learn "by becoming," let children become scientists by doing as scientists do. There is strong empirical evidence that "supports the promotion of inquiry in science teaching" (Tamir, 1983). In fact, writers of the National Science Education Standards include "science as inquiry" as part of the content standards (NRC, 1996). These standards mandate a prominent place for inquiry learning in science curricula. Sustained, integrated, inquiry-based lessons need to be commonplace in science education, because the benefits of "engaging students in investigations to answer authentic questions are substantial and include more thoughtful and robust science learning" (Krajcik, et al., 1998).

Inquiry is not a new concept in science education, having been around since the 1950s. For many years, science educators in the United States have recommended inquiry be placed at the core of science instruction (DeBoer, 1991; DeBoer & Bybee, 1995; Lawson, 1995; NRC, 1996; Schwab, 1962; and Tamir, 1983). Despite the recommendation, inquiry is rarely implemented: "Inquiry is shallowly taught if at all at any educational level from kindergarten through college, due in part to the dominance of textbooks as the true curriculum, most of which are not inquiry oriented" (Yager, 2000, 1997). The reasons for the lack of inquiry based curricula in science education are numerous. Inquiry experiments take much more time than "cookbook" based experiments, which merely force students to follow a series of steps to get the correct, predetermined answers (Tamir, 1983). Teachers fear that they will not be able to meet state mandates if inquiry is routinely incorporated into the classroom (Welch, et al., 1981). Teachers who support inquiry know "that they could 'cover' the curriculum much more rapidly through lecturing and telling the student the 'correct' scientific ideas, but they realize that genuine learning is an active process, and they prefer to guide the students in actively 'uncovering' the curriculum by setting up appropriate learning situations" (DuVall, 2001a). However, many teachers did not grow up with inquiry-based curricula and are therefore inexperienced and ill-prepared for conducting such investigations in the classroom (Welch, et al., 1981). Some teachers mistakenly become dispensers of knowledge and are viewed as all-knowing, information sources spewing information in a traditional, lecture based manner. Students remain passive and are "rarely involved in direct experiences with scientific phenomena" (Wise, 1996). An inductive, discovery method approach to science allows students to discover concepts, where teachers merely act as guides or facilitators of learning, leading students toward solving their own problems and determining individual answers (DeBoer, 1991).

True inquiry lessons require that students engage in hands-on activities. The NRC calls for hands-on and minds-on activities in science education (1996) helping students learn first-hand versus vicariously. Inquiry instructional strategies include many different components such as hands-on activities, questioning, and discovery learning, "all of which [show] significant and substantial effects on achievement" (Wise and Okey, 1983). In addition to helping children develop science concepts, hands-on activities also promote a feeling of excitement. Hadzigeougiou (2001) claims that "hands on activities that incite wonder can and should be incorporated into many, if not all, science activities." Finding activities that promote wonder is not too challenging since children are authentically motivated to do science. They simply want to "find out!" They are highly intrigued by the unknown, so "the world around them is a mystery to be unraveled and solved" (Pearce, 1999). If kids are allotted the time to explore they naturally develop ideas, ask questions, and make personal discoveries.

Implementing inquiry closely ties with the steps of the scientific method. Science needs to be taught as "process or method rather than as content" (Rutherford, 1964). Students grasp these steps or components of scientific investigations by: making observations; asking their own questions; formulating hypotheses; obtaining background information through research; gathering, analyzing, and interpreting data; proposing answers; and reporting findings (Byers and Fitzgerald, 2002). These steps give students first-hand experiences being scientists and performing scientific investigations. Such experiences teach more than just content, they also educate children about very important "attitudinal 'meta lessons' such as curiosity, perseverance, experiencing failure, and dealing with doubts" (Tamir, 1983). It is student attitudes towards science that are much more important than a strong conceptual, factual base since their attitudes are the motivators for engagement (Stern, 1971).

Children engaged in scientific inquiry take ownership of their investigations and are therefore highly invested in their questions, experiments, data and results. It is very rewarding asking a question meaningful to the individual and then, through hands-on experiments answering the question of interest: "True inquiry requires a strong sense of personal ownership and investment in the curriculum. If the investigation originated with someone else's questions, was carried out with someone else's set of instructions and suggested materials, and came to someone else's predetermined conclusions, then where is inquiry" (DuVall, 2001b). When students are actively involved in "real science," exploring the unknown and making discoveries about the natural world, rarely do they discover knowledge new to humankind. However, research shows that "students engaged in inquiry discover knowledge new to themselves" (Byers and Fitzgerald, 2002). This new knowledge excites the discoverer, the "owner" of the finding, and causes him/her to "tell other kids about what [he/she] had done" (Comeaux and Huber, 2001). Students begin to experience "intellectual joy and a sense of personal accomplishment that begins with genuine curiosity and leads to deeper, more lasting understanding" (DuVall, 2001b). Inquiry into authentic questions produced from student experiences is at the heart of science teaching (NRC, 1996).

In order for students to ask thought-provoking, quality questions, educators must allow time for "both wandering (digging in and having experiences) and wondering (trying to figure out what's happening and why)" (Merriam, 1991). Nurturing children's sense of wonder helps them move from "concrete observations and experiences to rich, meaningful questions" (DuVall, 2001b). Instead of students simply sitting back, attempting to absorb knowledge they are actively participating in their own learning, which has many positive impacts. Inquiry empowers and excites students and has been known to have a positive influence on students' science attitudes: "Inquiry-based science can produce scientific literacy, knowledge of science procedures, vocabulary, conceptual understanding, and positive attitudes toward science" (Haury, 1993). Furthermore, Shymansky, et al., (1982) reported that inquiry-based curricula had a positive impact on student performance including general achievement, attitudes toward science, processing skills, problem solving, creativity, and even mathematics and reading skills. Inquiry naturally promotes habits of mind associated with science, such as openness, skepticism, curiosity, and honesty (Larzarowtiz and Tamir, 1994).

Teaching science as inquiry is necessary to be scientifically literate: "To be truly scientifically literate in the 21st century, one must possess more than a mere collection of facts. Scientific literacy involves understanding, analyzing and explaining those facts. It involves active investigation, not just acquiring and memorizing this body of facts" (DuVall, 2001b). Inquiry involves active investigation. In fact, children involved with inquiry lessons become scientists by doing as scientists do: "observing, describing, questioning, and searching for answers" (Doris, 1991). The National Science Education Standards views scientific literacy as "being capable of asking, finding, or determining answers to questions derived from curiosity about everyday experiences" (NRC, 1996). Science educators strive to produce scientifically literate children who sustain their motivation for learning throughout their lives. In doing so, there is a prominent "need to create inquiry-based classrooms that embrace the tremendous curiosity children initially bring to school" (DuVall, 2001b).

QUESTIONS

At the very core of science is questioning (Pearce, 1999; Shodell, 1995). Without questioning there would be no scientific discovery or opportunity to explore the unknown world. "Authentic questioning, generated from student experiences is the central strategy for teaching science" (NRC, 1996). Authenticity is more than just performing investigations into questions that scientists might ask; it includes questions that are meaningful to students and related to their lives (Blumenfeld, et al., 1998). A wide consensus exists among researchers that students abilities to ask questions should become "a central focus of current science education reform" (Zoller, et al., 1997). Pizzini and Shepardson (1991) identified a goal for science educators: "To nurture student questions by actively involving students in learning." Instructional models must be identified that enhance student questioning. Gallagher, et al., (1995) proposed that science curriculum reconstruction begins by making science in the classroom "look and feel like science as it is conducted in the real world." It is a simple matter of putting nature to the question (Harre, 1981).

In the average classroom, whether it is at the elementary or college level, students sit passively, asking few questions. Unfortunately the vast majority of questions asked in a classroom are from teachers, not students, although students, even at very early ages, are capable of asking questions (Good, et al., 1987). In fact, Cooper, et al., (1981) found that successful learners in kindergarten and second grade used questions as an aid to learning. The fact that authentic, student generated questions are a rarity in the classroom was identified nearly seventy years ago (Dale, 1937) and this same issue still exists today. Dillon (1990) pointed out that children everywhere are schooled to become experts, masters at answering questions, while they merely remain novices at asking them. The social structure of the classroom may actually discourage student questioning, where students remain inactive, taking on a participant role and the teacher functions as the active questioner (Dillon, 1982). Dillon (1988) pointed out an interesting paradox: "Those who ask questions – teachers, texts, tests – are not seeking knowledge; those who would seek knowledge – students – do not ask questions." Commeyras (1995) stated that students are in need of instruction on questioning do to the fact that "their natural inquisitiveness has been depressed through current schooling practices." Learning should be based on what the students are interested in and driven by students' desire to answer their own questions (Chin and Li-Gek, 2004).

Question asking is known to have many positive effects on student learning, comprehension, and knowledge (Costa, et al., 2000; Gallagher, et al., 1995; LaFrance, 1992). True learning is characterized not so much by the answering of questions as by the asking of them (UNESCO, 1980). Shodell (1995) expressed that "knowing the answer to a question may or may not indicate an understanding of the subject matter. However, being able to formulate a good question is always contingent upon such understanding." Generation of questions was identified as one of the key components in the cognitive processes that contribute to certain aspects of learning (Olson, et al., 1985). Marbach-Ad and Sokolove (2000) reported that students who ask questions retain material longer than those who do not. Additionally, these students are more likely to develop into independent learners. Question asking ability has also been linked with increased problem solving performance (Dori and Herscovitz, 1999). Hadzigeorgiou (1999) noted that teachers can identify conceptual difficulties by just listening to students' questions. Questions provide insight into what students know and understand and can be used to identify misconceptions (Harper, et al., 2003). As students pose questions they are exposing their thoughts, providing teachers with opportunities to identify children's conceptual understanding and conceptual change over time (Woodward, 1992; Watts, et al., 1997). The questions that students put forth, "activate their prior knowledge, focus their learning efforts and facilitate the understanding of new concepts, help them elaborate on their knowledge, and arouse their epistemic curiosity" (Schmidt, 1993).

Questions that are spontaneously asked by students do not indicate high quality thinking, but tend to be of a low cognitive level (White and Gunstone, 1992; Pedrosa de Jesus and Maskill, 1990). Dillon (1988) supports this argument: "Students rarely use questioning to seek knowledge, explanations, and understanding." Graesser and Person (1994) documented students' questions as very infrequent and unsophisticated; they are normally shallow, short-answer questions addressing content and interpretation of material. The vast majority are factual, closed questions with a single, unambiguous answer. Imaginative questions, which require reflection and understanding, are extremely rare (Chin, et al., 2002). Learners' questions have the capacity to show curiosity, reveal deep thinking and to focus on complex, detailed issues (Watts, 1997).

To improve students question asking ability they must be given practice: "Students' abilities to generate questions are fostered through active engagement. Asking good questions comes from having experience asking questions" (Krajcik, et al., 1998). Students questioning becomes more specific over time, revealing variables and detailed relations (Roth and Roychoudhury, 1993). Furthermore, the level of questioning is dependent on prior knowledge. Krajcik, et al., (1998) found that fifth and sixth graders tended to "generate low-level factual questions rather than questions that could extend their understanding of a topic and that the level of questions students asked depended on their prior knowledge." Lack of domain knowledge did not hamper students in raising questions, rather it affected the kinds of questions that were asked. Students who generate low-level factual questions are more apt to ask higher order thinking questions as they gain more background knowledge. Already possessing a basic understanding of a topic allows students to ask questions that have potential to extend their conceptual understanding (Scardamalia and Bereiter, 1992). Asking a meaningful question implies that a student has enough knowledge structure to formulate it and understand the answer (Miyake and Norman, 1979).

Questions have been categorized in various ways. Watts, et al., (1997) grouped questions into three categories including consolidation, exploration, and elaboration. Chin and Li-Gek (2004) categorized questions as follows: validation of common beliefs and misconceptions, basic information, explanations, and imagined scenarios. Scardamalia and Bereiter (1992) distinguished two broad categories of questions including basic information and wonderment. Basic information questions have a textbook quality to them, are considered uneducated guesses and have two subtypes: factual and procedural. Factual questions are closed-ended and require recall of information while procedural questions inquire about how a task is to be carried out. Wonderment questions reflect "curiosity, puzzlement, skepticism, or knowledge-based speculation." Wonderment questions include the following subtypes: comprehension, prediction, anomaly detection, application, and planning or strategy. Comprehension questions seek an explanation of something not understood while prediction questions involve speculation or hypothesis verification. Anomaly detection questions show skepticism or a cognitive conflict. Application questions are those in which students wonder what use the new, given information is to them. Questions falling into the planning or strategy subcategory reveal that students are temporarily stuck and want to know how to proceed forward. Bloom, et al., (1956) identified six question categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. Knowledge questions are the most basic which require memorization and recognition. Comprehension questions involve interpretation, translating from one medium to the next. Application questions require problem solving or applying information to produce some result. Analysis questions subdivide something to show how it is put together, whereas synthesis questions combine ideas to form a new whole. Lastly, questions in the evaluation category develop opinions, judgments or decisions.

FIELD TRIPS AND INFORMAL LEARNING CENTERS

Over the past twenty years there has been a considerable increase in the number of informal learning centers such as museums, interactive science centers, and field study centers (Dierkling and Falk, 2000). In fact, there are reports that over twenty million elementary and junior high students take field trips to informal learning environments each year (Kubota and Olstad, 1991). Field trips have been used for over seventy years and are regarded as an effective teaching tool (Prather, 1989). However, rarely do science teachers use out-of-school learning environments to stimulate and engage their students (Ramey-Gassert, 1997).

Learning in school tends to be "solitary, based in symbols and the abstract, and divorced from real-world experiences, with little or no connection with the actual objects or events represented" (Resnick, 1987). Wellington (1990) points out that science in schools has very little resemblance to that which is experienced in the natural world where science and technology are everywhere. Science is all around, on playgrounds, in the kitchen, and in the backyard garden. Collectively, these common spaces can offer a lifetime of investigations (Wellington, 1990). Students need to experience these common spaces and the myriad of natural phenomena they house. One way to provide exposure to natural phenomena is through field trips to informal science learning environments including science centers, museums, and zoos. Ramey-Gassert (1997) argued that these informal science learning environments should be an important part of science education redesign, but are often overlooked. These places provide students with captivating science experiences that can be closely tied into curricular objectives.

Field trips, defined as "a trip arranged by the school and undertaken for educational purposes, in which students go to places where the materials of instruction may be observed and studied directly in their functional setting" (Krepel and DuVall, 1981), have many positive effects on students, including cognitive and affective learning outcomes (Riley and Kahle, 1995). Empirical research suggests that the major advantages of learning activities in informal education settings lie in the affective domain (Meredith, et al., 1997). Teachers have observed that field trips foster positive attitudes toward science in their students (Tuckey, 1992). Prather (1989) noted that field trips enhance students' attitudes toward science as well as their information gain. In a study by Orion and Hofstein (1994) classes that performed better in the field achieved significantly higher scores on a knowledge test and gained more positive attitudes. Field trips tend to "catalyze, enrich or culminate" instructional units (Delaney, 1967) providing opportunities to illustrate and reinforce concepts, facts, and skills being taught (Keown, 1984). There are immediate outcomes to the field trip experience including retention of knowledge (Knapp, 2000). Gagne and White (1978) noted that those participants actively involved in a field trip demonstrated a better understanding of course material immediately following the field trip and showed significantly less loss of knowledge over a twelve week period. Experiences that children have while participating in a field trip produce memorable events that stay with them long after the completion of the program (Knapp, 2000).

Science education is taught in three distinct environments: classroom, laboratory, and outdoors. It is clear that the outdoor environment is the one most neglected by teachers, curriculum developers, and researchers (Orion and Hofstein, 1994). There is a longstanding emphasis on outdoor experiences for young children (Bredekamp and Copple, 1997) that goes back at least to the 1800s. Louis Agassiz stated: "read nature, not books" (cited in Cooper, 1945), yet today children spend very little time outdoors, whether it be at school or home. Most of their time is spent in buildings or vehicles (Rivkin, 2000). If at all possible, students should go out into the field and experience nature firsthand (Krupa, 2002).

Field trips tend to be process, rather than content, oriented. The process approach "focuses on the interaction between the student and the environment; students actively construct information from the environment, rather than passively absorb information from teachers" (Orion, 1993). Since cognition is deeply rooted in perception (Gleitman and Liberman, 1995), and the outdoors is a prime source of perceptions, outdoor learning experiences should positively impact student learning. When the outdoor environment is integrated into a school's curriculum, achievement among students is higher (Lieberman, 1999). Peck (unpublished) discovered both cognitive and affective advantages for an outdoor, as compared to an indoor, environment teaching strategy (Cited in Martin, et al., 1981). McNamara and Fowler (1975) found that critical thinking is enhanced in the outdoor environment. If parts of a concept can be related to the students' immediate environment, the concept has a much better chance of being understood. Children need to be given the opportunity to experience the infinite and diverse sensory qualities of the world (Keown, 1984).

Field trips, as well as informal learning, which is characterized by free choice and unstructured and nonsequential experiences (Griffin and Symington, 1997), can promote student wonderment, curiosity, and motivation. Promoting curiosity ultimately effects student learning: "By nurturing curiosity, the desire to learn can be enhanced" (Ramey-Gassert, et al., 1994). Pedretti (2002) acknowledges that "science centers can generate a sense of wonder, interest, enthusiasm, motivation, and eagerness to learn, which are much neglected in traditional formal science training in school."

Children tend to lose their curiosity and natural ability to learn via exploration by the third grade do to the emphasis on rote learning in formal education (Harte, 1989). Science environments can enhance children's sense of wonder through direct interactive experiences with real objects (Falk, et al., 1986). Science centers provide rich learning environments for students which promote: curiosity resulting in intrinsically motivated learning, multiple modes of learning, play, and exploration during the learning process" (Semper, 1990). These experiences are crucial in fostering a child's natural curiosity, which in turn lays the foundation for conceptual science learning (Bresler, 1991). In addition, learners in an informal setting tend to be intrinsically motivated to gain personal meaning from their learning, which has been shown to correlate with memorizing facts and performing well on tests (Ramey-Gassert, 1997).

Field Trip Planning

McCurray (1895) divided the field trip experience into three general categories: preparation, trip itself and follow-up activities (cited in Krepel and DuVall, 1981). There have been numerous studies about field trip preparation and pre-visit activities, many of which show positive effects on student learners (Koran, et al., 1983). It has been shown that pre-visit instructional materials are valuable for students of all ability levels (Gennaro, 1981). Learning new content is strongly influenced by an individual's past knowledge (Falk, 2004); therefore, pre-visit preparation is essential to maximize student learning. Abad (2003) performed background activities two weeks preceding a field trip to establish a foundation for understanding the purpose of the field trip. Preparing students' background knowledge enabled them to readily absorb information acquired during the field trip. Preparation also resulted in students asking "off-the-cut" technical questions. Students generated questions, which led to attentive learners during the course of the field trip. Novak (1977) stated: "Carefully designed curricular materials and advance organizers can be effective instructional strategies for learning new information."

Post visit classroom activities are essential for reinforcing experiences, facts, skills, and concepts learned during the field trip (Bitgood, 1991). Rudmann (1994) suggested that post-visit materials, projects, or activities be administered to help students reinforce and transfer the learning experience beyond the field trip. However, there typically is little or no follow-up (Kubota and Olstad, 1991). Teachers seldom implement post-visit activities designed to provoke students to recall and extend their learning experience (Bitgood, 1989). Griffin and Symington (1997) noted that most teachers indicated that they would in fact do some type of follow-up, yet the results showed that there was very little done, less than the teachers had planned on. Additionally, very little research has been conducted on the influence of post-visit activities on student learning: "The effects of post-visit activities on learning from informal experiences have not been described extensively in the literature" (Anderson, et al., 2000). Lucas (1999) did however document a teachers experience with post-activities: "Mr. Jones remarked that he was surprised and pleased to conclude that the work sheet activities (post field trip) were helping students to consolidate information that otherwise might have remained fragmented." The benefits of post-visit activities could be substantial, but it has been neglected by researchers in the past (Anderson, et al., 2000).

CONCEPT MAPPING

As students learn, they look to their prior knowledge and link new information with what they already know. Novak (1993) stated that "meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures." Learners "actively try to incorporate new information into existing knowledge frameworks and thus make the new information understandable" (Resnick, 1983). New knowledge therefore reshapes prior knowledge (Freeman and Urbaczewski, 2003). Rumelhart and Norman (1981) affirmed this by pointing out that the majority of learning that occurs in life involves the incorporation of new facts into prior knowledge or the modification of existing organizational structures. Knowledge is highly interconnected. Ideas and concepts relate to each other and are stored as schemas, mental storage mechanisms that are structured as networks of knowledge (Marshall, 1995). According to Schau, et al., (1997), "knowledge must be organized into mental networks in order to be accessible from long term memory." Expertise requires "connected understanding" between concepts (Schau, et al., 1997). Research shows that understanding in a subject domain is associated with a rich set of relations among concepts (Mintzes, et al., 1997). Cognitive and educational psychologists suggest that the "organizational property of knowledge can best be captured with structural representations" (Bower, 1972).

Concept mapping is a valuable assessment tool used by educators and researchers to evaluate students' "connected understanding" of various science concepts (Novak, 1990). Concept maps have been utilized since the 1970s (Rice, et al., 1998) and have been effectively implemented with young children: "Children as young as primary grades have been found to be capable of developing and explaining concept maps" (White and Gunstone, 1992). Maps are constructed on paper or computers and are graphs that show how ideas or topics are related to each other (Crandell, et al., 1996). The fundamental unit of the map is the proposition, which is composed of two nodes, or concepts, linked together by a labeled line. The lines between nodes are known as relations (Ruiz-Primo, et al., 2001). The various components form a mental map and show students' connected understanding (Ruiz-Primo, et al., 2001). According to Wallace and Mintzes (1990) concept mapping was the only approach that attended to both student knowledge and the organization of that knowledge. McClure, et al., (1999) agreed that maps reflect the content and the organization of students' knowledge.

Traditional assessment techniques give students little opportunity to demonstrate knowledge and mastery beyond the assessment technique. Concept maps, visual representations of cognitive conceptualization, give viewers of the map an inside look into that student's mind (Freeman and Urbaczewski, 2003). Responding to traditional objective test formats depends on recall of information. The result is that "students' responses are strongly constrained by the context imposed by the test items. This limitation on students' responses may mask important individual differences in the organization of students' knowledge" (McClure, et al., 1999). The National Science Education Standards call for assessment processes that "probe the extent and organization of student's knowledge" (NRC,1996). The Standards also advocate for assessment that truly reflects what students do in fact understand (NRC, 1996). Furthermore, the Benchmarks for Scientific Literacy emphasize the importance of "coherence and connectedness" in science learning (American Association for the Advancement of Science, 1993). According to Markham and Mintzes (1994) scores derived from concept maps measure a very different dimension than scores revealed in more commonly used psychometric instruments like multiple choice tests. However, Freeman and Urbaczewski (2003) showed that students who typically do well with traditional assessment also score high with mapping: Students who typically do well "produced concept maps that were larger with more relations." Additionally, students view concept mapping as a fun task, which is a rarity amongst other assessment methods like exams and quizzes (Freeman and Urbaczewski, 1999).

Reliability and validity are of the utmost importance with any assessment method. Reliability refers to the consistency of scores assigned to students' concept maps, while validity is the extent to which students' cognitive structures, on the basis of their concept map scores, can be supported logically and empirically. Concurrent validity refers to the consistent correlations between concept map scores and other measurements of student achievement (Ruiz-Primo and Shavelson, 1996). Markham and Mintzes (1994) support the validity of concept maps as a measure of structural knowledge since it captures the configural property of knowledge better than any other presently available technique. Rice, et al., (1998) found high correlations between concept map scores and unit multiple choice tests providing strong evidence of the concurrent validity of the map scores. Further evidence of the concurrent validity of concept maps was presented by Wallace and Mintzes (1990) and they concluded that concept map tasks were a valuable tool for educational researchers.

Reliability and validity are largely dependent on the scoring method used to evaluate maps (McClure, et al., 1999). Ruiz-Primo and Shavelson (1996) argued: "If concept maps are to be used with confidence as valid measures of student achievement in support of classroom instruction, it is essential that scoring methods be developed and validated that result in scores that reflect a stronger relationship between concept mapping and student learning in science, scores that are reliable measures of intended learning outcomes" (Ruiz-Primo and Shavelson, 1996). Concept maps have various scoring systems from counting the number of nodes and linking lines to evaluating the accuracy of propositions (Ruiz-Primo and Shavelson 1996). Certain scoring systems assign points for the numbers of concepts, relationships, branchings, hierarchies, crosslinks, and examples given. McClure, et al., (1999) looked at the reliability and validity of several scoring techniques including holistic, relational, and structural, each with and without a master map. The holistic scoring method is somewhat arbitrary with raters assigning a value one to ten based on mapper's overall understanding of concepts. The relational method evaluates propositions, each of which is ascribed a point value according to "correctness" of the proposition (McClure and Bell, 1990). Goldsmith, et al., (1991) found that scoring based on relationships was the most robust indicator of understanding. The structural scoring method looks at both correctness of propositions and hierarchies within the map (Novak and Gowin, 1984). McClure, et al., (1999) found that the relational scoring method used in conjunction with a master map yielded the most reliable scores. The master or expert map, is the concept map constructed by a knowledgeable expert in the field, usually a teacher. This expert map is used as a rubric when scoring student maps. Rye and Rubba (2002) noted that authorities favor methods that employ an expert/criterion map and emphasize the use of concept relationships in deriving scores. Student concept maps typically are assessed by comparing them to an expert's map in either quantitative or qualitative forms (Freeman and Urbaczewski, 2003).

Concept maps have structural differences. Typically students are asked to construct-a-map from scratch on a piece of paper (Ruiz-Primo, et al., 2001; Schau, et al., 1997). The alternate fill-in-the map method is pre-formed. Students are given a map where some of the concepts and/or linking words have been omitted. Students fill in the blank nodes or linking lines (Schau, et al., 1997). There is controversy over which structural method is best for evaluating student learning. Schau and Mattern (1997) argued that asking students to draw a map from scratch "imposes too high a cognitive demand to produce a meaningful representation of their knowledge." However, the flipside to this argument is that by using the fill-in-the-map technique a structure is being imposed on the relations between concepts; therefore, "it is difficult to know whether or not students' knowledge structures are becoming increasingly similar to experts" (Ruiz-Primo, et al., 2001). Ruiz-Primo, et al., (2001) found that construct-a-map from scratch scores most accurately reflected the differences across students' knowledge structure.

INTERVIEWING

Interviews are a very common way to gather data. Briggs (1986) estimated that approximately 90 percent of all social science investigations use interviews in one way or another. In fact, both qualitative and quantitative researchers rely on the interview for data collecting. The interview is not just used by social science researchers; it is a "universal mode of systemic inquiry" (Holstein and Gubrium, 1995). Interviewing is one of the most powerful ways to gather information and used to understand fellow human beings (Fontana and Frey, 2000). According to Bogdan and Biklen (1982) an interview is a "purposeful conversation, usually between two people… that is directed by one in order to gain information." More simply put, an interview is a "conversation with a purpose" (Lincoln and Guba, 1985). Interviews are used to find out what is on someone's mind, which cannot be observed directly (Patton, 1990). According to Holstein and Gubrium (2002) the "interview conversation is a pipeline for transmitting knowledge."

Traditional one-on-one interviews are divided into two broad groups: close-ended interviews and open-ended interviews. Close-ended interviews consist of an interviewer asking predetermined questions, while open-ended interviews allow for question development within the interviewing process (Bogdan and Biklen, 1982). An open-ended interview is much more informal. The conversation makes natural progressions and is largely shaped by the individual situation and context of the dialog exchange (Hannabuss, 1996). The purpose of the open-ended interview "is not to put things in someone's mind, but to access the perspective of the person being interviewed" (Patton, 1990). Unstructured interviews provide a "greater breadth of data than the other types, given the qualitative nature" (Fontana and Frey, 2000). On the other hand, close-ended interviews are fully structured with a schedule of questions answered by each respondent (Hannabuss, 1996). With pre-established questions and a limited set of response categories, there is little room for variation in responses (Fontana and Frey, 2000). This type of interview makes organizing and quantifying findings rather straightforward (Hannabuss, 1996). Fontana and Frey (2000) agreed that structured interviews are a way of "capturing precise data of a codable nature in order to explain behavior within pre-established categories."

In regards to interviewing, some researchers believe that the "data speak for themselves, that the researcher is neutral, unbiased, and invisible" (Fontana and Frey, 2000). Holstein and Gubrium (2002) take a much different stance: "Respondents are not so much repositories of knowledge – treasuries of information awaiting excavation, so to speak – as they are constructors of knowledge in collaboration with interviewers." In active interviewing the interviewer is not "invisible," but rather aids in the dissemination of knowledge. Regardless of the type of interview, whether it be highly structured, standardized and quantitatively oriented or a free-flowing informational exchange, they are all interactional. Meaning construction is unavoidably collaborative (Sack, et al., 1974), which is why all participants in an interview are involved in making meaning. The interviewer offers ways of conceptualizing issues and making connections that help elicit responses (Gubrium, 1993). Holstein and Gubrium (2002) are in favor of active interviewing: "The active view eschews the image of the vessel waiting to be tapped in favor of the notion that the subject's interpretive capabilities must be activated, stimulated and cultivated." Through the interview process respondents construct, not merely discover or convey information.

CHAPTER 2

METHODOLOGY

INTRODUCTION

Images in this thesis are presented in color.

Seeds of Science is a program offered at Michigan State University's 4-H Children's Garden. Classes visit on multiple days, providing students with many opportunities to explore and discover in the garden. The Seeds of Science curriculum offers students the chance to wonder, ask questions, make keen observations, and experience authentic, hands-on plant science investigations. Classes are encouraged to visit for 3 full days, spaced about one week apart. The field trips are integrated into the schools' plant science curriculum and can serve to introduce or reinforce classroom content. The curriculum is shaped in collaboration with teachers, so specific needs can be met.

Five schools of fourth grade students participated in the Seeds of Science field trips. Schools A and D each visited for 2 full days and 1 half day for approximately 10 hours spent at the Children's Garden (Table 1). School B came out on 4 short field trips, which equated to about 6 hours at the gardens. Schools C and E spent 3 full days at the garden or about 12 hours.

Table 1. Logistics of Seeds of Science field trips to the 4-H Children's Garden.

School	# of Students	Season	# of Days	Hours
A	56	Spring 2004	3	10
B	41	Spring 2004	4	6
C	43	Spring 2004	3	12
D	82	Fall 2004	3	10
E	71	Fall 2004	3	12

Post-field trip follow up was also a part of the Seeds of Science experience for all schools except school A. Post-visit activities allowed students time to conclude an experiment started at the gardens, design a new experiment and continue asking questions. Post-visit activities, whether teacher or expert led, reinforced concepts explored at the 4-H Children's Garden.

All schools involved in Seeds of Science were from the same school district in Ingham County, therefore utilizing the same science curriculum. Schools A, B, and C visited the 4-H Children's Garden in the Spring of 2004, whereas schools D and E visited in the Fall (Table 1).

FIELD TRIP CURRICULUM

Wonder Wall

During the course of the field trips students were encouraged to share their questions and were given opportunities to write those questions on a Wonder Wall. Garden experts introduced the Wonder Wall on the first field trip and it was available to students in subsequent field trips. Experts expressed that they valued students' questions and assured them that their questions would be addressed at some point during Seeds of Science. Questions were organized after the field trip and specific questions were answered as a whole group activity during the following field trip. Wonder Wall questions were also addressed in smaller groups where more of a discussion took place. Students did not merely ask questions, but were also invited to try answering their peers' questions. Students from school E were given questions that had been posted to the wonder wall on a previous visit and were asked to work in groups to come up with potential answers. These answers were then posted on the Wonder Wall below the corresponding questions and later shared with the group.

Science Process

To help students get a better idea of the steps involved in the science process, seven students were selected, each of whom held up a card with a specific step written on it. The remaining students had to order their seven classmates to demonstrate steps 1 through 7 of the process. The significance of each step was clearly explained to all students. It was further demonstrated that the shape of the science process was not a straight line, but rather a spiral. The line of students formed a circle and it was emphasized that the science process does not stop after drawing conclusions and answering the research question. New questions must be asked and the process continues.

Authentic Experiments

Two experiments were set up during the first field trip to give students hands-on experiences with the steps of the science process. One experiment focused on how fertilizer effects the growth of fast plants. Students researched these plants by viewing a wondercast that was developed at the 4-H Children's Garden (4hgarden.msu.edu/wondercast/). The wondercast was a short video comparing the growth of fast plants in earth soil versus those grown in mars simulated soil. Students had to answer several questions about the differences in plant growth from these two soils (Appendix A). Students formed hypotheses for the experiment and predicted how these plants would grow if given fertilizer (Appendix B). Each student sowed a fast plant seed and added 2, 5, or 7 pellets of fertilizer to the potting media. In order to have a control, some students did not incorporate any fertilizer pellets into their media. During the second and third visits to the gardens students gathered plant growth data by recording plant height for each of the fertilizer treatments. During the final data collection, class data was combined and the question of how fertilizer effects plant growth was answered.

To reinforce the science process steps a second experiment was designed to compare lettuce cultivars (Appendix C). The experimental objective was to determine the best lettuce cultivar to grow for school lunches. After students were given background information about lettuce, hypotheses were formed, and the experimental set up was explained. Six different cultivars were sown, each student sowing one cultivar. Students were asked what data should be gathered and data tables were created for the second and third field trips that reflected students' data collection suggestions (Appendix D). Students collaborated in groups, using rulers to take height measurements of all cultivars. Students were also responsible for sketching the leaves, paying special attention to the leaf margins. Additionally, they had to indicate the color of each cultivar and note any other observations like differences between cotyledons and true leaves.

Plant Parts

Instead of spending a short period of time on all plant parts, teachers usually opted to explore certain parts in greater detail. Therefore, the plant parts that were covered differed slightly among schools. Garden exploration and observation was crucial in learning any of the plant parts: roots, stems, leaves, flowers, fruits, and seeds.

Sketching, describing, and collecting were common tasks carried out by students. Topics such as pollination, seed dispersal, and plant variation were introduced. When leaves were discussed the process of photosynthesis was examined. Some schools were involved with a stomata activity where the classroom was transformed into a leaf, each student becoming either a carbon dioxide or oxygen molecule. Four students, two at each door of the classroom, acted as guard cells letting only oxygen out and carbon dioxide in.

The majority of teachers decided to spend a significant amount of time on flower parts simply due to the readily available resources at the gardens, which are unavailable at their schools. On the first visit, participants were allowed to go out into the children's garden, collect a flower, split it open to reveal the reproductive parts and place it into a flower press. During the following visit, students were introduced to the different flower parts by watching as a garden expert assembled a flower on a felt board. Students then placed their pressed flower onto a piece of paper, labeled the various flower parts, and laminated their work. Through the course of the lesson pollination, seed formation, and fruit development were discussed. Schools A and B did not do a flower press, but rather two flower dissections. Students separated petals, stamens, and pistils, which were then glued to a sheet of paper (Appendix H). Dissecting microscopes were available and flower parts were examined up close. Some microscope stations were set up ahead of time with specific flowers and focusing questions: "How many pistils do you see?" "Which of these two flowers contains the female parts?"

Plant Problems

Insects, diseases, and nutrient deficiencies can all cause noticeable symptoms on plants, which without treatment can result in plant death. Students were shown a couple of plant problems in the children's garden and asked what may have caused such symptoms (yellow leaves, white coating on leaves, holes in plant tissue). After an explanation of plant problem causes, time was given for independent exploration. Each student found two plant problems, collected one leaf from each troubled plant, sketched and described the problem in detail (Appendix I). In the classroom, students used plant problems software designed for Michigan State University's 4-H Children's Garden (Lownds and Comm. Tech. Lab, 1999). The highly interactive software gave participants the opportunity to identify their own plant problems, whether it was powdery mildew, aphids, or iron chlorosis. Microscopic images allowed students to clearly view the disease causing organism or plant symptom. Additionally, the classroom was equipped with several dissecting microscopes, which gave further opportunity to correctly diagnose the plant problem by comparing the computer images with actual ones. Students then had to determine how to treat the problem, by selecting one of these options: doing nothing, biological control, plant removal or spray. Before they chose an action they could see what the ecological effects on the rest of the garden including humans, frogs, dragonflies, and butterflies would be. Ultimately a mode of action was determined and explained.

POST-FIELD TRIP CURRICULUM

Lettuce Growth and Evaluation Experiment

The lettuce experiment, started at the 4-H Children's Garden, was completed in participants' classrooms. In the classroom, students collected one more set of data, which again included height measurements, leaf observations, and also included a taste test of all six lettuce cultivars (Appendix E). For both the leaf observation and taste test, students were to ascribe a value 1 to 5 for each cultivar. A score of one equaled unacceptable. In the case of the leaf evaluation, leaves were brown, shriveled or close to dead. A score of five was for an outstanding leaf: striking with fantastic color and unusual, appealing shape. A similar scale was used for the taste evaluation. These numbers were used later in the lettuce report to create bar graphs (Appendix F). The lettuce report ultimately led students to answer the overarching question, which lettuce would be the best to grow for school lunches? Three factors weighed into this decision: 1) plant height, 2) overall leaf appearance, and 3) taste. After reviewing all three of these factors students selected what they viewed to be the best lettuce and justified their selection. After students shared their answers they had to identify a new research question that would be a follow up to the experiment they had just completed.

Student Designed Experiments

Upon conclusion of the lettuce experiment, students were encouraged to continue the science process by asking a new research question. The new question had to be testable and again focused around lettuce, due to its rapid growth. The researcher emphasized the need to have a testable question by using examples from the wonder wall:

"How many plants are there in the world?" versus "What would happen if seeds were planted really deep?" The first question illustrated the difficulty one might have in getting an answer, while the second question suggested how an experiment could easily be designed to get an answer.

Students were introduced to the experimental set up, which consisted of a self-watering plant growth system. The system was made of a small Tupperware container as a water reservoir, a piece of felt as a wick, and a Styrofoam cup with media as a planting container. Each student was given two growing systems so they could design an experiment to make comparisons between two treatments. The researcher showed how the two systems could be used to answer the wonder wall question of how depth of sowing affects lettuce growth. Students were then asked to think about a question that interested them and share it with the researcher, who verified that it was testable and had only one variable.

A demonstration of the making of a peanut butter and jelly sandwich was used to illustrate the meaning of a procedure. The researcher made the sandwich step by step according to what students suggested, which clearly showed the necessity of detailed procedures. Students then formed hypotheses and procedures according to their individual questions (Appendix G). Seeds were sown and participants were instructed to take the individual growing systems home, care for them, and note any differences between their two treatments.

On-Line Wonder Wall

An on-line Wonder Wall was created in collaboration with Michigan State University's 4-H Children's Garden and the Communication Technology Lab (Lownds, et al., 2004). The on-line Wonder Wall was implemented so that students could remain connected to the gardens and have their questions answered post-field trip. Times were arranged when garden experts connected on-line with participating classrooms. On-line chats took place where experts led students in plant science conversations. Students also posted questions to the Wonder Wall, which were answered by an expert.

Post-Field Trip Follow Up

After the Seeds of Science field trips were completed, schools were involved in various forms of post-visit follow up, which was carried out by either the teacher or a garden expert (Table 2). School A did not participate in follow up activities. The teacher from school C led post-field trip activities on her own after engaging in a 10 minute conversation with the researcher. The researcher explained what was necessary to complete the ongoing lettuce experiment and the teacher facilitated one final data collection. Students from school C were also introduced to the on-line Wonder Wall. School B was visited by the researcher at two different points for field trip follow up, with the first visit lasting 30 minutes and the second 50. Lettuce data collection occurred during both visits, with the last visit also including time for participants to fill out a lab report (Appendix F). The researcher made one follow up visit to school D during which the final data collection and lab report were completed in about 45 minutes. The researcher went to school E at two different times following the field trips with each visit averaging 45 minutes. During one visit the lettuce experiment, including the lab report, was completed. A different visit focused on the development of inquiry based, student designed experiments. The same school also utilized the on-line Wonder Wall to maintain connections with the garden.

Table 2. Post-field trip follow up leader and activities.

School	Teacher Led	Expert Led 1 Visit	Expert Led 2 Visits	Final Data Collection	Lab Report	Student Designed Experiments	On-line Wonder Wall
B			X	X	X		
C	X			X			X
D		X		X	X		
E			X	X	X	X	X

CONTENT KNOWLEDGE ASSESSMENT

Concept Maps

Student knowledge of plant science was assessed through the use of three different concept maps: science process, plant and flower parts, and plant problems (Appendix J). The maps differed not only in content, but also structure. Two different concept mapping techniques were utilized including a modified, high-directed "fill-in-the-map" technique and a low-directed "construct-a-map-from-scratch" technique (Schau, et al., 1997). Traditionally, the fill-in-the-map method requires participants to work from a pre-constructed, skeleton map where nodes/concepts, lines and linking words are given, but randomly selected nodes and linking words are omitted. Subjects are to fill in these blanks. Skeleton maps for both science process and plant/flower parts were developed that included 13 concepts for the former and 39 for the latter. Concepts were selected based on the Seeds of Science curriculum, which was largely shaped by the curricular needs of the teachers. Significant concepts were identified and arranged onto maps, but no connections of any sort were given on either of the maps. Participants were directed to connect the concepts with lines to represent relationships between them. It was clearly stated that multiple lines could extend from a single concept, and all concepts on the maps, regardless of shape could be linked. Students were also informed that if a concept was unfamiliar it did not have to be linked. Participants were not required to label the lines and thus did not create complete propositions; however, they were encouraged to include linking words if they felt comfortable with the task. In contrast, the map constructed from scratch, included only one central concept, "plant problems," from which subjects were asked to create their own concepts and links.

The science process map was given within one week of the first field trip, while the other two maps were administered between the first and second field-trip visits. The same concept maps were distributed following the conclusion of all post-field trip activities. Participants were given a brief explanation of concept mapping, shown an example, and were given 10 minutes to complete each map. Many finished before that time.

Concept map scoring

Two expert concept maps were created and used as rubrics when scoring the pre-constructed science process and plant/flower parts maps (Appendix K). The concept map scoring rubrics were developed prior to any data collection. Two experts in the area worked together to identify appropriate links between the various concepts. Weights were assigned to each link according to the strength of the relationship and given values of 3, 2, 1, 0 or -1 point(s). All participant concept maps were photocopied and links were color coded according to the point value of the weighted relationship. Links awarded the maximum score of 3 points showed the highest level of thought and structural organization of concepts. Two point links showed less structural organization than 3-point links, but more so than 1-point links. Links awarded 1-point are accurate connections, but show little organization of concepts. Links that scored 0-points show an accurate relationship between two concepts, but not the type of relationship that the maps were intended on evaluating. For instance, the concepts male and female, when linked together show a relationship, but the expert rubric was designed to evaluate how male and female are related to flower parts, so no points were awarded for such a connection. Scores of -1 reflect completely inaccurate connections and were incorporated into the rubric to avoid wrongfully rewarding random guesses. Two different experts using the same rubrics scored 20 total maps, 10 each of science process and plant/flower parts. Scores were very similar, differing by 1 or 2 points. Scores with greater differences were the result of human error, overlooking links. One expert, therefore offering consistency and uniformity in scoring, further evaluated all concept maps.

Science Process

The expert science process rubric contained 8, 3-point links, 12, 2-point links, and 3, 1-point links for a maximum score of 51 points. There were specific connections that were of interest on both the science process and plant/flower parts map. The science process map had 7 specific connections, each of which was a 3-point link. The connections linked the steps of the science process to each other, versus connecting each step to the concept, science process. For instance, ask a question linked to research which linked to hypothesis, etc. These links account for 6 of the specific connections. The final connection of interest links the concepts science process and ask a question; therefore identifying the start of the process.

Plant and Flower Parts

The expert plant/flower parts rubric had 16, 3-point links, 46, 2-point links, and 15, 1-point links for a maximum score of 155 points. There were 4 specific connections, weighted at 3-points each, on the plant/flower parts map, which showed expert organization of flower parts. The connections included pistil to stigma and to ovary, stamen to anther, and anther to pollen.

Plant Problems

Individual plant problems concept maps were not ascribed a score. Rather, concepts from all student maps were placed into a sub-category like "not enough water," grouped into a larger category like "growing conditions," and then collectively tallied to compare differences between pre-visit and post-visit maps. An example of a sub-category is weather. Concepts such as storm, tornado, and high winds all fit into this sub-category, but individual student maps could only receive credit for 1 concept per sub-category even if several were listed. This was to avoid giving credit for very similar concepts like tornado and high winds. Sub categories were numerous, but the major plant problem categories were: growing conditions, insect and disease, humans, symptoms, treatments and miscellaneous. Growing conditions groups the essentials for healthy plant growth (primarily abiotic factors) such as water, fertilizer, sun, air, etc. Insect and disease included biotic factors that cause plant problems like aphids and powdery mildew. Humans refers to actions of people that directly or indirectly cause plant problems including pollution or plant removal for human interest or needs, such as construction, making paper or perfume. Symptoms included descriptions of the plant problems such as shriveled, spotted, or holey leaves. Treatments suggested what might be done to overcome the plant problems including plant removal, replacement, spraying, or taking no action.

Case Studies

Four students' pre- and post-visit science process and five students' plant/flower parts concept maps were selected as case studies for in depth analysis. Maps were selected based on one or more of the following criteria: substantial increase in number of valid links, re-structuring of knowledge including higher-order, 3-point links, or a notable increase in the number of specific connections.

Student Lab Reports

Upon completion of the lettuce experiment, students were asked to document their findings in a lab report (Appendix F). Each step of the scientific process was emphasized. Students used their collected data to create graphs, make sense of their findings, and ultimately answer the question being tested. The researcher offered guidance, examples, and answered questions as students focused on each step of the report. After completing the lettuce experiment and answering the question of interest, participants from schools B and D asked new questions that would be ideal for the next experiment. Due to time limitations a new experiment was not set up. The researcher and an additional garden expert visited school E to assist students in developing their own, personal experiments.

Interviews

Students from schools A, B, and C were interviewed within one week of the completion of all post-field trip activities. Interviews were unstructured and driven by a set of open-ended questions such as, "What things did you enjoy doing at the gardens? What sticks out in your memory?" "Do you have any unanswered questions?" The bulk of the interview questions came from reviewing participants concept maps. The maps were used as a tool to evoke an explanation as to why certain concepts were linked together. Students were allowed to add or delete connections on the maps during the interviews to stimulate further discussions.

Students from schools D and E were interviewed at two different points, one week prior to the first field trip and within 3 days following post-field trip activities. Interviews were semi-structured with subjects answering a set of questions, however more questions were asked upon hearing subjects' responses. Questions developed in advance organized the conversation: "What do you wonder about when it comes to science?" "Describe a time when you were doing science." "What are the different parts of a plant?" In addition to these questions, post-interviews for school E also included a sorting task. Students were asked to group the following words according to how they felt they should be organized: pistil, stamen, stigma, anther, pollen, root, leaf, flower, stem, fruit and seed. Participants were then asked to justify their groupings. All interviews were digitally recorded and later transcribed.

WONDERMENT ASSESSMENT

Questions

All questions regardless of source (Wonder Wall, on-line Wonder Wall, student designed experiments, or interviews) were initially divided into basic information and wonderment questions (Scardamalia and Bereiter, 1992). According to Bloom's taxonomy, basic information questions are knowledge based questions, which are factual or procedural. All wonderment questions were divided into one of the following categories: comprehension, application, analysis, or synthesis (Bloom, et al., 1956). Comprehension questions seek to interpret or retell information. Application questions are of higher order than comprehension questions and typically produce some result, a form of problem solving. Analysis questions subdivide something to show how it is put together, and synthesis questions combine ideas to form a new whole (Bloom, et al., 1956).

On-line Wonder Wall

All Wonder Wall questions from the various field trips were recorded and organized. Schools C and E were introduced to the on-line Wonder Wall following post-field trip activities. A garden expert went to each of the schools and explained how to use the technology. After a brief introduction students posted questions and engaged in on-line synchronous chats for 30 minutes with garden experts at the 4-H Children's

Garden. Students from school E were given the web address and some participants accessed the Wonder Wall at a later date. Asynchronous communication between garden experts and select students occurred for up to three and a half months after initial exposure to the on-line Wonder Wall. The on-line Wonder Wall provided students with an opportunity to ask questions about their personal experiments they were tending to at home. Experts answered questions in a timely manner.

CHAPTER 3

WHAT IMPACT DO SEEDS OF SCIENCE FIELD TRIPS HAVE ON STUDENTS' LEARNING AND KNOWLEDEG STRUCTURE?

RESULTS

CONCEPT MAPS

Concept maps administered pre-field trip and post-field trip provided evidence that students had increased their knowledge and reshaped their knowledge structure of plant science. Students' science process and plant and flower parts post-maps more closely resembled the expert map than the pre-maps did. The plant problems concept maps revealed a broadening of students' understanding of issues related to causes, treatments, and symptoms of plant problems.

Science Process

Students' understanding of science process increased significantly following their Seeds of Science field trip experiences for four of the five schools examined (Table 3). The average pre-visit score was 12.7 points while the average post-visit score increased 3 points. When compared to an expert response map, students correctly identified 24.9% of the concepts and this increased to 30.8% following the field trips.

Table 3. Pre and post-visit science process concept map scores.

School	N	Mean Pre-visit	Mean Post-visit	Sig. (2-Tailed)
All	262	12.7	15.7	.000*
A	55	12.9	17.0	.001*
B	29	12.6	16.6	.001*
C	39	12.7	16.0	.013*
D	77	14.3	15.5	.253
E	62	10.5	14.3	.001*

*Differences between pre- and post-visit scores were analyzed with paired T-tests. Significant difference at $p < .05$ is marked with asterisk.

There were seven specific connections that were also examined in the science process concept map. The overall mean for pre- and post-visit specific connections increased significantly from 1.31 to 1.97 (Table 4). Scores increased significantly for three of the five schools. School B showed a significant increase in score with $p < .10$.

Table 4. Pre- and post-visit science process specific connections scores.

School	N	Mean Pre-visit	Mean Post-visit	Sig. (2-Tailed)
All	262	1.31	1.97	.000*
A	55	1.25	1.67	.118
B	29	1.24	1.90	.055
C	39	1.56	2.64	.001*
D	77	1.12	1.57	.019*
E	62	1.47	2.34	.000*

*Differences between pre- and post-visit scores were analyzed with paired T-tests. Significant difference at $p < .05$ is marked with asterisk.

Plant and Flower Parts

Student scores on plant and flower part concept maps increased significantly between pre- and post-visit for all five schools (Table 5). Pre-visit scores ranged from 8.4 to 16.7 which was 7.1 to 16.6% of the expert map points. Post-visit scores ranged from 18.9 to 34.8 or 12.2 to 22.5% of the expert map points. Post-visit scores were 9.8 to 20.0 points higher than pre-visit scores.

Table 5. Pre- and post-visit plant and flower parts concept map scores.

School	N	Mean Pre-visit	Mean Post-visit	Change in Mean	Sig. (2-Tailed)
All	216	11.0	25.8	14.8	.000*
A	53	11.0	22.3	11.3	.000*
B	32	16.7	34.8	18.1	.000*
C	39	8.4	18.9	10.5	.000*
D	69	9.2	29.2	20.0	.000*
E	23	12.8	22.6	9.8	.001*

*Differences between pre- and post-visit scores were analyzed with paired T-tests. Significant difference at $p < .05$ is marked with asterisk.

There were four specific plant and flower part connections of particular interest, weighted at three points each, which were counted on student maps. The scores for these specific connections increased significantly for four of the five schools (Table 6). Pre-visit connections ranged from 0.07 to 0.87 or 1.8 to 21.8% of the expert score. Post-visit connections increased 50.7 to 90.8%. Only school C did not show a significant increase in score at the 0.05% level.

Table 6. Pre- and post-visit plant and flower parts specific connections scores.

School	N	Mean Pre-visit	Mean Post-visit	Sig. (2-Tailed)
All	216	.34	1.5	.000*
A	53	.42	1.34	.000*
B	32	.44	2.09	.000*
C	39	.33	.67	.085
D	69	.07	1.65	.000*
E	23	.87	2.00	.005*

*Differences between pre- and post-visit scores were analyzed with paired T-tests. Significant difference at $p < .05$ is marked with asterisk.

In addition to the four specific connections mentioned above, the ability of students to identify the stamen as the male flower part and the pistil as female was examined. The ability of students to identify the stamen as the male flower part and pistil as the female flower part increased across all schools (Table 7). For individual schools, scores increased significantly for 3 of the 5 schools examined. Pre-visit scores showed that only 6% of students identified stamens as male and 9% identified pistil as female.

This ranged from 3 to 17% for stamens and 1 to 17% for pistils among the schools. Post-visit scores showed that on average 41% of students identified stamens as male flower parts and 49% identified pistils as female flower parts. This ranged form 5 to 72% for stamens and 21 to 91% for pistils among the schools (Table 7).

Table 7. Association of stamen with male and pistil with female flower parts.

School	N	% Correct Pre-Visit		% Correct Post-Visit		Sig. (2-Tailed)	
		Stamen	Pistil	Stamen	Pistil	Stamen	Pistil
All	216	6	9	41	49	.000*	.000*
A	53	8	13	38	43	.000*	.000*
B	32	3	9	72	91	.000*	.000*
C	39	10	10	5	21	.421	.253
D	69	1	1	52	55	.000*	.000*
E	23	17	17	30	30	.328	.328

*Differences between pre- and post-visit scores were analyzed with paired T-tests. Significant difference at p< .05 is marked with asterisk.

Plant Problems

All concepts from the plant problems maps were grouped into six categories. Combining concepts from all participating schools, concept number was higher in post-visit maps than it was in the pre-visit going from 1612 to 2047. Categories that showed significant differences were: insect and disease, symptoms, and treatments (Figure 1). The insect and disease category showed the greatest gain in concept number with 401 (Figure 2), an increase of 1.51 concepts per student map.

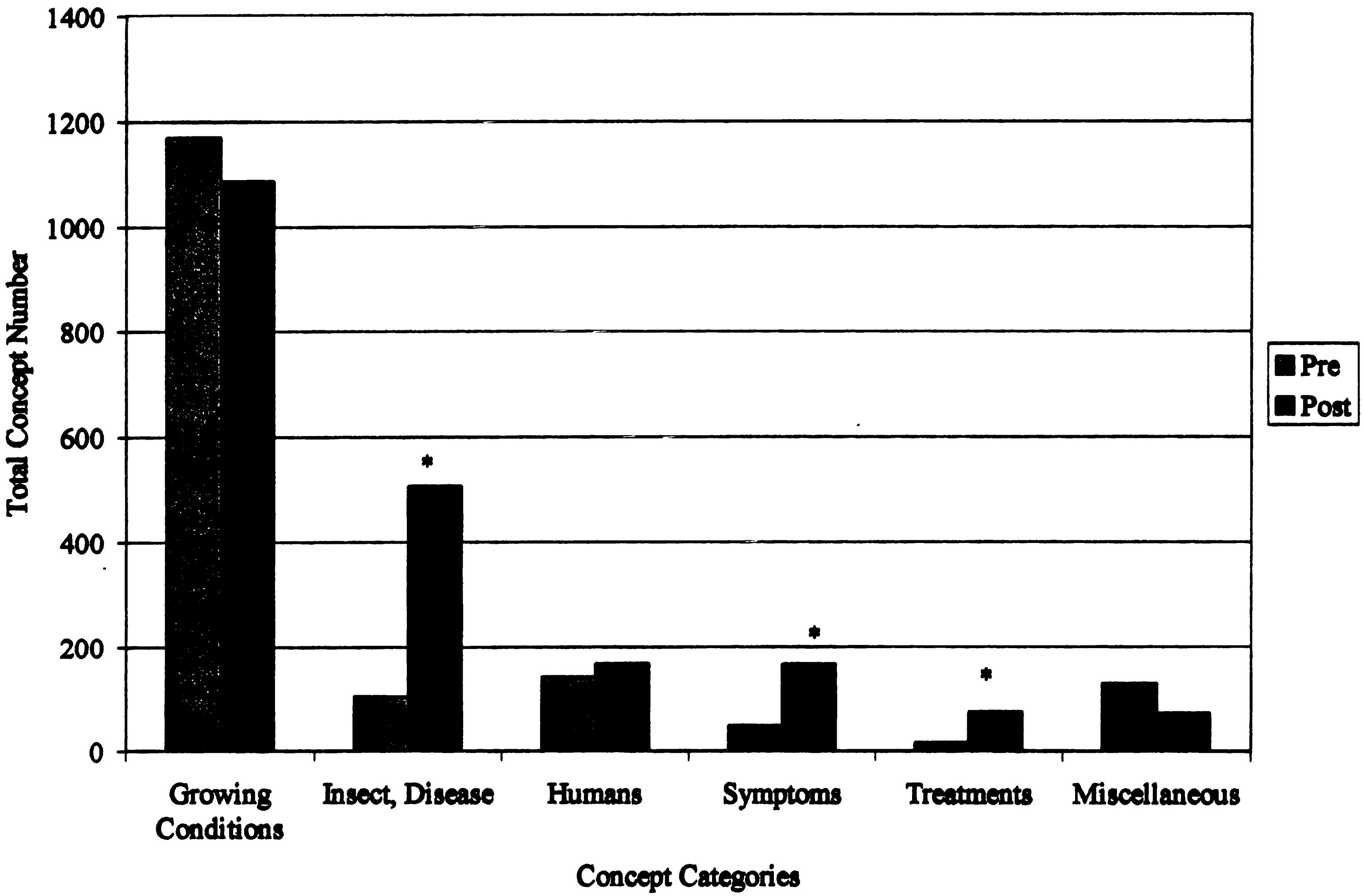


Figure 1. Total number of plant problems concepts on pre- and post-visit maps. Differences between concept numbers were analyzed with paired T-tests. Significant difference at $p < .05$ is marked with asterisk.

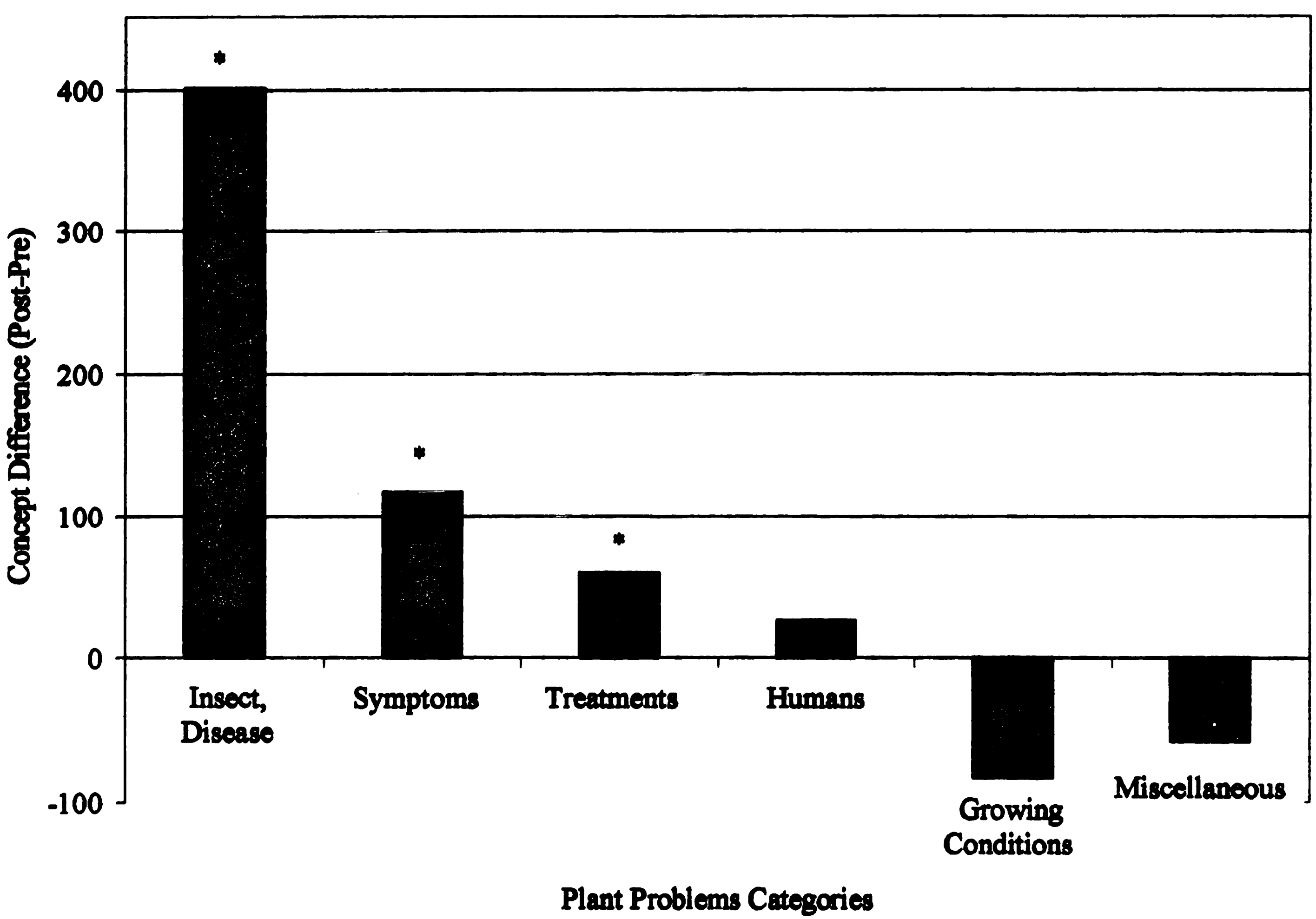


Figure 2. Change in plant problems concepts between pre- and post-visit. Differences between concept numbers were analyzed with paired T-tests. Significant difference at p< .05 is marked with asterisk.

SCIENCE PROCESS CONCEPT MAP CASE STUDIES

Four students' science process concept maps were selected to illustrate the gain in knowledge as well as the re-structuring of knowledge as a result of the Seeds of Science field trips. Gains in knowledge were evidenced by changes in total scores. Total scores increased for all students (Table 8). Total valid links, which are total links minus incorrect links, increased dramatically for students A and B, slightly for D and decreased by 1 for C. Students showed an increase in the highest weighted connections, (those scored at 3 points each), between pre- and post-visits (Table 8). Student A went from 0 to 2, students B and C went from one 3-point connection to identifying all 8 in the post-visit map, and student D went from 3 to 6, therefore showing a more expert-like knowledge structure. Incorrect links were relatively similar pre- and post-visit for student A, B and C, but decreased greatly for student D. The way in which students' knowledge was structured also varied from pre- to post-visit concept maps (Figure 3, Table 8). Students A and B identified all of the steps of the science process; however, student A connected all of the steps to the science process bubble whereas student B showed ordering of the steps. Student B clearly showed that the science process begins by asking a question and each step builds off of the previous; therefore showing the cyclical nature of the process. Both students showed a gain in knowledge and knowledge structure, student A going from nearly a blank map to a much more complex map and student B going from very few connections to a much more expert based, higher-order thinking map.

Table 8. Pre- and Post-visit science process scores for 4 individual students.

Student	Total links		1 pt. links		2 pt. links		3 pt. links		Incorrect links		Total score	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
A	3	18	1	2	1	11	0	2	1	3	2	27
B	8	13	1	1	3	2	1	8	3	2	7	27
C	12	12	1	0	9	4	1	8	1	2	21	30
D	20	16	1	1	9	8	3	6	7	1	21	34

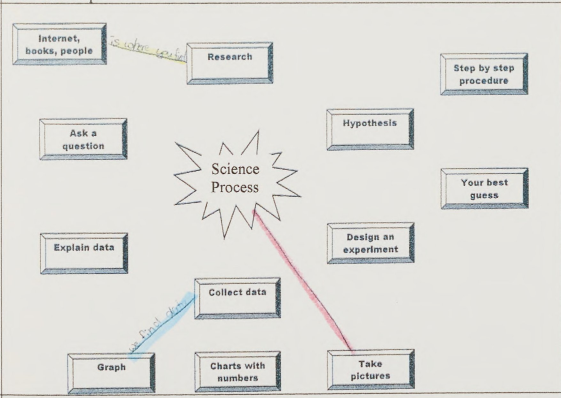
Pre-visit concept maps by students C and D showed that they did in fact have prior knowledge of science process, which is evident by the links from science process to nearly all of the steps (Figure 3, Table 8). The post-visit map of student C is very similar to student B. Student C identified the first step of the process by connecting science process to ask a question. The steps were then connected to each other instead of linking each to science process. Student D linked each step to science process as was done in the pre-map, but also connected the steps to each showing a relationship between the steps and the process.

Figure 3. Pre- and Post-visit science process case studies. Student work depicted below.

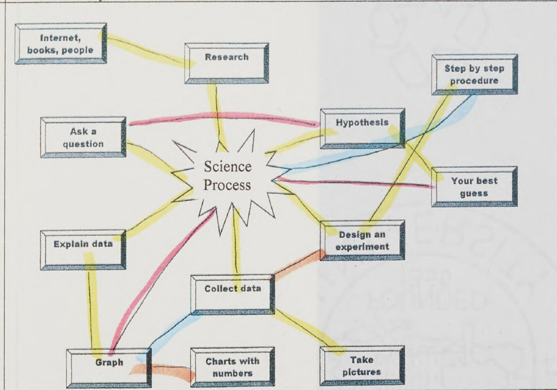
Student	Pre-Visit Map	Post-Visit Map

A

Pre-Visit Map

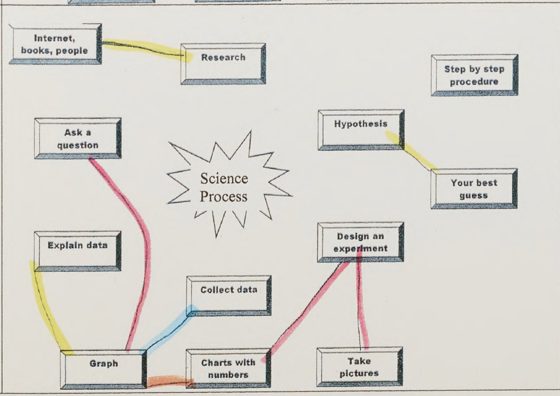


Post-Visit Map



B

Pre-Visit Map



Post-Visit Map

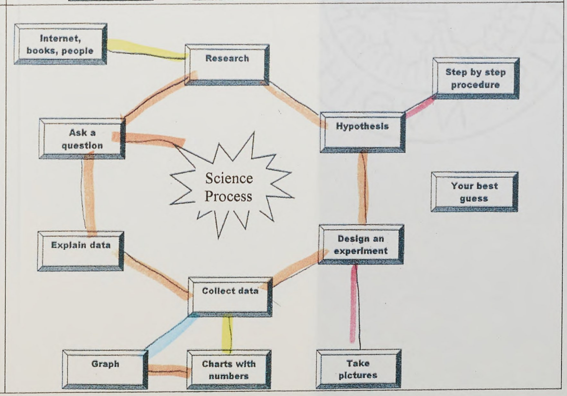
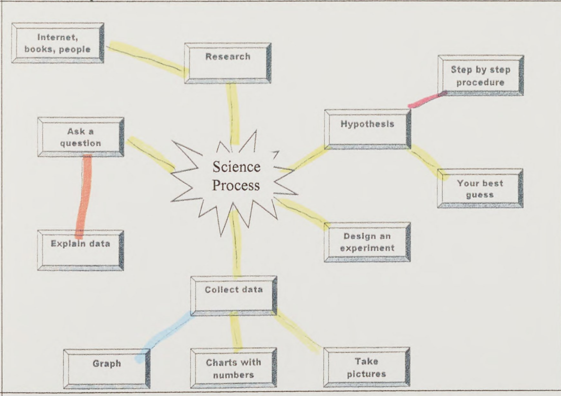
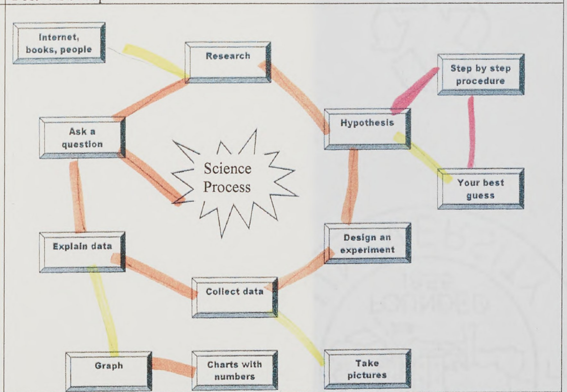
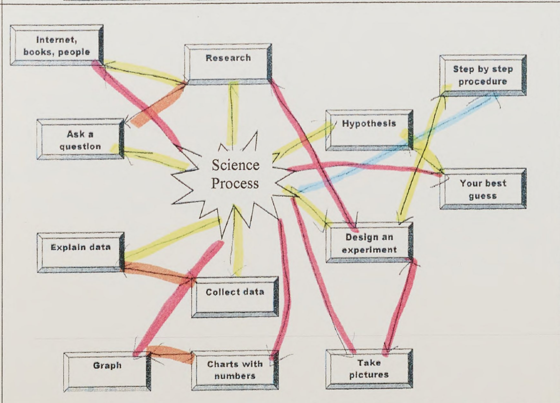
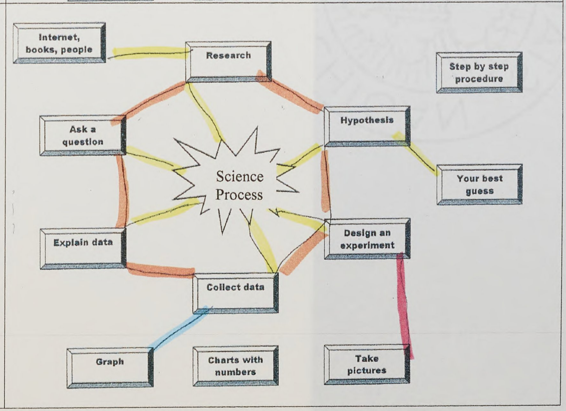


Figure 3 continued.

<table>
<tr><th>Student</th><th>Pre-Visit Map</th><th>Post-Visit Map</th></tr>
<tr><td>C</td><td>
</td><td>
</td></tr>
<tr><td>D</td><td>
</td><td>
</td></tr>
</table>

Pl

sel

we

pa

ma

and

Stu

ma

Tab

Stu
C
I

con

Stu

not

In th

form

leve

stud

post-

PLANT AND FLOWER PARTS CONCEPT MAP CASE STUDIES

Pre- and post-visit plant and flower part maps from five different students were selected to look more closely at the links. Total scores and total number of valid links were greater for post-visit compared to pre-visit (Table 9). Overall, the plant and flower parts pre-visit concept maps were less extensive and complex compared to post-visit maps. Total links increased between 29 and 84%, while valid links increased between 74 and 236%. Incorrect links decreased for all students except E, which remained the same. Student D showed the greatest decrease in invalid links going from 10 in the pre-visit map to just one in the post-visit map.

Table 9. Pre- and post-visit plant and flower parts scores for 5 individual students.

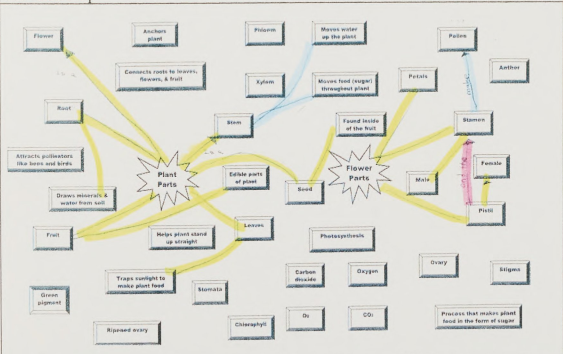
Student	Total links		1 pt. links		2 pt. links		3 pt. links		Incorrect links		Total score	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
E	19	35	3	2	15	25	0	7	1	1	32	72
F	26	37	3	2	17	24	3	7	7	4	39	67
G	28	43	3	6	14	29	0	4	11	4	20	72
H	21	38	2	7	9	26	0	4	10	1	10	70
I	21	27	1	1	5	11	2	7	13	8	4	36

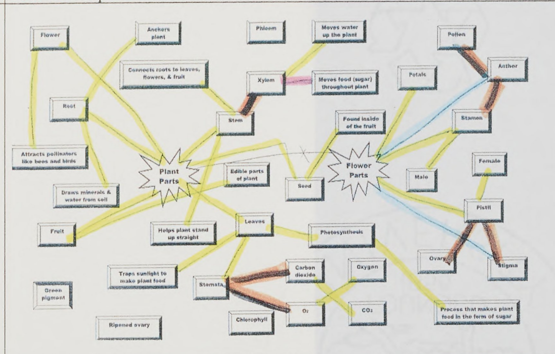
Post-visit maps of students of E, F, G, and H showed an increase in knowledge concerning leaves and photosynthesis (Figure 4). This is evident in the number of links. Student E went from 2 links off of leaves to 4. Furthermore, the following concepts were not linked at all in the pre: photosynthesis, carbon dioxide, CO_2, oxygen, O_2, and stomata. In the post-map student E had 2 links off of photosynthesis, connected the chemical formula with the appropriate gas and had 3 links to stomata, two of which were higher level links. Similarly, student F went from 2 links off of leaves in the pre-visit map and student G had only one link. Both students increased the links off of leaves to 5 in the post-visit map.

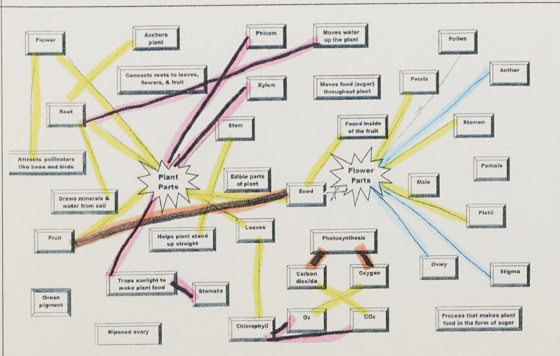
In the pre-visit map only student E was able to identify the stamen as male and the pistil as female (Figure 4). All students identified the male flower part as the stamen and the female part as the pistil in post-visit maps. Post-visit maps revealed expert-like organization of flower part concepts. Students E, F, G, and H went from zero specific connections to linking all four. Student H differed from E, F, and G in the pre-visit map. There were no valid links from flower parts other than the concept 'petals.' In general there were very few flower part concepts linked. However, the post-map showed expert-like organization of concepts, similar to that of students E, F, and G. Students E, F, and G showed a restructuring of knowledge whereas student H took new knowledge and put it into an expert framework immediately.

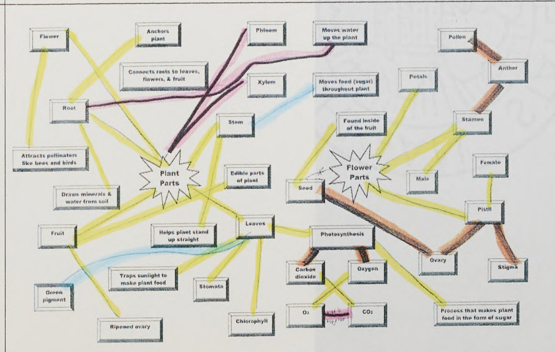
Student I approached identifying plant parts differently than the other four students (Figure 4). Individual plant parts were connected to each other, as if the student was visualizing a plant and assembling it roots up. In the pre-visit map student I had one 3-point link, but in the post-visit map this increased to 4 links. The concept stem was linked to the concepts 'flower,' 'root,' and 'leaves.' Also, 'fruit' was connected to 'seed.' These links show a more sophisticated level of thinking. Each plant part leads to another versus just connecting a specific plant part to the concept 'plant parts.'

Figure 4. Pre- and Post-visit plant and flower parts case studies.

<table>
<tr><th>Student</th><th>Pre-Visit Map</th><th>Post-Visit Map</th></tr>
<tr><td>E</td><td>


</td><td>


</td></tr>
<tr><td>F</td><td>


</td><td>


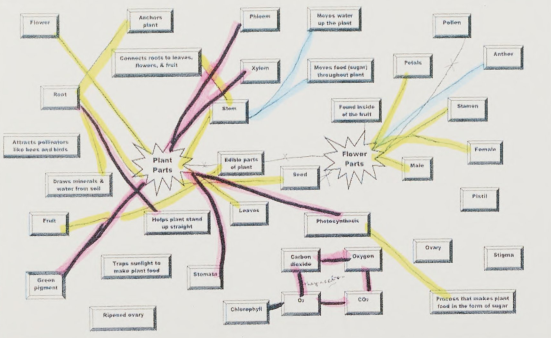
</td></tr>
</table>

Figure 4 continued.

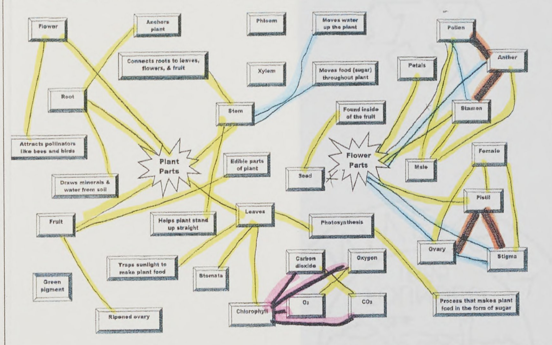
Student | Pre-Visit Map | Post-Visit Map

G

Pre-Visit Map

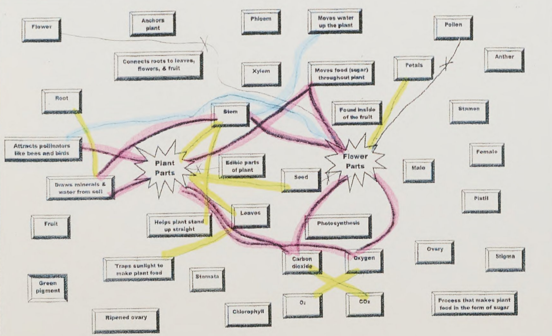


Post-Visit Map

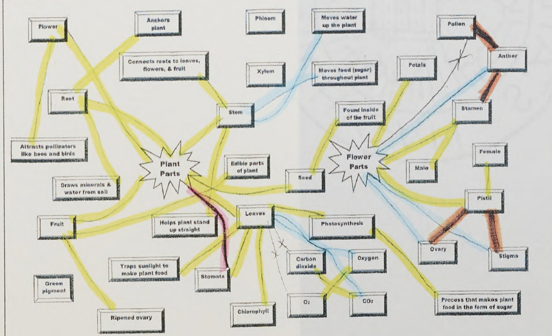


H

Pre-Visit Map



Post-Visit Map



Fi
St
I

Figure 4

Student	
I	

ANSWERS TO WONDER WALL QUESTIONS

On the third and final field trip, students from school E were asked to write responses to questions posted on the wonder wall during their earlier field trips. The questions and answers below illustrate their knowledge of plant science (Table 10). Questions were selected to represent different levels of thought, comprehension being the lowest level and synthesis being the highest level. Comprehension questions involve interpretation of information. Application questions use problem solving to generate answers and apply information to produce some result. Synthesis questions combine ideas to form a new whole (Bloom, et al., 1956).

Table 10. Selected examples of student questions and their answers.

Question Type	Question	Answers
Comprehension	How many times can a plant grow?	Most plants only grow once, but some others grow once a year for a few years. They can grow infinite because it can reproduce for a guess of 1,000 times. Since a plant can reproduce it can make a lot of itself. A plant can grow as many times as it wants as long as it has seeds.
	How does lettuce reproduce?	Lettuce reproduces with its flowers because it has a pistil. Lettuce reproduces by its flowers. All plants reproduce by their flowers so the lettuce should. Lettuce has seeds on the flower.
	Does lettuce have seeds?	Yes. Lettuce has seeds. It needs seeds to reproduce. All plants need to reproduce to be counted as living things. Yes. It has seeds because it has a flower and that is its only purpose.
	Is lettuce a flower? What part of the plant is lettuce?	Lettuce is not a flower. Lettuce is a leaf. The lettuce plant can grow flowers, but lettuce itself is not a flower.

Table 10 continued.

	Why do plants give off oxygen?	Plants take in carbon dioxide, sunlight, and water to mix with chlorophyll to make plant food and oxygen.
	Do plants need leaves to survive?	Yes, plants need leaves to survive because they take in carbon dioxide and lets off oxygen.
Application	Why is it so important to fertilize? How does fertilizer help a plant?	It's important to fertilize because the plant needs extra nutrients to grow strong. Fertilizer or nutrients help a plant to grow strong. Plants need nutrients so fertilizer is a big help.
	Why don't some plants die in the winter?	Some plants don't die in the winter because the snow is like a warm blanket, with no wind to freeze the plant or no one to pull out or hurt it.
	How do plants know which season is which?	A plant knows which season it is because the time of day, if the days are getting shorter or longer.
	Does chlorophyll wear off?	Yes, chlorophyll does wear off then it grows back in the spring.
	How do plants eat?	They eat by taking in water and minerals from the roots. Plants eat by their leaves. They use their leaves to get sunlight. The process is called photosynthesis.
	Can plants grow in the arctic?	Yes, plants can grow in the arctic. Plants can adapt to their surroundings.
	Do all plants need soil and sun?	No, not all plants need soil such as moss. Moss grows on rocks. All green plants need sun to live though.
	How do plants protect themselves?	When the plant is a bud, the sepals will protect it. When a plant grows older, it may develop poison or barbs to protect it. Some plants have prickles or bad smells to protect themselves.
Synthesis	If four flowers were planted and only three grew, what could be the cause?	The other three seeds took all of the water and nutrients. The other three plants are taller than the one and it can't get enough sun.
	Does a poinsettia have red chlorophyll?	No, because all chlorophyll is green.

Answers reflect a sound understanding of plant science and the ability of students to hypothesize, trying to make sense of the question based on their current understanding and knowledge level. Students were able to use the information they learned and apply it to questions and scenarios they had not encountered previously.

INTERVIEWS

Personal, one on one interviews provided students an opportunity to verbalize their understanding of plant science. All excerpts are from post-visit interviews. In most cases students had their post-visit concept maps in front of them and referred to them to explain their understanding of specific concepts. Students were allowed to add links as they were explaining relationships if they discovered new connections while verbalizing their thoughts. Four major topics were discussed: science process, flower parts, photosynthesis, and plant problems.

Students demonstrated a good working knowledge of science process indicating its start and the order of the process (Table 11). Students could give a good explanation of the relationships among the female flower parts and their function (Table 12), and the male flower parts and their function (Table 13). Students gave good explanations of the relationships between seeds and ovary and where seeds were located (Table 14). Students recognized the relationships among photosynthesis, carbon dioxide, and oxygen and could explain that (Table 15). In addition, they displayed a good understanding of relationships among leaves, photosynthesis, stomata, carbon dioxide, and oxygen (Table 15). Students' understanding of plant problems was directly related to the concepts addressed on the Seeds of Science final field trip. Students were able to explain their reasoning quite well (Table 16).

Table 11. Science process concept map connections and student explanations.

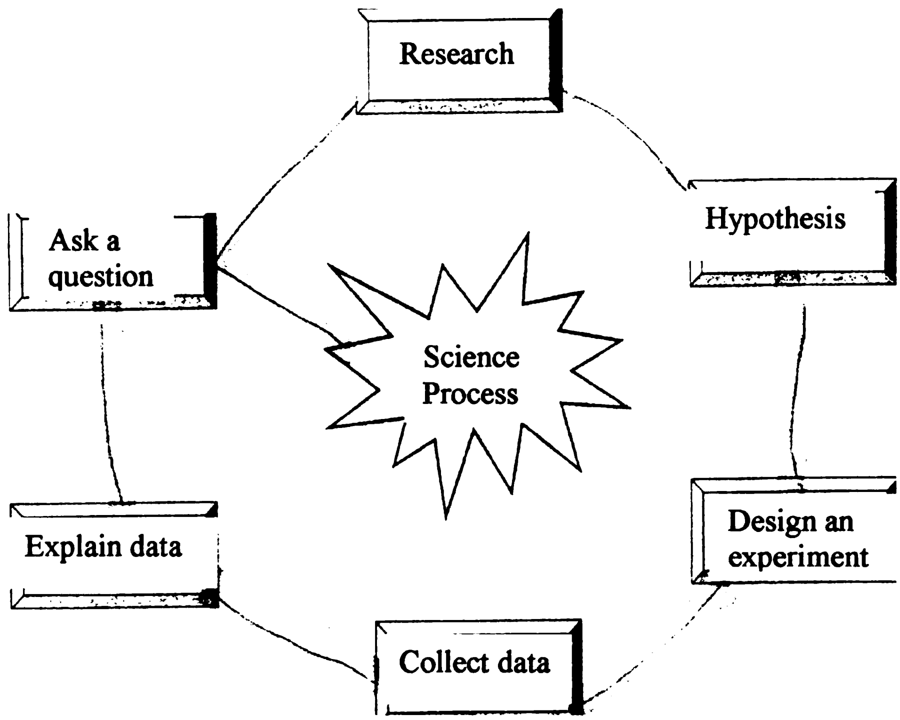
Concept Map Representation		
Question	Why did you make a circle?	When you get to the end, how come you have a line between explain data and ask a question?
Explanation	That's how you do the whole thing. When you ask a question you explain it and then that question is answered. You answer your own question.	Since there was no 'ask new question' I connected it here. You can ask another question and do the science process all over again with your new question.

Table 12. Female flower parts concept map connections and student explanations.

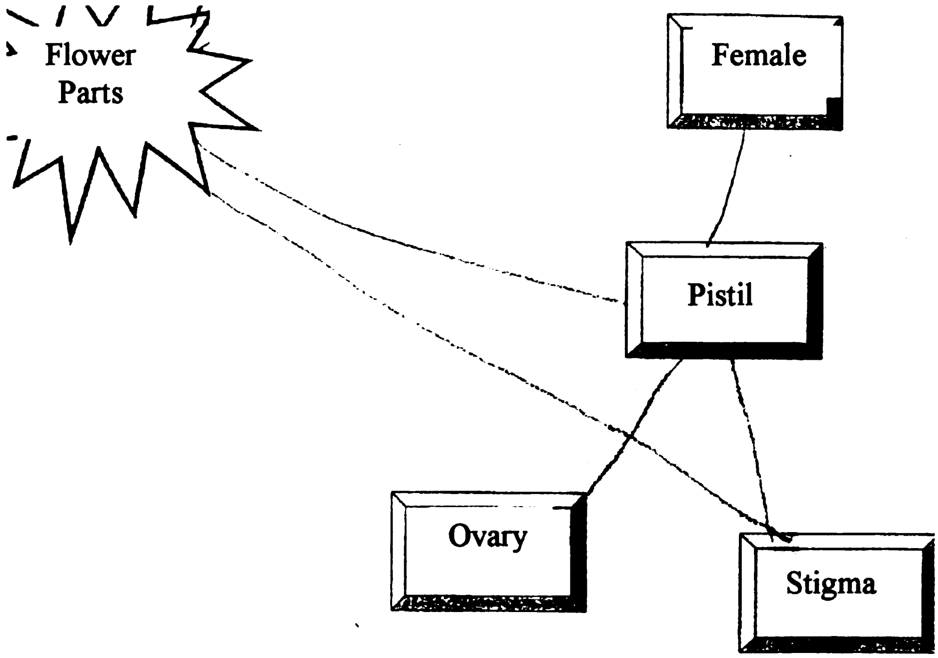
Concept Map Representation	
Questions	Why do you have a link between flower parts and pistil? Why is female connected to pistil and then pistil connected to both ovary and stigma?
Explanations	The pistil is the female part of the flower and the stigma is the sticky part on top of the pistil. It's usually sticky and that's where the pollen gets stuck to the stigma, which goes down to the ovary part and makes the seeds and that's the pollination. So it's making seeds. Because the stigma is female and is also on top of the pistil and the pistil is also female and the ovary is female. The stigma is part of the pistil which is the female part. The ovary is below the stigma where the seed is made.

Table 13. Male flower parts concept map connections and student explanations.

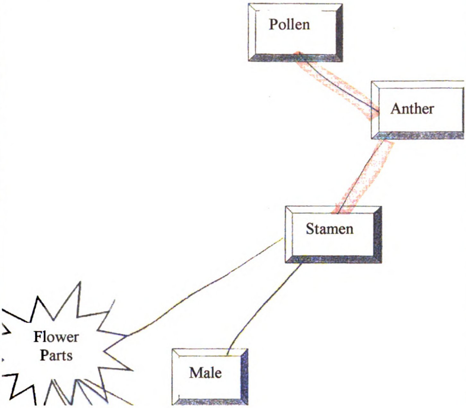
Concept Map Representation	
Questions	Why did you connect male to stamen, stamen to anther, and anther to pollen?
Explanations	The pollen is on top of the anther. The anther is on top of the stamen and the stamen is male and so is the pollen. I connected flower parts to stamen because stamens are the male parts of the flower, which pollinate the pistil because the stamen have the anthers and the anthers hold pollen. The stamen is the filament and the anther combined and the anther is the top part that gives off the pollen. The stamen is made up of two parts and one of them is the anther.

Table 14. Seed and fruit concept map connections and student explanations.

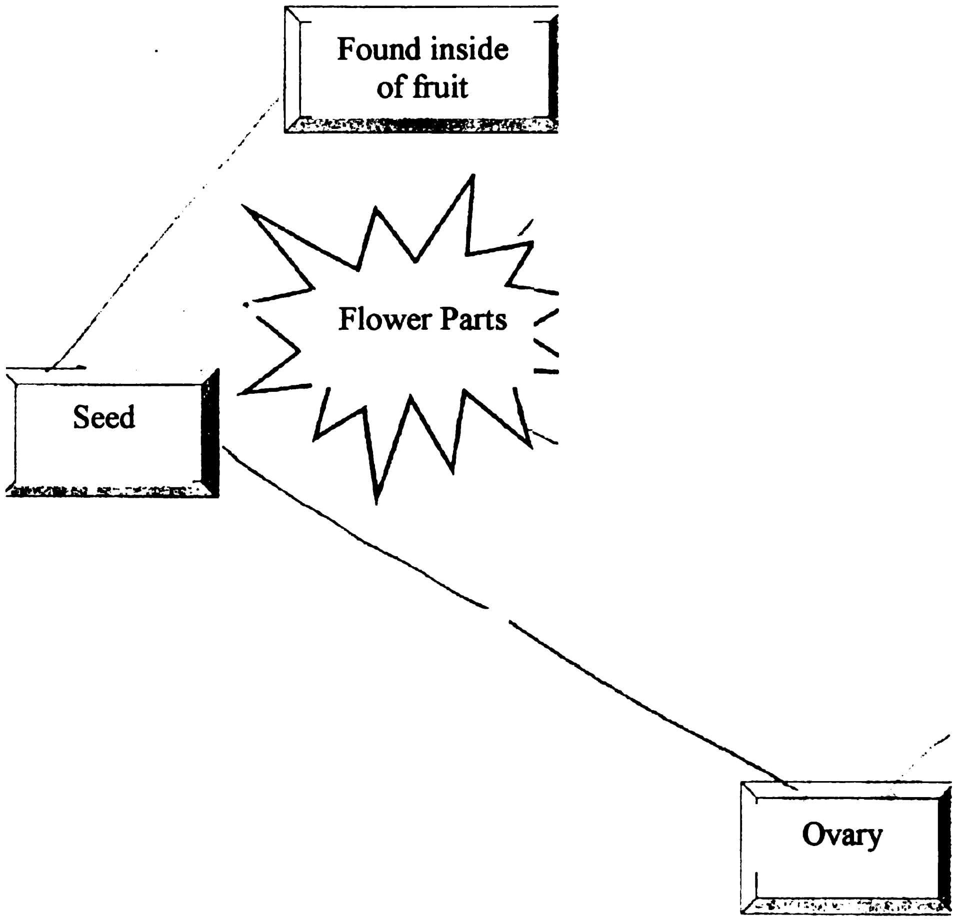
Concept Map Representation	
Question	You have a link between seed and found inside of fruit, and seed connected to ovary, so when you eat a fruit what part of the flower are you eating?
Explanations	The seed first starts out in the ovary and once the seed develops it (the ovary) forms into a fruit. Pollen from another flower… because a bee comes and it goes to the pistil and rubs it all over the stigma, and it goes down to the ovary and the seed is fertilized, and then the ovary grows into a fruit. The fruit comes from the pistil and ovary area because the seeds are from the ovary.

Table 15. Photosynthesis concept map connections and student explanations.

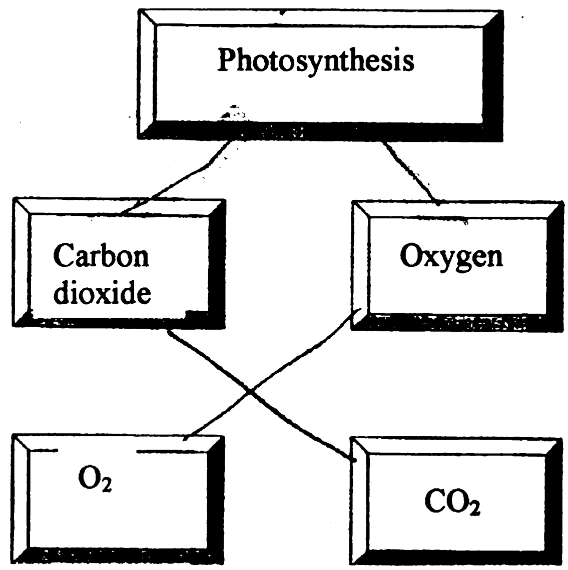
Concept Map Representation		
Questions	Tell me a bit about photosynthesis. Why do you have photosynthesis linked to carbon dioxide and oxygen?	How come you have links from O_2 to oxygen, and CO_2 to carbon dioxide?
Explanations	Photosynthesis has to have oxygen, which is O_2 I think and it has to have carbon dioxide, which is CO_2 and then of course it's a process that makes food in the form of sugar. It takes in carbon dioxide and oxygen gets breathed out. Animals or human beings breathe it in and animals breathe out carbon dioxide.	It's the abbreviated form.

Table 15 continued.

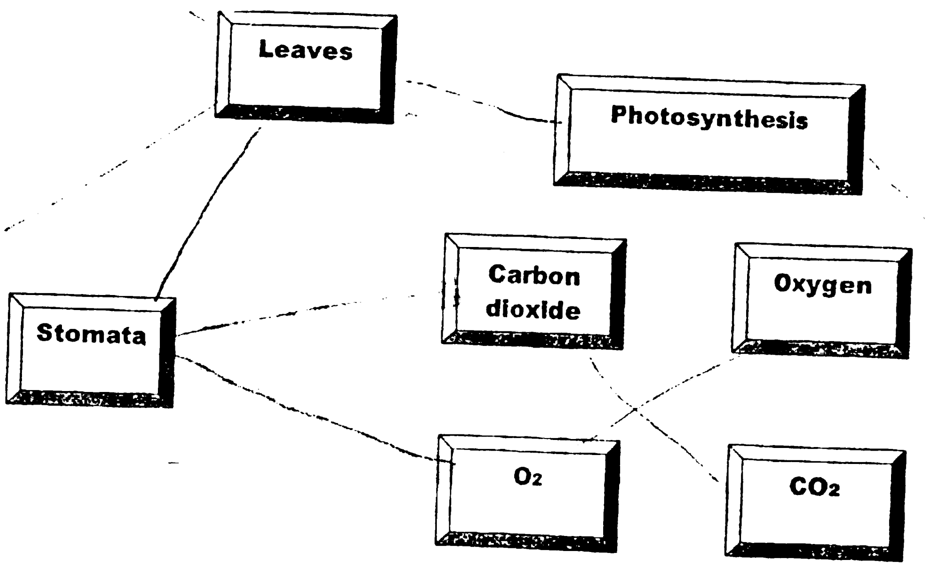
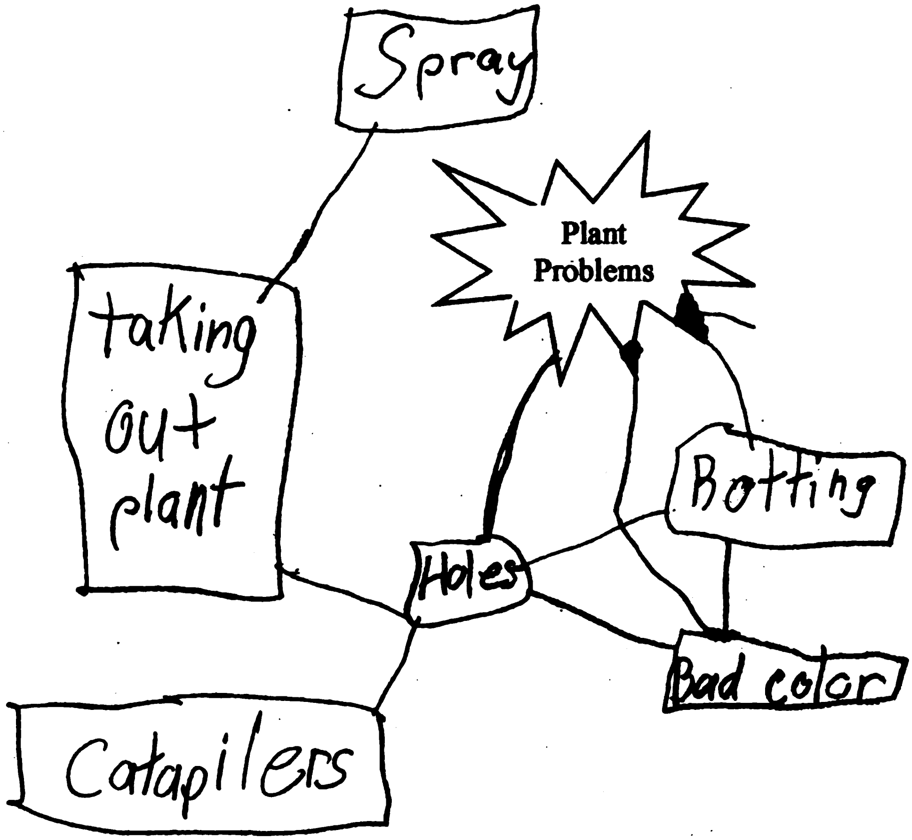
Concept Map Representation	
Questions	Why do you have stomata connected to leaves? How do carbon dioxide and oxygen factor in with stomata and leaves?
Explanations	They are these tiny holes on the leaf and they let the carbon dioxide in and push oxygen out. That's the really small hole in the leaf. There are two guards. They would let carbon dioxide in and oxygen out. The leaves have the stomata, which are the holes and the stomata take in carbon dioxide and give out oxygen.

Table 16. Plant problems concept map connections and student explanations. Images are that of student work.

<table>
<tr><td>Concept Map Representation</td><td colspan="2">
</td></tr>
<tr><td>Questions</td><td>When you went around the children's garden looking for plant problems, what were you looking for? How could you tell if it was a plant problem?</td><td>What are some things that could cause color change or the holes in leaves?</td></tr>
<tr><td>Explanations</td><td>Like maybe 5 leaves out of 20 would be red and shriveled and then all the others would be green and healthy looking or maybe one leaf would be eaten and turning brown or yellow and the others were a different color.

I was looking for insect holes in the leaves and the different colors from the nutrients problem.</td><td>The holes probably the insect is eating at it. If it's shriveled up maybe there's a disease in it. If it's and entirely different color it might be disease.

Caterpillars make the holes in leaves.</td></tr>
</table>

Table 16 continued.

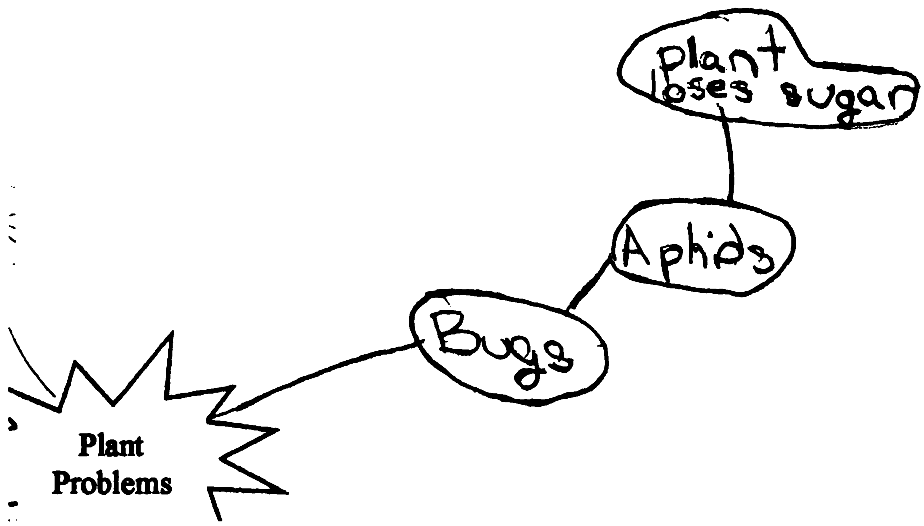
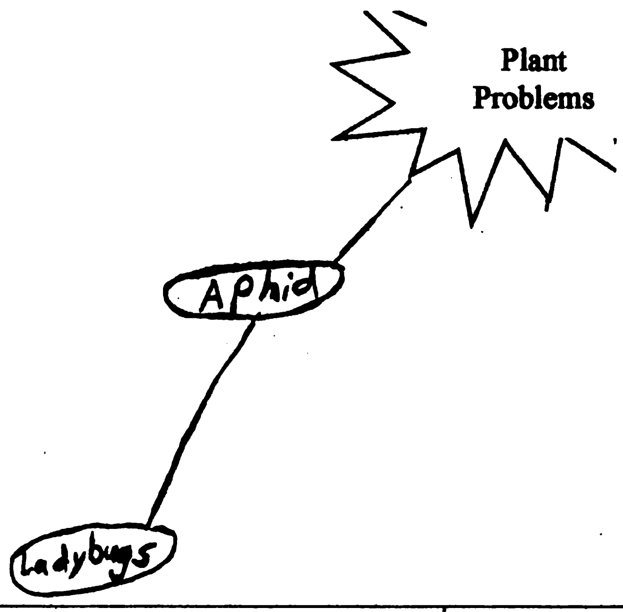
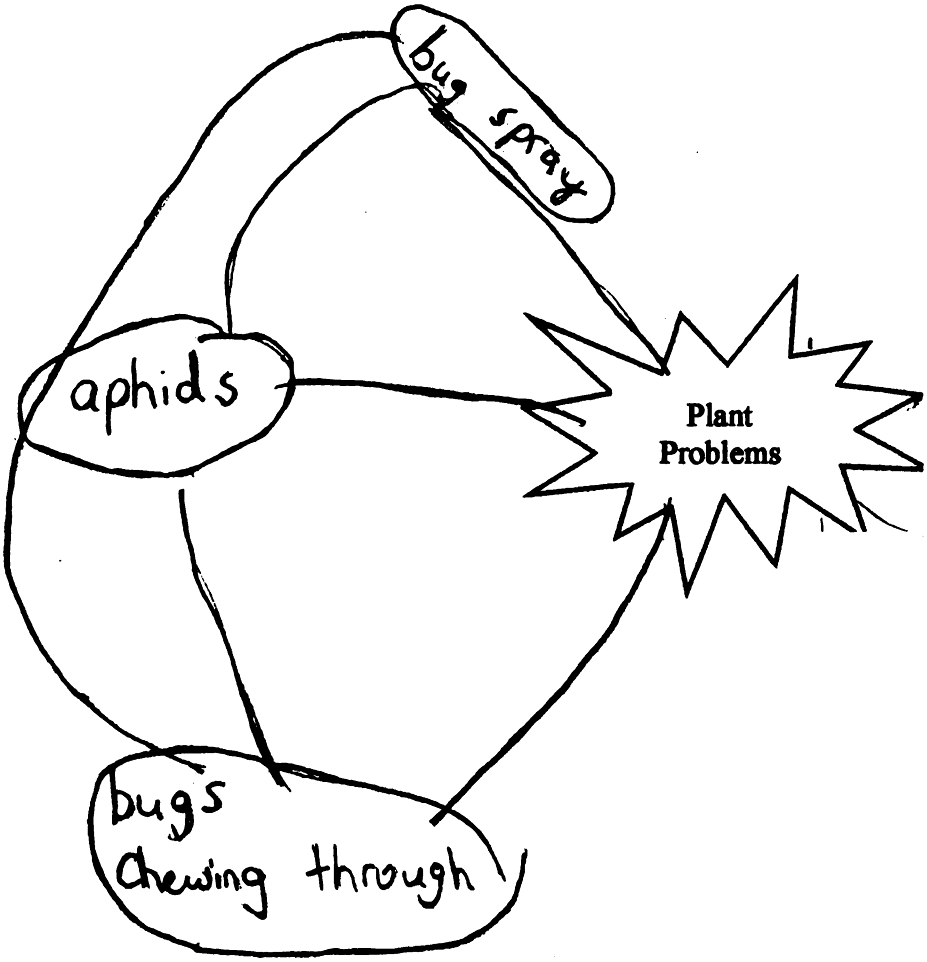
Concept Map Representation		
Question	Explain why you have bugs to aphids to plant loses sugar.	
Explanation	Because aphids are insects or bugs and the aphids bite the leaf and start to eat the sugar, so the plant starts to lose its sugar.	
Concept Map Representation		
Questions	Why do you have ladybugs on your map?	Biological control is like good insects eating bad insects…
Explanations	Because ladybugs eat aphids. If you spray a plant you are going to have to take it out because it sometimes kills it. It can kill the bugs and hurt the plant.	Like ladybugs eating aphids!

Table 16 continued.

Concept Map Representation	
Question	Why do you have aphids and bug spray and bugs chewing through the plant?
Explanation	Bugs chewing through are aphids and if you want to get off the aphids you need the bug spray and bug spray controls the bugs that are chewing through, but then again bug spray kills the plant.

DISCUSSION

INTRODUCTION

Seeds of Science field trips offer students many opportunities to explore and discover through hands-on activities and authentic scientific investigations. These opportunities occur within the rich context of the 4-H Children's Garden across several visits and were integrated into the plant science unit. This type of support and scaffolding would be expected to result in marked content learning. Such results were observed throughout the Seeds of Science.

Hands-on activities facilitate the construction of concepts and enhance meaningful learning, providing the necessary framework to incorporate new knowledge into long term memory (Orion, 1993). Providing direct experiences with concrete phenomena is the main role of the field trip and is essential in the learning process (Orion, 1993). The Seeds of Science curriculum gives students direct experiences with scientific phenomena. Students learned about science process through activities where they ordered the steps of the process and examined the shape of science. In addition, all experiments explicitly focused on science process steps. Hands-on activities such as collecting and pressing flowers, followed by labeling the parts, provided students a direct experience to learn and develop the cognitive framework for new flower part information. Similarly, plant problems involved student exploration of the garden, collecting samples, sketching, and an interactive technology piece. Such experiences "invite an avalanche of questions and foster the webwork of connections that configurate a learning life" (Carr, 1989).

Piaget (1964) stated, "To know an object is to act on it." Learners must physically manipulate objects in their environment for learning to be internalized (Rudmann, 1994). Through carefully designed curriculum, Seeds of Science field trips push students to experience plants by acting on them, and engage students in hands-on, minds-on activities. Through these experiences students take an active role in their own learning in contrast to rote learning (memorization) that will not be assimilated (Novak, 1993). Seeds of Science is designed to foster student learning and promote development of new knowledge structures.

STUDENT LEARNING

Science Process

Students involved in the Seeds of Science field trips increased their understanding of science process. The increase in science process specific connections (Table 4) was also likely a direct result of Seeds of Science activities. Schools C, D, and E showed significant differences ($p<0.05$ and school B at $p< 0.10$) in science process specific connections, whereas school A did not (Table 4). School A was the only school that did not receive any form of post-visit follow up. The post-visit activities, especially for those schools involved with the lettuce growth and evaluation lab report, provided a framework for understanding the science process in its entirety. By completing the lab report, students experienced each step of the science process within the context of an experiment they did. Therefore the lack of change for school A may be the result of no field trip follow up. The lower significance level for school B may be related to the fact that two different teachers were responsible for teaching science, one of whom had the steps of the science process posted in her classroom. One step, "research," was omitted from her process. Students in her class may have been more apt to connect "ask a question" directly to "hypothesis," thereby skipping "research." In doing so, negative point values would have been awarded and fewer correct specific connections would have been tallied in their post-visit maps.

Plant and Flower Parts

Plant/flower parts concept maps, showed significant differences between pre- and post-visit scores for all schools (Table 5). All schools, except C showed significant differences in plant and flower parts specific connections (Table 6). School C was one of the first schools to be involved with Seeds of Science and although they spent three full days at the garden, there was not enough time to discuss individual flower parts. Students did collect and press flowers, but the details of the flower parts were not covered; therefore, it is not surprising that there was not a significant increase in specific connections, since the connections are all flower part links. Likewise, school C did not show a significant difference in identifying stamen with male and pistil with female, whereas schools A, B, and D did (Table 7). School E also did not show a significant difference associating stamen and pistil with male and female.

Plant Problems

Through the plant problems curriculum, students significantly increased their knowledge of insects and disease, plant problem symptoms, and treatments (Figure 1). Post-visit maps covered a much broader spectrum of plant problems revealing a more diverse idea of what constitutes a plant problem, how it can be identified as well as treated. This new information is directly from the plant problem activities in the garden as well as on the interactive plant problems computer software. This is most exciting because post-visit is the first that students went beyond what the problems were and thought about solutions. Comparing pre- and post-visit maps is a way of documenting an intellectual journey. A child's mental representation of knowledge about a topic is a valid indication of that child's current state of understanding (King, 1994).

KNOWLEDGE STRUCTURE

Science Process

Looking closely at individual student pre- and post-visit science process and plant/flower parts maps, reveals a general trend of increasing complexity and a greater number of valid and higher-order links (Tables 3, 4, 5, 6, 7 and Figures 3, 4). As students gain knowledge their concept maps become increasingly more interconnected (Ruiz-Primo and Shavelson, 1996). Carey (1986) pointed out: "By comparing successive concept maps, produced as the student gains mastery of the domain, the researcher can see how knowledge is restructured in the course of acquisition." All science process case studies had very few, if any, higher-order, 3-point links in pre-visit maps (Figure 3). Student A clearly gained knowledge since the pre-visit map was virtually blank and the post-visit map had many more valid links (Figure 3). Student A's concept map reveals an understanding of the steps of the science process, but not how the steps relate to each other. Similar to student A, student B's pre-visit map had very few valid links. Comparing pre- and post-visit maps, student B moved from not being able to identify a single step of the science process to putting the steps into an expert framework. Unlike students A and B, students C and D identified steps of the science process in pre-visit maps (Figure 3). Post-visit maps reveal that knowledge was restructured. In post-visit maps they clearly showed how each step of the process leads to a new step, ultimately showing that the process is ongoing.

Plant and Flower Parts

Ausubel (1968) claimed that "the most important single factor influencing learning is what the learner already knows." As the constructivist theory suggests, students learn only if they actively construct knowledge from existing prior knowledge (Lanzing, 1996). In order for information to be remembered and retrievable new knowledge should be integrated into existing structures (Lanzing, 1996). Novak (1993) reported that learners must possess relevant prior knowledge for meaningful learning and that this condition is easily met by age 3 for virtually any domain subject matter. Students by the fourth grade have an existing knowledge structure of plants. When students were asked during pre-visit interviews to visualize and name the major parts of a plant, students were quite capable of the task: "Flower, stem, leaves, and the roots" "Stem, leaves, flower. I know inside they have the pistil and stuff." Most students were capable of identifying several plant parts and some even could name a flower part.

The Seeds of Science curriculum engages students in discovery learning and through this active, inquiry-based learning, students can incorporate new content and science phenomena into pre-existing knowledge structures. Pre-visit plant/flower part maps showed an existing knowledge of plant parts for all students and a range in knowledge of flower parts (Figure 4). Students E, F, and G showed the most knowledge of flower parts in the pre-visit maps. Meaningful learning involves assimilation of new concepts into existing cognitive structures (Novak, 1993). Focusing in on the connections made off of the plant parts concept, students E, F, G, and H have a similar knowledge structure. In the pre-visit map they identify the individual parts and link them to the concept plant parts. The post-maps show the same 2-point connections, but the number of links increases or stays the same. Student I had a different knowledge structure. He chose to connect individual parts together, essentially building a plant on the map. The pre- and post-visit maps show the same knowledge structure, but an increase in links. Therefore, students assimilated new concepts into their pre-existing cognitive structures.

Knowledge is organized hierarchically in cognitive structures (Novak, 1993). When individuals learn, they naturally organize new concepts and propositions into a series of ordered groupings. Wandersee (1990) points out that "concept maps are designed to parallel human cognitive structure, in that they show concepts organized hierachically." When comparing the organization of flower parts on pre- and post-visit plant/flower maps, students clearly placed new concepts into hierarchies (Figure 4). Students E, F, G, and H all started with zero specific connections in the pre- and all 4 in the post-visit maps. These 4 links show that new knowledge was arranged into organized groupings. For instance, pistil was connected to both ovary and stigma because the pistil is made up of those two parts. Likewise, stamen was connected to anther since the anther is the tip of the stamen. Anther was then connected to pollen because the pollen is released from the anther. Even with pre-constructed concept maps, students were able to

arrange concepts from general to more specific, showing meaningful relationships between concepts. Glaser and Bassok (1989) note that one aspect used in defining competence in a domain is that knowledge is well structured. The grouping of the flower part concepts in post-maps reflects well structured, expert-like organization. Freeman and Urbaczewski (2003) found that as students progressed throughout the semester, their concept maps significantly increased in size and similarity to the expert's map, as did the plant/flower part maps.

Post-visit interviews gave students the opportunity to verbalize why they connected concepts as they did. Higher-level, 3-point links were clearly explained and it was evident that students had developed a method of organizing the new material (Tables 12, 13, 14, 15). This display of grouping concepts in ways that are easily retrievable bears a similarity to the structure of long-term memory (Jonassen, et al., 1993). For instance, a student explained why she connected pistil to both stigma and ovary: "The stigma is part of the pistil, which is the female part. The ovary is below the stigma where the seed is made" (Table 12). A different student explained the parts that comprise the stamen: "The pollen is on top of the anther. The anther is on top of the stamen and the stamen is male and so is the pollen (Table 13)." Both students have mental maps or ways of storing concepts in an organized manner, which they verbalized as well as mapped.

Plant Problems

Plant problems concept maps showed signs of arranging concepts in a hierarchy (Table 16). One student connected plant problems to bugs, which was connected to aphids, which was linked to plant loses sugar. The student justified the connection:

"Aphids are insects or bugs and the aphids bite the leaf and start to eat the sugar, so the plant starts to lose its sugar." When a student creates a visual representation of his/her cognitive conceptualization, viewers of the map get an inside look into that student's mind (Freeman and Urbaczewski, 2003). It is clear based on the students map, as well as his verbalized response, that he knows that aphids are bugs and that they can harm plants. He even addressed how the insects are harming the plants.

ANSWERS TO WONDER WALL QUESTIONS

Students were involved in helping answer Wonder Wall questions, which was followed by a discussion of potential solutions. McNay (1985) stated that "children in upper elementary grades may be able to suggest possible answers to the questions at hand. Discussing the merits and likelihood of different hypotheses encourages children to consider different viewpoints and encourages critical thinking." Expecting children to be able to contribute to a discussion encourages and creates confidence in the child's authentic intellectual involvement and promotes among children the view that learning is something in which they themselves play an active role (McNay, 1985). Even if students were not confident that they knew the correct answer they hypothesized possible explanations. Students were able to use the principles they learned in the flower part curriculum and apply it to a new situation in which they were growing lettuce: "How does lettuce reproduce?" Students responded: "Lettuce reproduces with its flowers because it has a pistil." "Lettuce reproduces by its flowers. All plants reproduce by their flowers, so the lettuce should" (Table 10). Having never been shown a lettuce flower at the garden, students took new knowledge learned from various flower part activities and

applied it to a slightly different context. Meaningful learning and the creation of powerful knowledge frameworks permit utilization of the knowledge in new contexts (Novak, 1990). Similarly, a different Wonder Wall question was posed: "If four flowers were planted and only three grew, what could be the cause?" Students responded: "The other three seeds took all of the water and nutrients." "The other three plants are taller than the one and it can't get enough sun." Students were taught that plants need water, nutrients, and sun. They used this knowledge, applied them to a new situation, and made thoughtful hypotheses.

Another question posed was, "Do all plants need soil and sun?" A student responded: "No, not all plants need soil such as moss. Moss grows on rocks. All green plants need sun to live though" (Table 10). The student used his prior knowledge to respond to the part of the question concerning soil. Students were never introduced to moss during the Seeds of Science field trips, so he drew on past observations to arrive at a reasonable hypothesis. As to whether or not plants need sun, the student associated green plants with needing sun to survive because green plants have chlorophyll and therefore go through photosynthesis to make food. It is a powerful answer since he specified green plants, as if he questioned whether non-green plants would go through photosynthesis, in which case sun may not be essential. Different colored plants and their relationship with photosynthesis had yet to enter his knowledge structure.

Students were able to combine and synthesize information from several sources and gathered over a period of time to create solutions to new questions and problems. They were able to structure their knowledge in "expert-like" ways. It would be interesting to follow these students as they continue their science studies to see if the continue to use these knowledge structures and to see how and why they change over time.

CHAPTER 4

HOW DO SEEDS OF SCIENCE FIELD TRIPS INFLUENCE THE QUESTIONS STUDENTS ASK?

RESULTS

WONDER WALLS

Students posted many questions to the Wonder Wall while they were on their field trips. For the four schools that used the Wonder Wall, students posted an average of 122 questions per school with a range from 69 to 181 (Table 17). In addition, students asked other questions that were not recorded on the Wonder Wall. The types of questions students asked were 33% basic information and 67% wonderment questions (Table 17). Basic information questions ranged from 22 to 42% and wonderment questions form 58 to 78%. Basic information questions were those that inquired about specifics related to the 4-H Children's Garden or the people involved with the Seeds of Science field trips. The following are examples of such questions: "How many different colors are in the children's garden?" "How old are the ferns in this room?" "What is your favorite plant?" Wonderment questions stemmed from the Seeds of Science curriculum such as: "How does a plant produce pollen?" "Why do fast plants grow fast?" "How do plant problems start?"

Table 17. Wonder Wall basic information and wonderment questions

School	Total # of Questions	% Basic Information	% Wonderment
A	71	42	58
C	69	28	72
D	169	39	61
E	181	22	78
Average	122	33	67

The percentage of questions asked that were basic information and wonderment remained about the same for each visit (Table 18). The total number of questions per school was greatest for visits 1 and 2 and decreased by about 45% for visit 3 (data not presented).

Table 18. Types of Wonder Wall questions asked (%) on each Seeds of Science field trip.

Visit 1		Visit 2		Visit 3	
Information	Wonderment	Information	Wonderment	Information	Wonderment
33	67	24	76	33	67

Wonderment questions were further divided into one of four categories: comprehension, application, analysis, or synthesis. Wonderment questions were 69% comprehension, 25% application, 5% analysis, and 1% synthesis across all schools (Table 19). A notable difference was that school C asked 16% analysis questions.

Table 19. Types of Wonder Wall wonderment questions.

School	# of Wonderment Questions	Question Type (%)			
		Comprehension	Application	Analysis	Synthesis
A	41	76	20	2	2
C	50	52	30	16	2
D	103	76	22	2	0
E	141	71	27	1	1
Average		69	25	5	1

Comprehension questions included the following examples: "How do plants grow?" "How do trees make fruit?" "Why do plants have roots?" Application questions included: "How come fast plants need CO_2 instead of O_2?" "Why do the plants in the Mars soil not grow so well?" "How do plants get different genes?" Analysis questions included: "Why is it that in earth soil plants grew faster, but in Mars soil plants lived longer?" "Why do tulips close at night and open at daytime?" "How can flowers sense things like another plant and the temperature if they don't have brains?" Examples of

synthesis questions are: "If four flowers were planted and only three grew, what could be the cause?" and "Does a poinsettia have red chlorophyll?"

INTERVIEWS

Post-visit interviews evoked many great questions that stemmed from the plant science unit and experiences at the 4-H Children's Garden. The questions students asked were first divided into basic information and wonderment categories. Only one basic information question was asked while all others were wonderment. There were a total of 28 wonderment questions asked by 11 students. Of these, 11 were comprehension, 16 application and 1 synthesis (Table 20).

Table 20. Types of wonderment questions from student interviews.

# of Wonderment Questions	Question Type			
	Comprehension	Application	Analysis	Synthesis
28	11	16	0	1

The specific questions students asked provide valuable insight into the wonderment and curiosity they had connected to Seeds of Science. Examples of specific questions asked during the interviews are presented in Table 21.

Table 21. Questions students asked during post-visit interviews.

Question Type	Question
Basic info	Did the toads come in on their own or did you put them in their?
Comprehension	How many types of plants like cactus can live in the desert?
	Do the chives have seedpods or anything?
	Do toads help the plants at all?
	Would it (the seed) dry up?
	How does a plant grow?
	How did plants start?
	Are night crawlers bad?
	How does chlorophyll become that natural substance?
	How do seeds get made?
	How high can a plant grow?
	How does carbon dioxide help a plant?

Application	Do turtles and other water animals help underwater plants like worms do?
	But how does the plant grow (in just water)?
	When you pluck flowers usually you leave part of the stem on the ground. Why is there white stuff coming out of it? Is that chlorophyll or something?
	Why would they (plants) defend themselves from insects if insects help them pollinate?
	To make a new plant and seeds like fall onto the ground. I know they get pushed into the ground by the rain. What if that doesn't like happen for hundreds of years? Would the seed die or would something pick it up and bury it?
	What makes the ovary grow into the fruit?
	How does a plant get the energy to make seeds?
	Some of the peoples cotyledons were green, but some of them weren't. Why were some cotyledons brown?
	If they (plants) didn't start then we wouldn't be here right?
	What happens to the chlorophyll in the fall in the leaves?
	Why does too much water effect the plant? I know it will drown, but how will it drown? It needs water.
	How come the cactus lives in the desert and we have a few plants that live in the desert? How do they live when they're not in this grassy area with water and rain?
	(Explanation of cactus storing water). So, they are kind of like a camel?
	Where are the leaves on a cactus? Are they the spines or spikey thingies?
	So the spines are leaves… do they do photosynthesis?
	When he (a classmate) got his leaf it was a long leaf and now it's basically a liquid. How did that happen?
Synthesis	What if a seed like from a regular flower landed in the desert just for like one day and then it gets picked up by the wind again and blown into a place where it could grow and then it gets pushed into the ground, would it still grow?

DISCUSSION

INTRODUCTION

Seeds of Science field trips, held at the 4-H Children's Garden, give students many opportunities to wonder. This is partly because the outdoors, in general, provides a rich environment to wonder and sparks many great questions from students: "Why aren't maple trees tapped in the fall when the sap must be moving down in trees" (McNay, 1985). The 4-H Children's Garden is filled with plants that fascinate and delight children. From watching the leaves of a sensitive plant collapse to using chives as a straw, children become captivated and intrigued by their surroundings. Secondly, opportunities to wonder are actively encouraged and modeled as an important part of the Seeds of Science experience.

Walter E. Massey, president of the National Science Foundation, argued that museums and informal learning centers can play a large role in nurturing curiosity in youngsters by creating a sense of wonder that underlies the basis for the desire to learn and understand (Bresler, 1991). Interactive, hands-on experiences with real objects at museums and informal learning centers can enhance children's sense of wonder (Falk, et al., 1986). Unfortunately, outdoor learning environments have been neglected by teachers and researchers (Orion and Hofstein, 1994), yet they provide a wealth of wonderment opportunities. The Seeds of Science location and curriculum give students the chance to explore, discover, and investigate. Through hands-on activities and experiments, students have ample opportunity to wonder.

Children's wonderment can be expressed through questioning. Children do not want to just sit and wait for the world to impinge on them. They try actively to interpret it, to make sense of it (Donaldson, 1978). In their attempts to make sense of this mysterious world, student questions must be appreciated, acknowledged, and explored. McNay (1985) pointed out that not appreciating student questions leads children to believe that science in school is not meant to answer the questions that really puzzle one. The wonder questions must be dealt with. Time is allotted during Seeds of Science field trips to sit down and examine Wonder Wall questions. Students and garden experts discuss potential answers to questions, which show children that their questions are indeed valued and respected: "We see a need to nurture learners' natural curiosity by developing a spirit of inquiry in the classroom: in which questions are respected for themselves, whether or not we know or can even find out the answer" (Fisher, 1990).

The moral of science is clear: keep asking (Hoffmann and Torrence, 1993). Question generation, an important cognitive strategy, shows what students know about the content and is a strong indicator as to whether the concepts were understood (Roshenshire, et al., 1996). Encouraging students to ask questions makes them become actively involved in their own learning (Marzano, et al., 1988). During Seeds of Science field trips students were encouraged and challenged to generate questions. Many of their questions were quite thoughtful: "What would happen if you take pollen from an apple and put it on a lily, would you get a new plant?" "Why do two seeds with the same conditions grow at different rates?" Clearly these two questions show that there is an understanding of how pollen is involved in reproduction and how seeds can behave differently.

STUDENT GENERATED QUESTIONS

The Wonder Wall provides a comfortable place for children to freely ask questions and an opportunity for teachers to go back to students' questions when there is time; therefore, showing students that their questions are indeed appreciated and valued. It is similar to the question board used by Dixon (1995), which enabled children to express themselves freely and to grow in confidence as questioners, improving their questioning skills. If given the opportunity to ask questions, students will (Costa, et al., 2000). However, in a classroom setting some students may often times feel shy asking questions in front of peers. The Wonder Wall provides a safe, comfortable place for all students to voice their questions.

The percentage of wonderment questions that students asked on the Wonder Walls (Table 18) (67%) was quite high relative to previous studies. Chin, et al., 2002 reported that students averaged 14% wonderment questions during the course of five different hands-on activities. A previous study at the 4-H Children's Garden found that 2nd and 3rd grade students averaged equal amounts of wonderment and basic information questions on the Wonder Wall (Driscoll, 2004). Scardamalia and Bereiter (1992) found that students asked mainly basic information questions for a less familiar topic, but concentrated on wonderment questions on a more familiar topic. Basic information questions, which seek factual or procedural knowledge, are of minimal difficulty, low-level questions (Harper, et al., 2003). Basic information questions are often times elicited in new surroundings, since everything is so unfamiliar. Questions like, "Do you ever eat from the garden?" "How many plants are here?" "How long did it take to build this place," are expected as children become acquainted with their surroundings. The lower percentage of basic information questions in this study may be because these students were a bit older than previous studies (4^{th} grade versus 2^{nd} and 3^{rd}), because they were already somewhat familiar with the 4-H Children's Garden, or because greater emphasis was placed on asking thoughtful questions. From the data we cannot separate these possibilities. Regardless, these 4^{th} grade students asked many wonderment questions indicating their high level of interest and engagement.

The breakdown between basic information and wonderment questions remained quite constant across visits (Table 18). The content and activities differ on each field trip, therefore some level of basic information questions is expected since students are unfamiliar with the new concepts and procedures. There was a decrease in total number of questions asked for visit 3 and is likely related to the nature of the third visit. Since it is the final visit, everything is being wrapped up and there is less emphasis on writing questions on the Wonder Wall. School E was also more focused on answering questions from the Wonder Wall than writing new questions.

Wonderment questions reflect curiosity, puzzlement, skepticism, or a knowledge-based speculation for a more familiar topic (Scardamalia and Bereiter, 1992). Wonderment questions are associated with a deep approach to learning science, whereas basic information questions are related to a more surface approach (Chin, et al., 2002). Post-visit interviews elicited 97% wonderment questions because students were at the end of their plant science unit and had a larger knowledge base to work from (data not presented).

Wonderment questions were further divided into the following categories according to Bloom's Taxonomy (1956): comprehension, application, analysis, and synthesis. Comprehension questions are low-level, which may require some organization and selection of facts and ideas (Bloom, et al., 1956). Examples of Wonder Wall comprehension questions include: "Why did the plants grow so fast?" "How do plants make food?" Application and analysis questions are medium-level questions. Application questions deal with applying information to a new context or showing relationships between ideas (Harper, et al., 2003), which include: "Why is chlorophyll green instead of red?" and "How do plants know when to let go of their seeds?" Analysis questions require a bit more thought to generate and answer, and are higher up in Bloom's taxonomy. Analysis questions include: "Why do tulips close at night and open at daytime?" and "How come the plants grew so tall in earth soil, but not in Mars soil?" Synthesis questions are high level questions that combine ideas to make a new whole (Harper, et al., 2003), and include: "If four flowers were planted and only three grew, what could be the cause?" and "Does a poinsettia have red chlorophyll?" More than two-thirds of the Wonder Wall questions were comprehension, whereas over half of the interview questions were application. These differences may reflect students' greater understanding. The interview questions were asked at the end of the plant science unit, so students had a broader knowledge base of plants and could formulate higher order questions, which require more extensive and elaborate answers. Alternatively, the answers may reflect the method in which the questions were asked. – On the Wonder Wall students wrote what came to mind. In the interviews students were prompted by the interviewer. There were very few analysis and synthesis questions from either the Wonder Wall or interviews (Tables 19, 20). This is similar to the small number of analysis and synthesis questions that students asked in previous studies (Driscoll, 2004).

The fact that some higher order thinking questions were asked is exciting and should be explored and encouraged in future Seeds of Science explorations and studies.

Wonderment and learning go hand in hand. Students who are naturally curious and wonder, are intrinsically motivated to learn (Jenkins, 1969). In elementary school, concept development is a primary objective in science and curiosity is the motivational force in children to form concepts (Jenkins, 1969). As students wonder and question they begin to learn. Taba, et al., (1964) found that instructional models that utilized extensive student questioning had a great impact on their cognitive performance. The questions raised through interviews (Table 21) showed signs of both wonderment and learning. A student was curious about cacti and inquired: "Where are the leaves on a cactus? Are they the spines or spikey thingies?" The student had an idea as to where leaves are typically found on plants. A cactus however, did not fit perfectly into his knowledge structure of plants, but he was trying to reformulate his mental network and make meaning from it. King (1994) stated: "During this meaning-making process, individuals may draw inferences about the new information, take a new perspective on some aspect of their existing knowledge, elaborate the new material by adding details, and generate relationships between the new material and information already in memory." After a brief discussion between the student and researcher the student agreed that the spines must in fact be leaves and asked, "So the spines are leaves... do they do photosynthesis?" As Shodell (1995) stated, the best thinking comes from the best asking. This is a great question because the student's prior knowledge of photosynthetic leaves conflicts with cactus needles. Green leaves, having chlorophyll, are capable of photosynthesis, but would cactus spines function the same way? Individuals reformulate new information or restructure their existing knowledge and thereby achieve deeper understanding (Brown and Campione, 1986). Eventually the student comes to the realization that the green trunk or stem of the cactus is the photosynthetic organ of the plant. Through wonderment the student broadened his knowledge of plants.

Another example of how wonderment questions can reflect student learning is seen in Wonder Wall questions. A student asked "Why did plants grow so tall in earth soil, but not in Mars soil?" This question is based on observations made from the Wonder Cast. Plants were both growing in soil, yet those growing in earth soil out performed those growing in mars simulated soil. The student recognized that the growing conditions (light and water) were uniform between treatments, but the soil differed. At the time the student did not have the knowledge base to understand that the answer comes down to the properties of the soil and the nutrients it supplies to the plant. However, a fertilizer experiment, using the same type of plants in the Wonder Cast showed students firsthand that plant growth is influenced by nutrition. Through the Seeds of Science field trips many Wonder Wall questions were answered directly and many were answered by experimenting and drawing conclusions.

Another question from the Wonder Wall showed a connection between wonderment and learning: "Does a poinsettia have red chlorophyll?" The student had been told that the red "flowers" were actually leaves. The student knew that the leaves do photosynthesis, that photosynthesis involves chlorophyll, and that chlorophyll is green. Leaves must do photosynthesis and therefore must have chlorophyll. The student synthesized this information and a red leaf contradicted his existing knowledge structure, so asking if there is red chlorophyll is a logical, high level wonderment question. The

question reflects what the student learned and pushed the student to broaden and re-structure his knowledge.

CHAPTER 5

HOW DO POST-FIELD TRIP ACTIVITIES INFLUENCE STUDENTS' WONDERMENT AND LEARNING?

RESULTS

WONDERMENT

ON-LINE WONDER WALL QUESTIONS

Two schools utilized the on-line wonder wall following post-field trip activities. School C posted entirely wonderment questions, where as school E generated 56% wonderment (Table 22).

Table 22. On-line wonder wall basic information and wonderment questions.

School	Total # of Questions	% Basic Information	% Wonderment
C	21	0	100
E	125	44	56
Average		22	78

The wonderment questions posted on the on-line wonder wall were mainly comprehension questions (74%) (Figure 6). There were also 21% application question, while 5% were synthesis. No analysis questions were posted.

STUDENT DESIGNED EXPERIMENTAL QUESTIONS

One class from school E was involved with inquiry based, student-designed experiments. Students came up with their own question and designed an appropriate experiment to test their personal question. Each student came up with one question, all of which were wonderment questions. The wonderment questions were 11% comprehension, 5% application, 11% analysis, and 74% synthesis (Figure 6).

Comparing the types of questions students asked on the wonder wall, on-line wonder wall and as part of student designed experiments, students asked the highest percentage wonderment questions in student designed experiments with 100% compared to the wonder wall and on-line wonder wall with 67% and 78% wonderment, respectively (Figure 5). Student designed experiments also resulted in higher-level question asking with 74% synthesis compared to the wonder wall at 1% and the on-line wonder wall at 5% (Figure 6). Similarly, the percent of analysis questions was highest in the student designed experiments, 11%, and the wonder wall and on-line wonder wall at 5% and 0%, respectively.

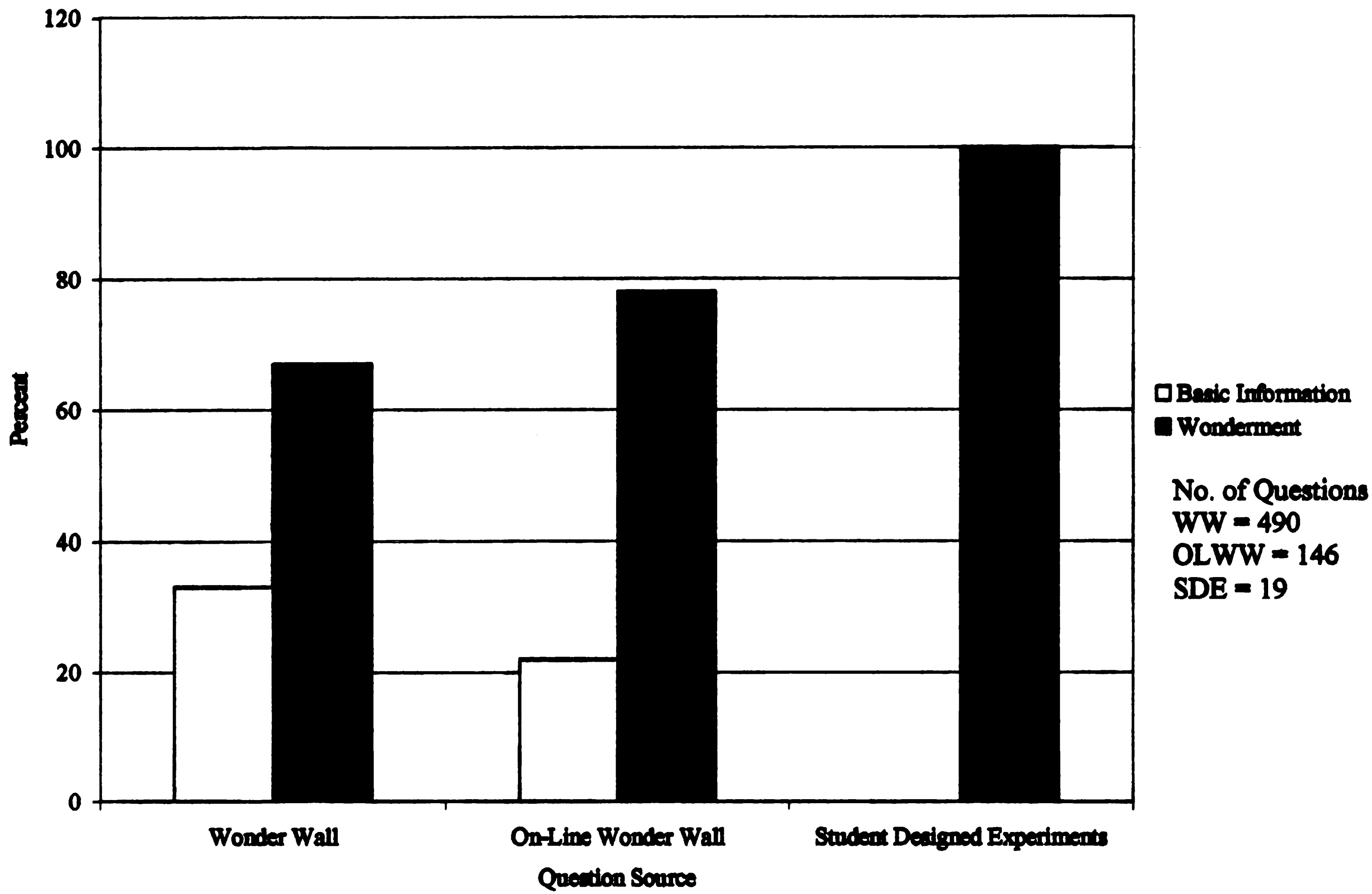


Figure 5. Basic information and wonderment questions generated from wonder walls, the on-line wonder wall, and student designed experiments.

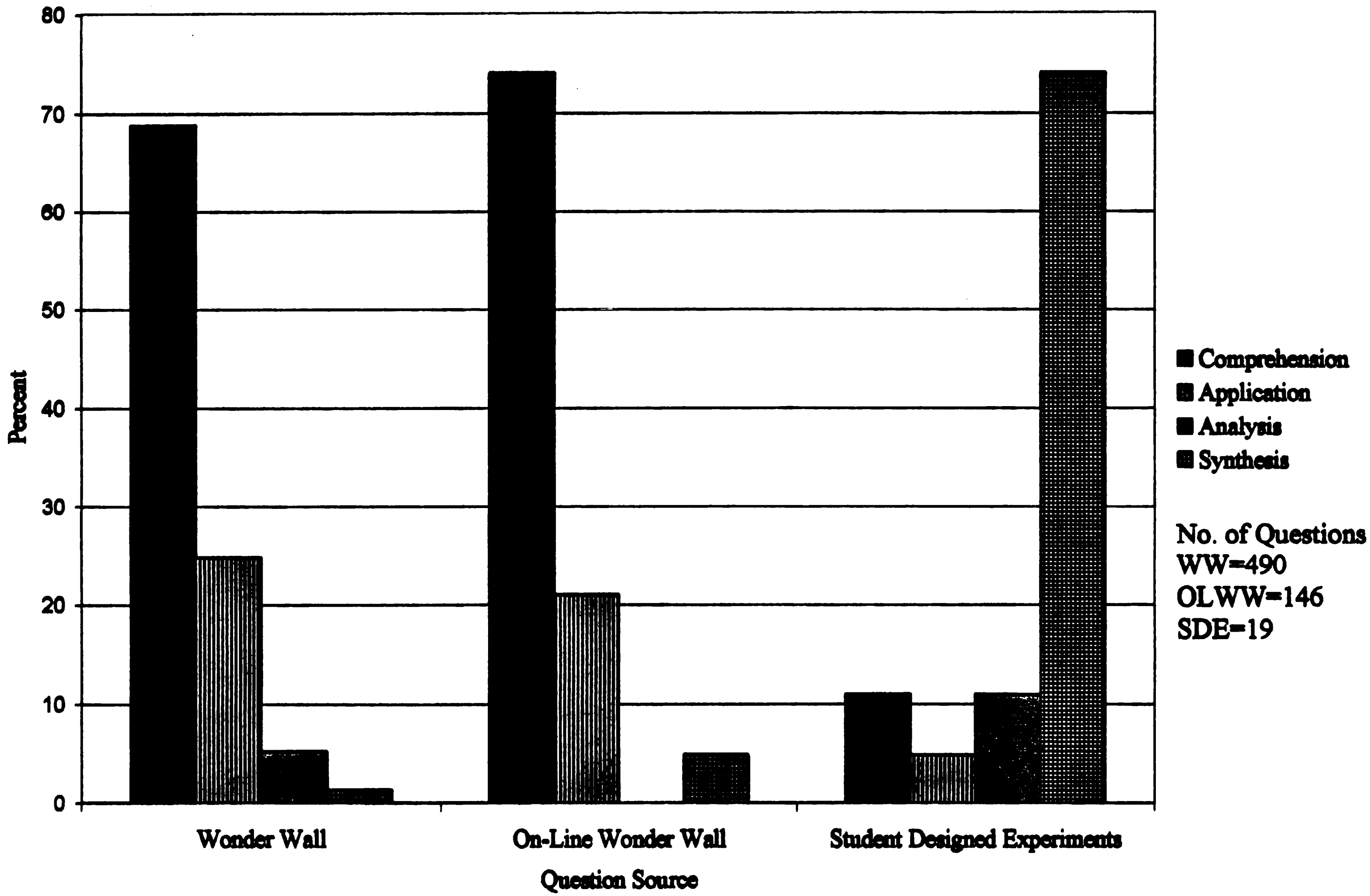


Figure 6. Types of wonderment questions asked on wonder walls, the on-line wonder wall, and student designed experiments.

LEARNING

ON-LINE WONDER WALL

Schools C and E utilized the on-line wonder wall as a means of staying connected to plant experts and scientist at the 4-H Children's Garden. Chat sessions with students can be used to pose questions to the students and quickly get a reading of their level of understanding (Table 23). In addition, student questions and the subsequent asynchronous communication with an expert can allow and encourage students to hypothesize or formulate reasonable answers to some of their own questions (Table 24). It also provides students opportunities to reflect on field trip experiments and then asking the next questions that they have.

Table 23. Expert generated questions and student responses from the on-line Wonder Wall chatroom.

Question from expert	Student responses
What will happen to a plant if tin foil is placed over a leaf?	It will die because the leaves need to do photosynthesis. It will die because it can't get any sunlight.
There was this lady who had an apple orchard. One day she discovered something very strange about her apple blossoms. They were all missing stamens! Will her trees produce apples?	She is not going to get apples because the stamens produce pollen. The pollen makes seeds. The pollen lands on the pistil and the tube grows down to the ovary and then the flower is pollinated. No it won't. She needs the stamens because pollination happens when pollen moves from the stamens to the pistil.

Table 24. Student generated questions and ongoing conversation with an expert on the on-line Wonder Wall.

Student Question or Statement	Expert Response
With my lettuce project, my lettuce is growing very well, but I can't see the orange dye in it yet.	Are you testing orange dye in one and just water in the other? Did you mix water in with the dye? If you did, you could try adding less water and more dye this next time to see if that makes a difference?
I'm wondering why me lettuce (freckles) is growing sideways? Is that a good thing? I got your answer about my lettuce (freckles) growing sideways. Yes it is by a window. I think it might be good because when we were growing lettuce at the MSU gardens freckles was growing sideways just the same as it is doing now.	Hmmmm.... Is your cup of lettuce by a window? If so, do the leaves seem to be heading in that direction (toward the window)? If that is the case, perhaps you could hypothesize why freckles is growing sideways. What do you think? So, why do you think that the leaves might be growing toward the window? Think about what the leaves for the plant and why that window is so important. I'm excited to hear your thoughts! This is fun!
Why do pansies have blue pollen? I got your answer on my blue pollen question. I'm not sure why either, but I think it might be because the flower is such a strong color (blue/purple). P.S. Please write back with your guess.	You know that's a great question. I have asked that myself before and I am just not sure. I could come up with a hypothesis, but I'd like to hear your guesses first. Why do you think they have blue pollen? Ok, you know how chlorophyll is a pigment that is found in leaves. Well, we know that chlorophyll gives leaves their great green color. There are all kinds of different pigments with crazy names. There are a group of pigments called anthocyanins that could be responsible for making that pollen blue. Why in those pansies (or were they petunias) that you were observing... I'm still not sure. What advantage might the petunia have if its pollen is blue and not yellow? Any thoughts?
Try putting lemonade and pop in two different cups with seeds. If you find out which grows better, tell me.	I don't have lemonade. Why don't you give it a shot and report back to me. Be sure to make a hypothesis first!

LAB REPORT

Schools B, D, and E were involved in post-visit activities with a garden expert. The lettuce experiment was finished with a final data collection and lab report. Students were asked: "Based on the data you have collected and the graphs that you have created, what is the best lettuce cultivar that other students would love eating in their school lunches? Why is it the best? Think about height, leaf characteristics and taste." Select responses with corresponding data are presented in Table 25.

Table 25. Lettuce experiment "best" cultivar selection. Images are that of student work.

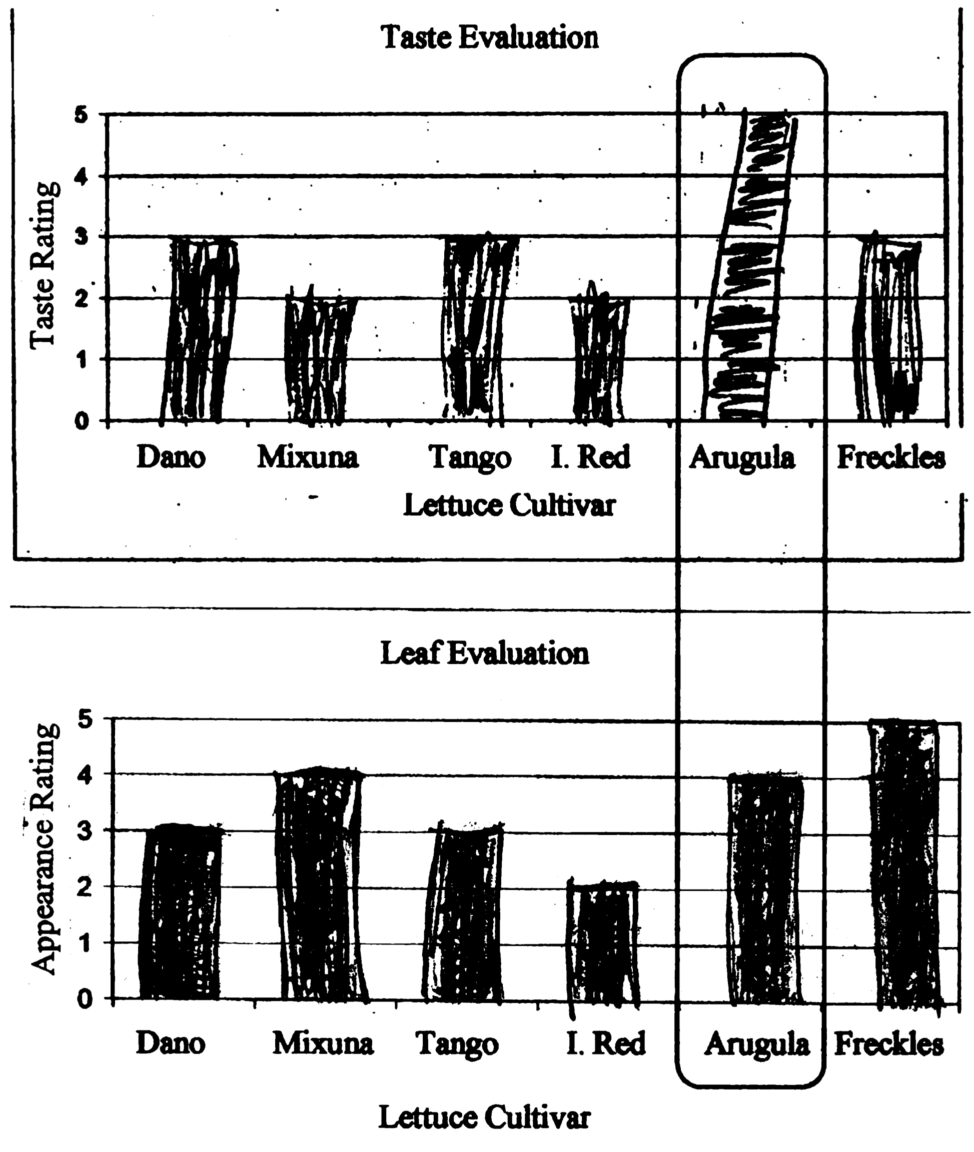
<table>
<tr><td>Data</td><td>
</td></tr>
<tr><td>Response</td><td>I think Arugula is the best because in taste I think I would give it a 5 and in appearance probably a 4. It is 5 inches and that is tall.</td></tr>
</table>

Table 25 continued.

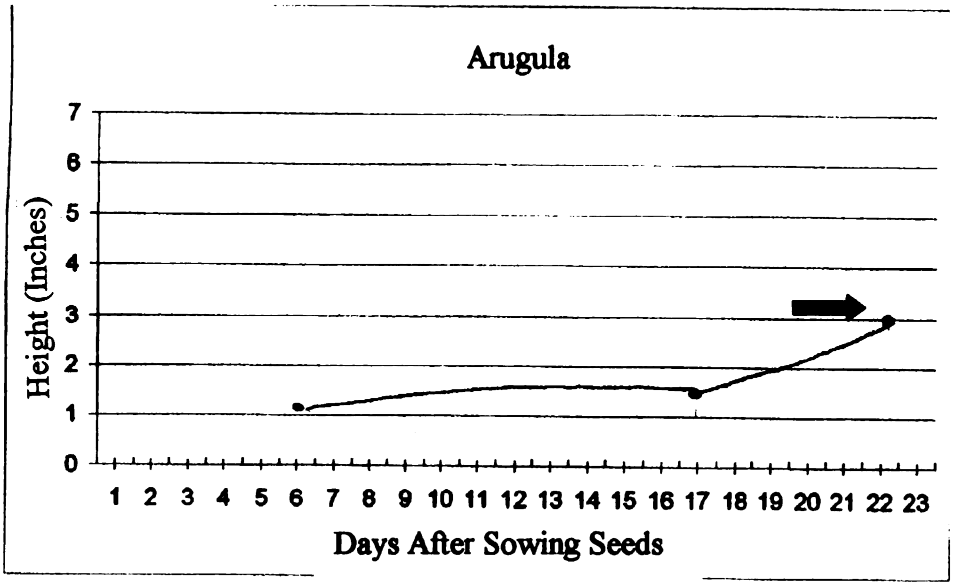
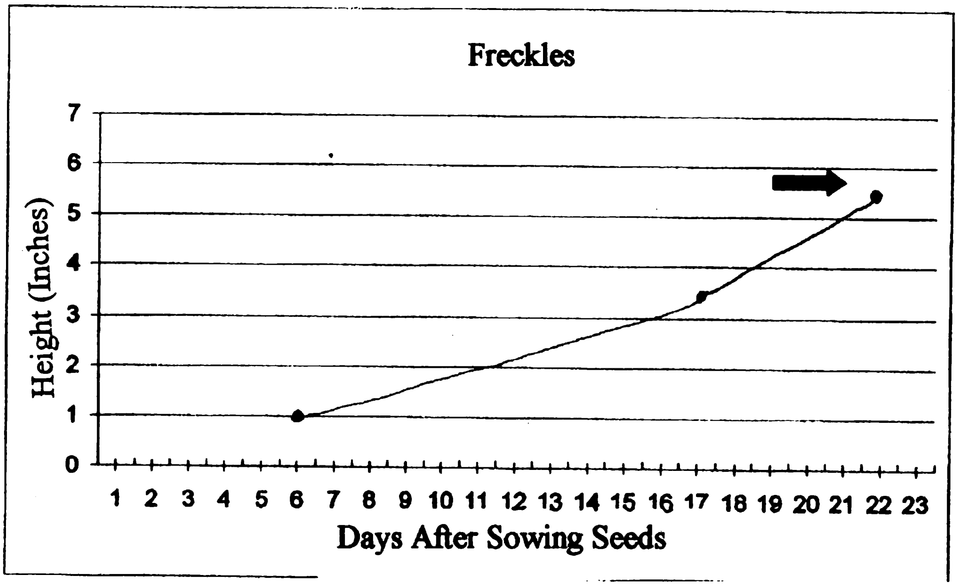
Data	 
Response	I think you should pick Freckles because it is the tallest, great shape, exciting, and great taste.

Table 25 continued.

Data	
Data	**1. Plant Height**

	1 – Dano	2 – Mizuna	3 – Tango	4 – Integrata Red	5 – Arugula	6 - Freckles
Height (Inches)	2 in	3 in	4 in	4 in.	1/2 in.	2 in

2. Overall Leaf Evaluation

In the table below evaluate each of the lettuce cultivars on their overall leaf appearance. Assign a number 1 to 5 for each of the cultivars. You may think all six of the cultivars are outstanding and give them all 5's or you may assign a range of numbers.

1 – Unacceptable. Leaves brown, shriveled, close to dying or dead.
2 – Poor – Leaves have some dead/brown spots.
3 – Average – Typical color, texture, and leaf shape
4 – Good – Leaf appears healthy and has good color and shape
5 – Outstanding – Leaf is striking with fantastic color and unusual, appealing shape.

	1 – Dano	2 – Mizuna	3 – Tango	4 – Integrata Red	5 – Arugula	6 - Freckles
Appearance Rating	3	4	2	4	5	1

3. Taste Evaluation

Taste a portion of a leaf for each cultivar and assign them a number according to the following scale:

1 – Unacceptable – Disgusting, can't hardly swallow it
2 – Bad
3 – Average
4 – Good
5 – Outstanding – You just love the flavor!

Assign a number 1 to 5 for each of the lettuces below.

	1 – Dano	2 – Mizuna	3 – Tango	4 – Integrata Red	5 – Arugula	6 - Freckles
Taste Rating	2	4	3	2	3	5
	7	11	9	10	9½	8

Response

Mizuna is the best because all of the ratings added up to make it the best.

DISCUSSION

INTRODUCTION

Post-visit activities were designed to reinforce what was learned on Seeds of Science field trips including science content and asking questions. The influence of post-visit activities in the classroom on subsequent learning and knowledge construction has largely been neglected by researchers in the past (Anderson, et al., 2000). Through use of the on-line Wonder Wall, student designed experiments, and the lettuce growth and evaluation lab report, students were immersed in hands-on, minds-on activities that all happened post-visit and required continued thinking and wonderment in plant science.

WONDER

ON-LINE WONDER WALL

The on-line Wonder Wall provides students with a place to voice their wonderment, note observations, ask questions and seek answers. Isaacs (1930) viewed the child's own question as a prized object that should be at the center of the curriculum. By having experts respond to questions posted to the on-line Wonder Wall, students know that their questions are important, valued, and "prized objects." Encouraging and emphasizing question-asking better exposes students to the fundamental inquiry nature of science (Marbach-Ad and Sokolove, 2000). Thus the on-line Wonder Wall actively encourages students to ask and think, to do science on their own.

As students continue to explore and question, they will need help in seeking some answers (McNay, 1985). The on-line Wonder Wall provides a way for experts to answer questions post-field trip, thus allowing continued inquiries in plant science. Chin and Li-Gek (2004) point out that "students are sometimes puzzled or intrigued by observations and events in their lives beyond school and have questions pertaining to these." The on-line Wonder Wall is an outlet for student curiosity. Students can continue to question natural phenomena that they have personally experienced or observed and via the on-line Wonder Wall find answers.

Out of all the questions posted to the on-line Wonder Wall, 78% were wonderment questions (Table 22), a similar percentage as questions posted on the Wonder Wall in the garden and as questions asked in the interviews. Wonderment questions were largely comprehension, 74% (Figure 6) (Bloom, et al., 1956). These questions included: "What was the last plant found?" and "Why do plants produce oxygen?" Another 21% of the wonderment questions, were application questions including: "Why do pine trees keep their needles and why don't they change?" and "How do roots grow out of the seeds hard covering?" Few synthesis questions were posted, only 5% and included: "How does food coloring in the water for spinach effect the color of the spinach and growth?" and "How long does it take to grow lettuce by a tree blocking it? Will it survive? Or will it live, but not perfect?" The on-line Wonder Wall provided yet another opportunity for students to express their wonderment in the form of questions.

STUDENT DESIGNED EXPERIMENTS

Teachers who practice inquiry-based education encourage their students to wonder by pushing them to ask questions that are personally meaningful and interesting

(DuVall, 2001b). Students feel as if they are doing 'real' science and take ownership of the problems when they pursue answers to questions which they find meaningful (Chin and Li-Gek, 2004). What may start off as a wonderment question can quickly turn into learning: Learning is based on what the students are interested in and driven by students' need to answer their own questions (Chin and Li-Gek, 2004). Falk (2004) stated that "learning is influenced by an individual's desire to choose and control his/her own learning." Through inquiry-based experiments students can explore their own wonderment questions and therefore, they can essentially control their own learning. Inquiry learning seeks to excite curiosity in students, encouraging them to investigate questions on their own initiative and grounding this activity in authentic situations (Byers and Fitzgerald, 2002).

Chin, et al., (2002) noted that "allowing students to generate their own investigation questions stimulated curiosity and encouraged profound thinking about relationships among questions, tests, evidence, and conclusions." Pupils should ask questions related to their work in science and turn their own ideas into a form that can be investigated (DfE, 1995). However, Dixon (1996) noted that very few student questions are suitable for testing. Enquiries that lead to investigations are often more difficult to stimulate (Dixon, 1996). This was true in the Seeds of Science student-designed experiments. Although students came up with their own testable question, many of their initial questions were not testable. This is clear by looking at the types of questions asked on the Wonder Wall (Figures 5,6), which were largely basic information questions plus comprehension and application wonderment questions. Garden experts worked with students and challenged them to think of a question that could turn into a scientific

investigation. Students were told to think about a question that they wanted answered, which "engages students in formulating questions, supporting the notion that inquiry and investigation need to be based on student curiosity and interest" (Long, et al., 2004). Many of the children were capable of the task and asked questions that could lead to an investigation.

The questions students asked when developing their own experiment were all wonderment questions (Figure 5). This is a much greater percentage than when students asked questions using the Wonder Wall (67%) or the on-line Wonder Wall (78%). This in part is the result of experts pushing students to come up with testable questions, which forced students to think beyond low-level, basic information questions. Nearly three quarters of the questions students asked for their personal experiments were synthesis questions, which is a substantially greater percentage than questions generated from the field trip Wonder Walls and the on-line Wonder Wall (Figure 6). Again this may be due to experts encouraging the students to think and plan beyond what is right in front of them. These types of inquiry-based experiments begin with student wonderment, push students to question at a higher level, and solve their own problems through active exploration, discovery and reflection (Latham, 1996). Kleinman (1965) found that science instruction that utilized higher level questioning, resulted in greater scientific achievement of students.

During an interview a student commented that her lettuce, from her personal experiment, was not growing well. The question she was asking in her experiment was: "What would grow if one was in a cupboard and one in the freezer?" When asked why they were not growing well the student responded: "I think one of the reasons why is because they are not getting enough sunlight." She was able to draw conclusions based on her own observations. What started out as a seed of wonderment became a learning experience. Even though she has likely heard that plants need light to grow, she saw first hand that their survival is dependent on it. Inquiry privileges students' natural questions, which become the center of their own learning experiences (Commeyras, 1995).

LEARNING

ON-LINE WONDER WALL

The on-line Wonder Wall can help students learn content in at least two different ways. First, synchronous chat sessions between experts and students can reinforce science material that was learned on field trips. During one chat students were asked "What will happen to a plant if tin foil is placed over a leaf" (Table 23). This question was never raised during any of the field trips, but it required students to tap into their plant science knowledge and hypothesize potential outcomes. Students had to recall the function of leaves and therefore hypothesized that either the plant or leaf would die since "the leaves need to do photosynthesis" and "it can't get sunlight." Students' plant science knowledge was further probed by asking them if apple blossoms without stamens would be capable of producing fruit. Students recalled propositions, linking concepts like stamen and pollen together: "She is not going to get apples because the stamens produce pollen." Students acknowledged that without pollen fruit set would not occur. Chatting with students on-line is a way of maintaining connections with students between field trips or upon completion of Seeds of Science. Conversations challenge students to recall information learned during their plant science unit, which reinforces existing cognitive schemas.

The on-line Wonder Wall further stimulates learning by engaging students asynchronously through question asking and expert responses. Students' questions can be used to direct their inquiry and guide construction of knowledge (Chin, et al., 2002). Students' questions are addressed in one of two ways. Basic information questions and lower level questions are often times answered directly. Thought provoking questions allow the expert to offer guidance to the student, leading him/her to the answer. For instance, a student inquired as to why her lettuce was growing sideways, to which the expert responded "Is your cup of lettuce by a window? If so, do the leaves seem to be heading in that direction (toward the window)? If that is the case perhaps you could hypothesize why Freckles is growing sideways" (Table 24). The expert's role was to lead the student to the answer, so she could discover herself. McNay (1985) pointed out that "some of the best questions in science are those children can answer through their own activity – observing, measuring and experimenting for themselves, and finding out through a discovery process." Weber (1971) stated that a child must find a solution for the problem he was searching to understand, a solution that makes sense of the observations he has made. The on-line Wonder Wall provides an outstanding tool to carry on these conversations, direct inquiry and facilitate wonder and discovery. In addition, it is fun to use.

LAB REPORT

The lettuce lab report was intended to embody the scientific method, giving students firsthand experience with each step of the process. The investigations required them to develop hypotheses, collect data, analyze data, and draw conclusions. Students did the lettuce experiment to answer the driving question: "Which lettuce cultivar would be the best to grow and eat for 4th grade school lunches?" Metz (1995) presented a strong argument that elementary students are capable of performing investigations and learning from them, even though, due to limited prior knowledge, their investigations will be less sophisticated than those of adolescents and adults. This experiment actively engaged students in collecting and analyzing data (height, color, taste) over time, in order to identify the "best" lettuce cultivar. As expected, the "best" varied among students, but their rationale for choosing a particular cultivar was fairly consistent and was based on the data they had collected and analyzed. Student bar and line graphs aided them in determining the "best" lettuce. One student creatively tallied up the numbers ascribed to each cultivar on the final data collection to see which scored the highest overall when it came to height, leaf and taste evaluations (Table 25). Other students based their determination of "best" based on a single characteristic that was most important to them. They were exposed to the concept that there may be more than one "best" cultivar depending on the criteria used in the evaluation. During an interview about the lettuce experiment, one student stated: "I learned that lettuce leaves can look different. They can be different colors: green, red, and pale green. The edging of the leaves, some are round like clovers and some are spiky. How they feel - some of them feel soft, some of them feel rough, some of them feel smooth." For these students, this was a unique experience that we hope will influence their understanding of science and their attitude toward science for years to come.

Upon completion of the lab report and time permitting, students were encouraged to ask a new scientific question. They were asked to voice their thoughts as to what the next investigation should be, therefore reinforcing the idea that the science process is ongoing. There are always more questions to ask and more experiments to design. As McNay (1985) stated: "Science is, after all, not the acquisition of right answers but the growth of understanding; and children learn something valuable when they sense that in science there is always more to discover." Based on these students' new questions we expect to see experiments examining, "What would happen if you put 7 drops of red dye in the water, would the leaves turn red?" and the effects of placing "2 fertilizer pellets on the bottom in one and 2 fertilizer pellets on the top in the other one." And best of all, these students are excited about carrying out these experiments and confident, based on their experiences with Seeds of Science, that they can carry them out.

CONCLUSIONS

Hypotheses

Seeds of Science field trips and subsequent post-visit activities had marked impacts on student learning and knowledge structure, wonderment, and the questions students asked.

Hypothesis 1 stated that students' post-visit knowledge of plant science will be greater than students' pre-visit plant science knowledge. The hypothesis is supported for all schools in science process except for school D, and is further supported since all schools showed significant differences in plant and flower parts total scores. Students also broadened their knowledge of plant problems, identifying significantly more concepts in the following categories: insect and disease, symptoms, and treatments. These categories are specific to the Seeds of Science curriculum and are a direct reflection on the program.

Hypothesis 2 stated that students' post-visit concept maps will be more similar to the expert map, in terms of concept organization and number of valid links, compared to students' pre-visit maps. Hypothesis 2 was supported for all schools in science process specific connections, except for school A, which was not involved in post-field trip follow up. This reflects the importance of post-field trip activities, which reinforce and elaborate on concepts learned during the Seeds of Science field trips. School D showed a high level of science process knowledge prior to the Seeds of Science field trips, and although there was not a significant increase in knowledge, students did show a significant increase in science process specific connections. This indicates that students restructured the knowledge into a more expert-like schema. The hypothesis is further supported since five of the six schools showed a significant increase in plant and flower parts specific connections. The only school that did not show significant increases did not experience the complete flower part curriculum at the 4-H Children's Garden.

Hypothesis 3 stated that students will express basic information questions and wonderment questions relatively equally during the Seeds of Science field trips. Hypothesis 3 was not supported. Two thirds of the questions asked during the field trips were wonderment questions. In previous studies in the 4-H Children's Garden 50% of the questions were wonderment. It is not clear why there was this increase in wonderment questions, but it is exciting to note that 4th grade students ask such a high percentage of higher order, thinking questions.

Hypothesis 4 stated that students engaged in post-field trip activities will have a greater change in science process knowledge compared to those students who did no follow up. Hypothesis 4 was supported since those schools who participated in post-visit activities showed a significant difference in science process specific connections, and the only school not involved in post-visit activities did not.

Hypothesis 5 stated that students will express more wonderment questions in post-visit activities than during the course of the Seeds of Science field trips. Hypothesis 5 was supported. Students expressed the highest percent wonderment with student designed experiments followed by the on-line Wonder Wall, both of which were implemented during post-visit activities.

Seeds of Science Stimulates Wonder

Children love exploring and making discoveries. Children come to know the world at large via wonder (Cobb, 1977). Field trips in general stimulate wonderment by being in a new setting, leaving the confines of the traditional classroom. The 4-H Children's Garden provides an environment conducive to exploration, allowing children to imagine, wonder, and be curious. Seeds of Science field trips encourage student wonderment by giving students time to make detailed observations and reflect on their findings. Two-thirds of the questions posted to the Wonder-Wall were wonderment questions, which is a remarkable amount and is an indication of student wonderment.

Seeds of Science Stimulates Learning

In addition to stimulating wonderment, field trips also stimulate student learning. Field trips provide opportunities to illustrate and reinforce concepts (Keown, 1984). Seeds of Science field trips, being integrated and spread out through the course of students' plant science unit, provide a way of either establishing the foundation for new concepts or reinforcing concepts that have already been introduced in the classroom. Since Seeds of Science is centered at the 4-H Children's Garden, concept development is largely driven by students' experiences in the outdoor environment.

Knapp (2000) indicated that one primary outcome of the field trip experience is retention of knowledge. Seeds of Science curriculum is largely comprised of hands-on activities and explorations. When students are actively engaged in hands-on activities, they are more apt to associate the concepts with the experience, thus recalling the information more readily. As new information is learned and processed students assimilate the information into existing mental schemas: "Individuals may draw inferences about the new information, take a new perspective on some aspect of their existing knowledge, elaborate the new material by adding details, and generate relationships between the new material and information already in memory" (King, 1994). Organization of information influences learning. (Weinstein and Mayer, 1986).

Students showed a gain and re-structuring of knowledge through the Seeds of Science program. Plant science knowledge was fairly limited and unstructured in pre-visit concept maps, but post-visit maps were much more sophisticated. Crandell, et al., (1996) stated that "in the beginning, or when information is incomplete, [young children] may construct naïve explanations. These explanations may be revised, and they can become much more sophisticated as the learning process proceeds." Post-visit maps were more similar to the expert map. Relationships became more complex and intricate in the post-visit maps, similar to changes noted by Freeman and Urbaczewski (2003).

Wonder Stimulates Learning

Plato stated that the origin of knowledge emerges from a child's sense of wonder (cited in Nikola-Lisa, 1988). Wonder leads to learning. Seeds of Science field trips and post-visit activities encourage wonderment and therefore offer the foundation for learning. The Wonder Wall used during field trips, the on-line Wonder Wall, and student designed experiments all provided means for students to express their wonderment questions. Questioning, a sign of student wonderment, is also known to have many positive effects on student learning, comprehension, and knowledge (Costa, et al., 2000). Yolen (1981) noted that wonderment is the beginning of understanding. Through the course of the Seeds of Science field trips, garden experts worked to stimulate curiosity and wonderment amongst students, ultimately leading them to draw their own conclusions and answer some of their own questions. Seeds of Science activities provided numerous opportunities for students to take an active role in their own learning. Garden experts provided the necessary scaffolding to encourage student questioning. In this way students' curiosity could lead to learning.

Future Studies

To further our understanding of how Seeds of Science field trips and post-visit activities impact student learning and wonderment future studies are necessary. Several aspects of Seeds of Science should be studied further. First, additional work should be done to study how teachers deal with wonderment questions pre- and post-Seeds of Science. This would provide insight into how students' questions are handled throughout the entirety of the plant science unit versus just at the 4-H Children's Garden. Students' questions need to be continuously valued. Garden experts need to help teachers in promoting wonder and curiosity in the classroom.

Second, additional investigation of the on-line Wonder Wall as a tool to promote student questioning between and after Seeds of Science field trips is needed. The on-line Wonder Wall has the potential to actively engage students both in and out of the classroom, linking them directly to scientists and other experts. The impact of experts promptly answering students' questions and encouraging them to ask more should be studied to determine the effects on students' willingness to ask questions and on the type of question they ask.

Third, inquiry-based, student designed experiments need to be tested on a larger scale and followed through to completion. Will students be able to make observations, collect data, and answer their own research question? Can students effectively carry their experiments out using the on-line Wonder Wall as a resource for answers and guidance? Implementing student designed experiments in the Seeds of Science field trip curriculum may offer students the confidence to see subsequent inquiry experiments through to the end.

APPENDIX A

Fast Plants Wondercast

Scientific name: *Brassica rapa*

Explore the fast plants Wondercast. Watch how the plants grow and flower. When you have explored the Wondercast answer these questions:

1. What was the first day of the Wondercast?

2. What was the last day of the Wondercast?

3. How tall were the plants growing in earth soil on 10/15/02?

4. What date can you see the first flower?

5. How much did the earth soil plants grow between 10/10/02 and 10/17/02?

6. What questions about Fast Plant growth do you have after exploring the Wondercast?

APPENDIX B

Fast Plants
Fertilizer Experiment

Name: __________________ Date: ______________

Collect data:

Your experiment – Amount of fertilizer: _______________________________

Days after seeding: ____________________

Number of seeds germinated: ____________________

Plant height: _________________________________cm

Notes: ____

____

____

____

____

Name: __________________ Date: ______________

Collect data:

Your experiment – Amount of fertilizer: _______________________________

Days after seeding: ____________________

Number of seeds germinated: ____________________

Plant height: _________________________________cm

Notes: ____

____

____

____

____

APPENDIX C

Lettuce Growth and Evaluation Experiment
Introduction and Experimental Design

1. ASK A QUESTION:
   Is there a lettuce cultivar that 4th graders will think is the best to grow and eat for school lunches?

2. RESEARCH
   a. There are many different lettuce cultivars
   b. There are differences in what lettuce cultivars are used for
   c. Different lettuce cultivars have differences in the leaves – color, leaf margin (edge of the leaf), and other differences

3. HYPOTHESIS:
   I predict that all the lettuce cultivars (circle one) will will not grow the same and will taste the same.

4. DESIGN EXPERIMENT:
   a. We will plant 6 lettuce cultivars
      - One - Dano
      - Two - Mizuna
      - Three - Tango
      - Four – Integrata Red
      - Five - Arugula
      - Six - Freckles
   b. All cultivars will be planted in growing cells.
   c. Soil – greenhouse soil mix
   d. Fertilizer – none
   e. Watering – uniform
   f. Growing conditions – under fluorescent lights

   These are the lettuce characteristics that we should measure.

   ____

   ____

   ____

APPENDIX D

Lettuce Growth and Evaluation Experiment
Data Collection

Date_______________

1. Record plant height

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Plant Height (Inches)						

2. Leaf Data

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Describe the leaf edge						
Sketch leaf						
Color(s)						
Other observations						

APPENDIX E

Lettuce Growth and Evaluation Experiment
Final Data Collection

Date ________________

1. Record plant height

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Plant Height (Inches)						

2. Leaf Data

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Describe the leaf edge						
Color(s)						

1. Overall Leaf Evaluation

In the table below evaluate each of the lettuce cultivars on their overall leaf appearance. Assign a number 1-5 for each of the cultivars. You may think all six of the cultivars are outstanding and give them all 5's or you may assign a range of numbers.

1 – Unacceptable. Leaves brown, shriveled, close to dying or dead
2 – Poor. Leaves have some dead/brown spots
3 – Average. Typical color, texture and leaf shape
4 – Good. Leaf appears healthy and has good color and shape
5 – Outstanding. Leaf is striking with fantastic color and unusual, appealing shape

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Appearance Rating						

2. Taste Evaluation

Taste a portion of a leaf for each cultivar and assign them a number according to the following scale:

1 – Unacceptable. Disgusting! You can't hardly swallow it!
2 – Poor. You are pretty tough to taste it, but you won't eat it again!
3 – Average. Not bad, not great, either.
4 – Good. Its...good, you could eat this again (maybe with a little ranch dressing)
5 – Outstanding. You just LOVE the flavor and will eat it at any opportunity!

Assign a number 1-5 for each of the lettuces below.

	1 Dano	2 Mizuna	3 Tango	4 I. Red	5 Arugula	6 Freckles
Taste Rating						

APPENDIX F

Lettuce Growth and Evaluation Report

When carrying out a scientific investigation, a scientist must go through the steps of the scientific process. The lettuce experiment is a great example of a scientific investigation and you as a scientist need to report back on your findings.

1. Ask a question

What question did you ask to start this experiment?

2. Research

People, the internet, and books/magazines can be used to get more information on a topic.

- Miss Kelli offered some information on her experiences growing and tasting lettuce.
- We looked at the Johnny's Selected Seeds Catalog, which had pictures of many different types of lettuce.

3. Hypothesis

What was your educated guess as to how the lettuces would look, grow, and taste?

4. Design an experiment

What did you do to set up your experiment? Be sure to list everything so that someone else could read this and do your experiment. This is called a procedure.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

5. Collect Data

You collected data at three different times.

May 10th, At the Children's Garden – Height measurements, leaf sketches, etc.
May 21st, In class - Height measurements, leaf sketches, etc.
May 26th, In class – Height measurements, leaf and taste evaluations

*Please attach all 3 data sheets to the report.

6. Explain Data

Use the data you have collected to create some graphs below. The following dates are important:

May 4th – Sowed lettuce seeds at the Children's Garden
May 10th, 6 days after planting – 1st data collection at the Children's Garden
May 21st, 17 days after planting – 2nd data collection in class
May 26th, 22 days after planting – 3rd data collection in class

Line graph example.

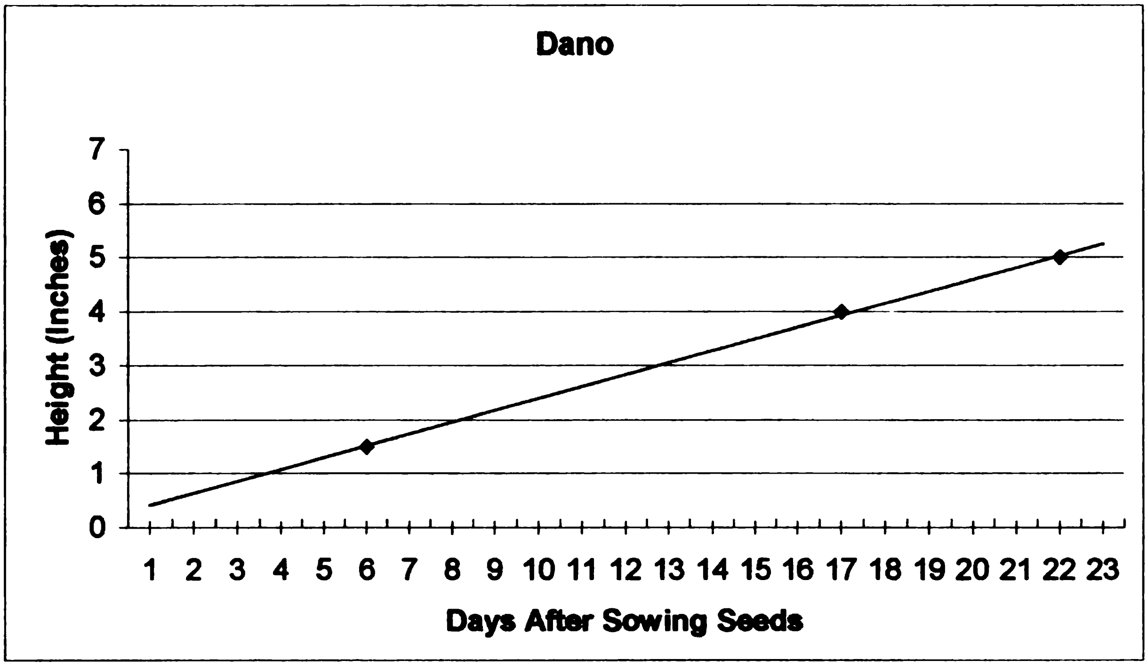


Figure 1. Height of Dano lettuce from planting to _ days after planting.

Create your own line graphs below using the data you have collected.
See the 1st, 2nd, and final "Lettuce Experiment Data Collection" sheet, #1.

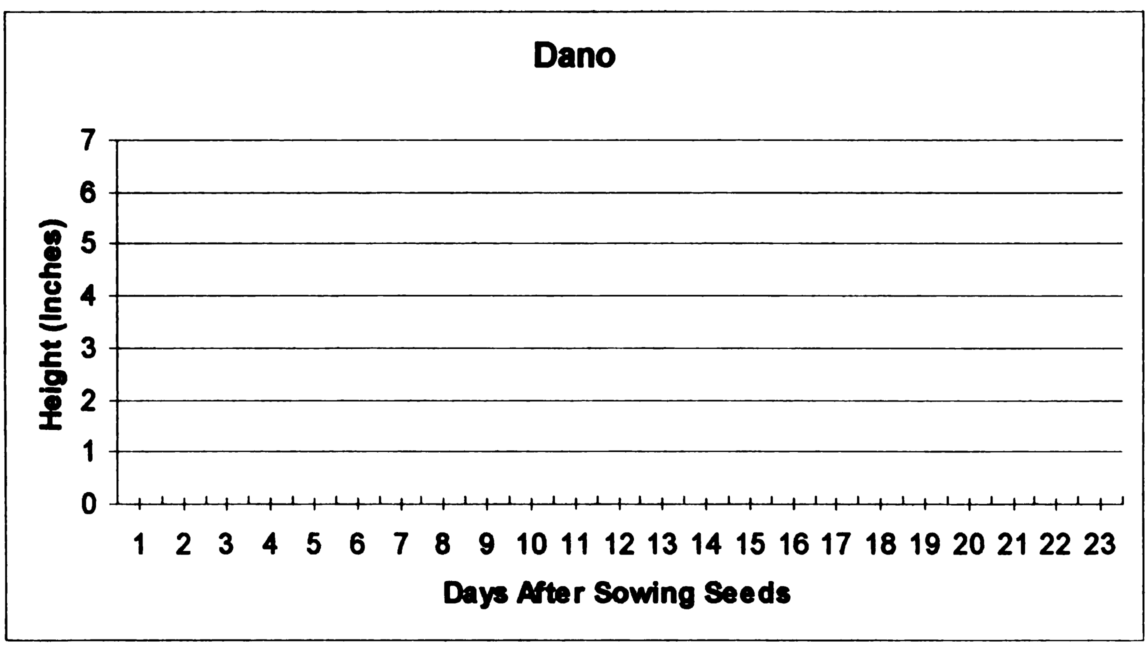


Figure 2. Height of Dano lettuce from planting to _ days after planting.

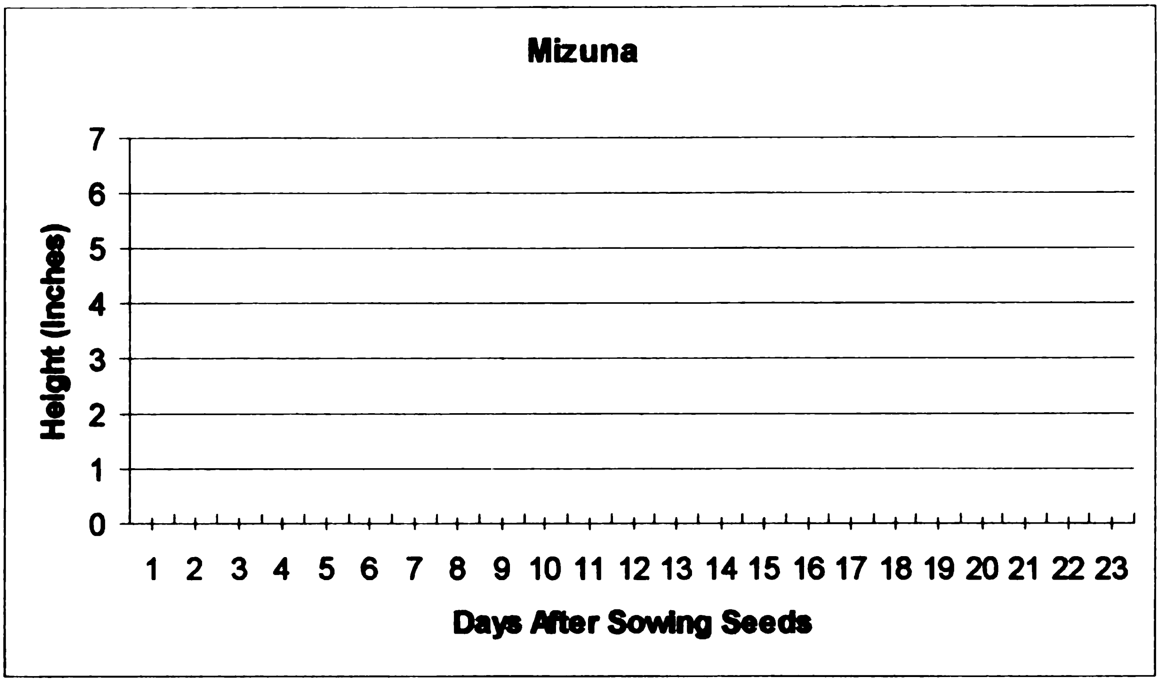


Figure 3. Height of Mizuna lettuce from planting to _ days after planting.

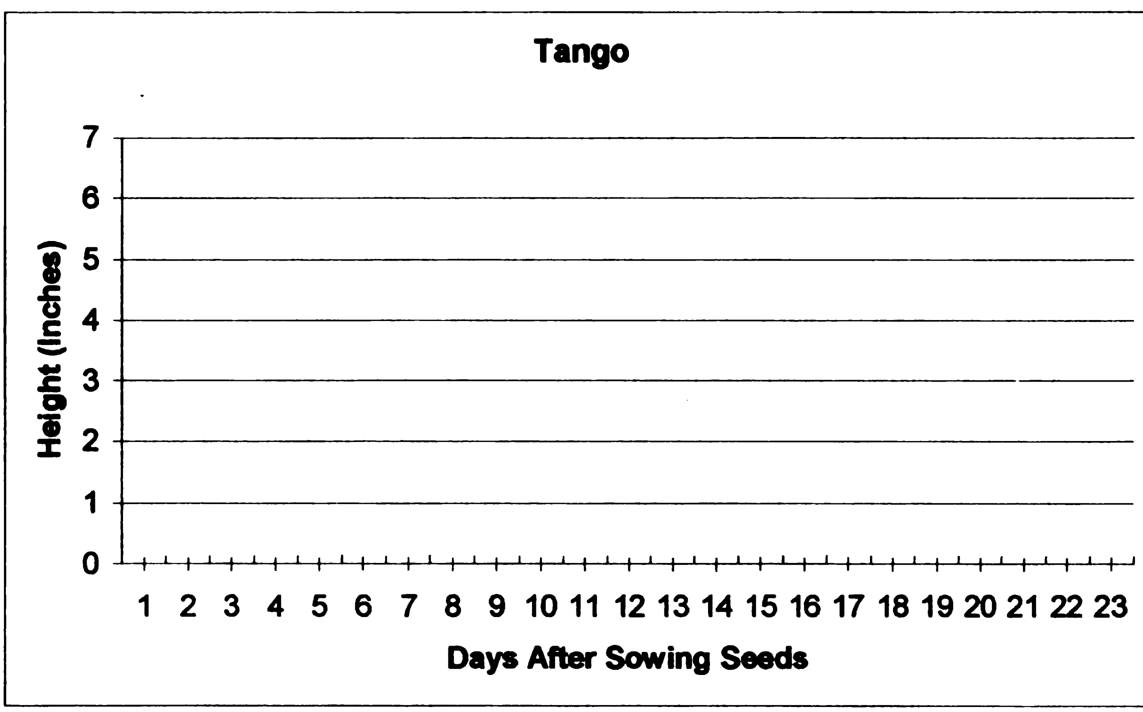


Figure 4. Height of Tango lettuce from planting to _ days after planting.

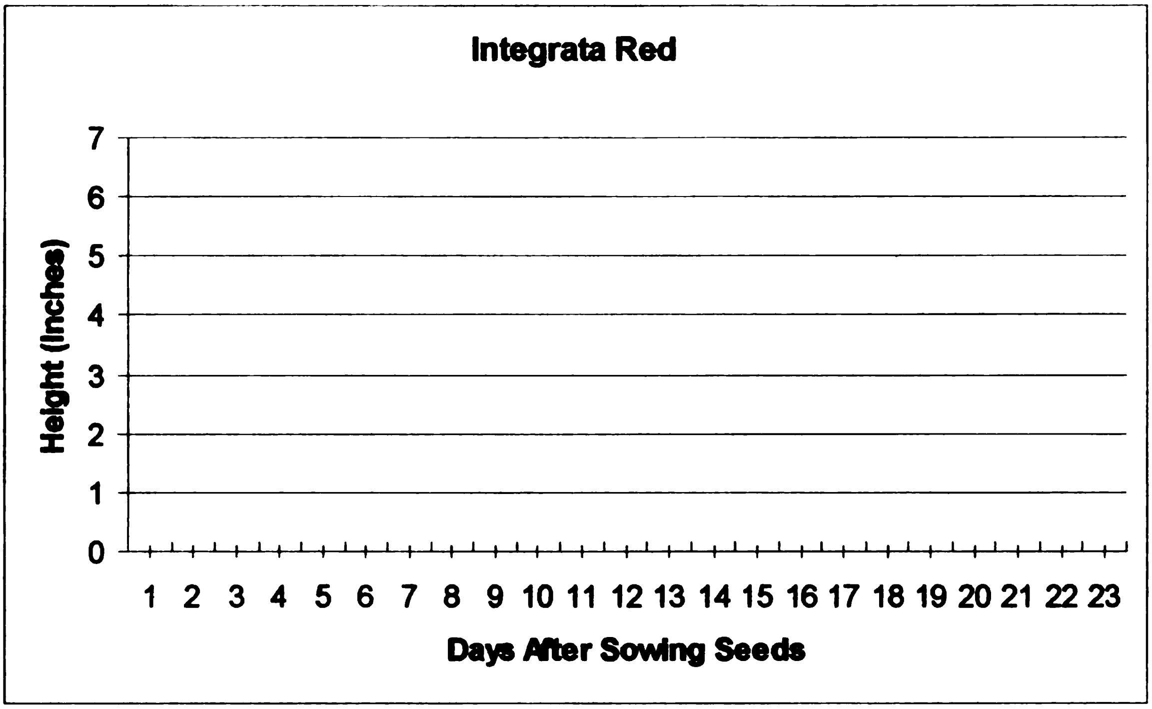


Figure 5. Height of Integrata Red lettuce from planting to _ days after planting.

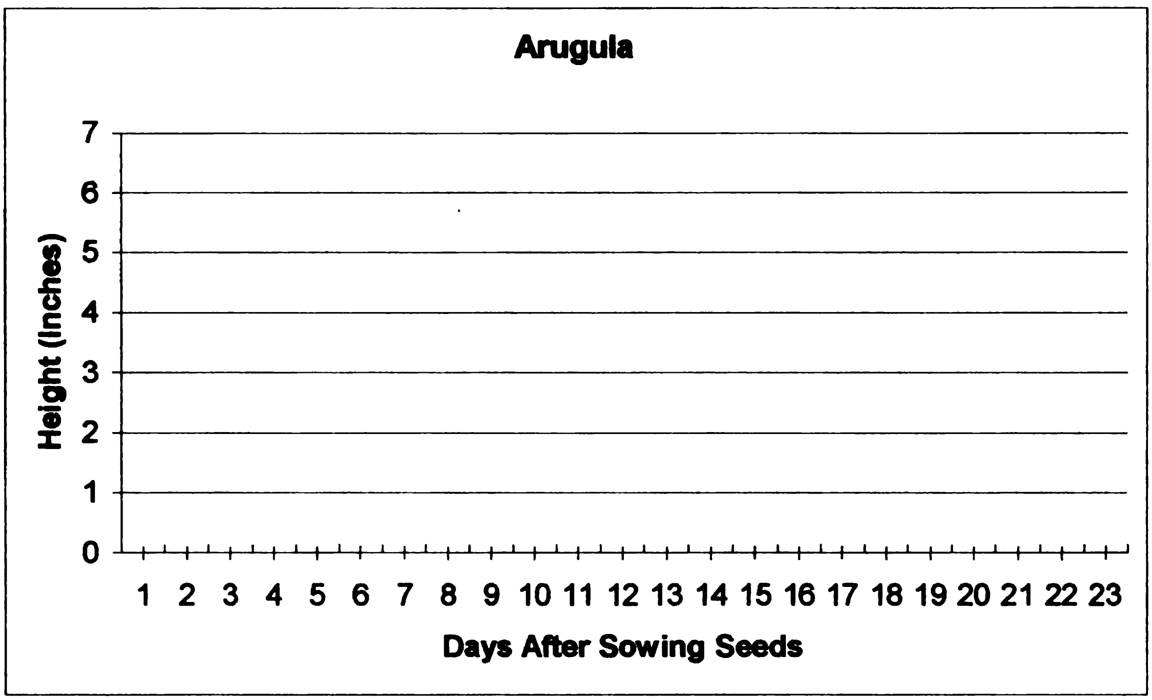


Figure 6. Height of Arugual lettuce from planting to _ days after planting.

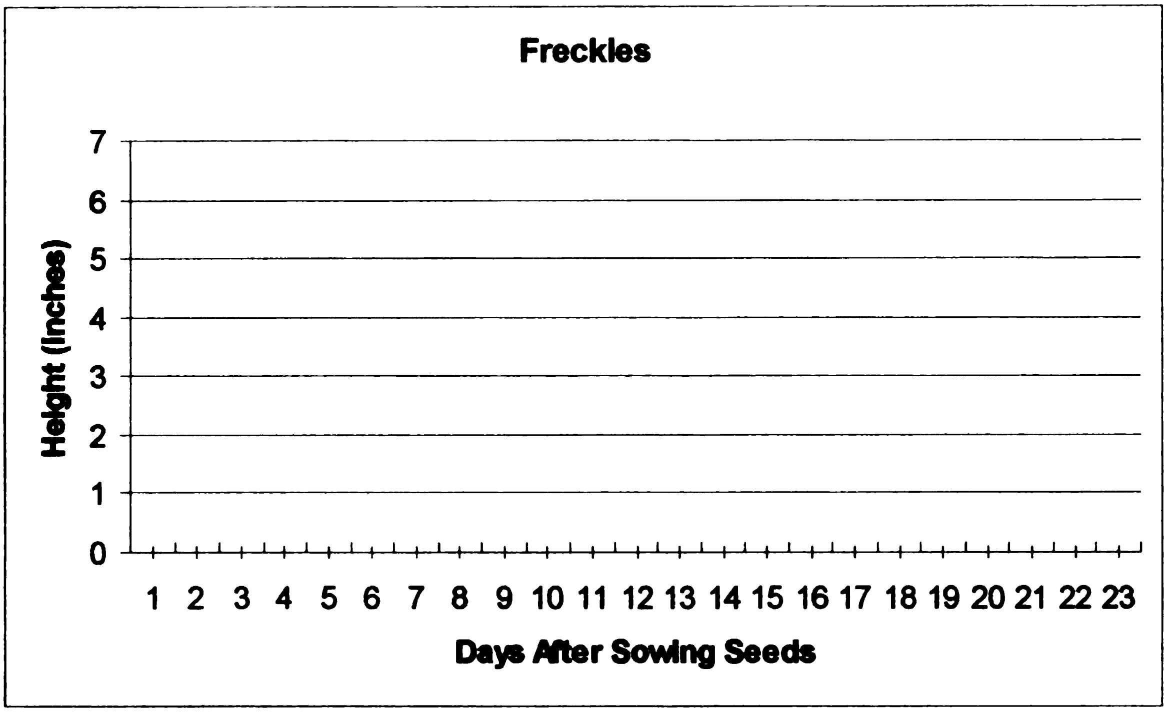


Figure 7. Height of Freckles lettuce from planting to _ days after planting.

Leaf evaluation - bar graph example

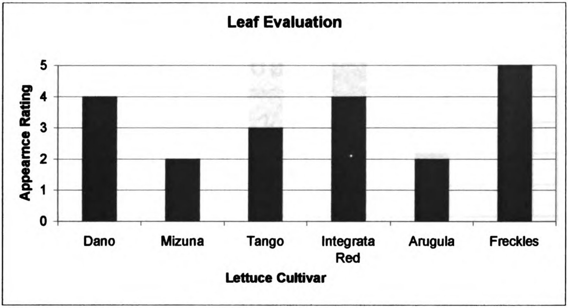


Figure 8. Evaluation of leaf appearance for six lettuce cultivars, _ days after seeding.

Use your data to make a bar graph below.
See "Lettuce Experiment Final Data Collection"sheet, #3.

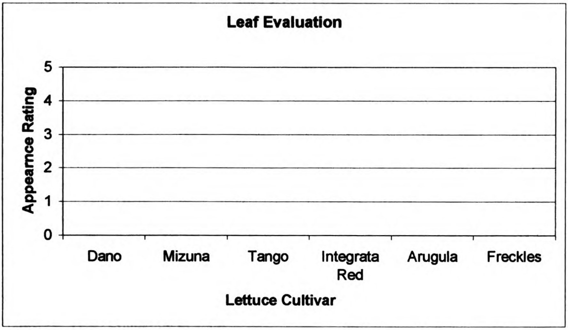


Figure 9. Evaluation of leaf appearance for six lettuce cultivars, _ days after seeding.

Taste evaluation - bar graph example

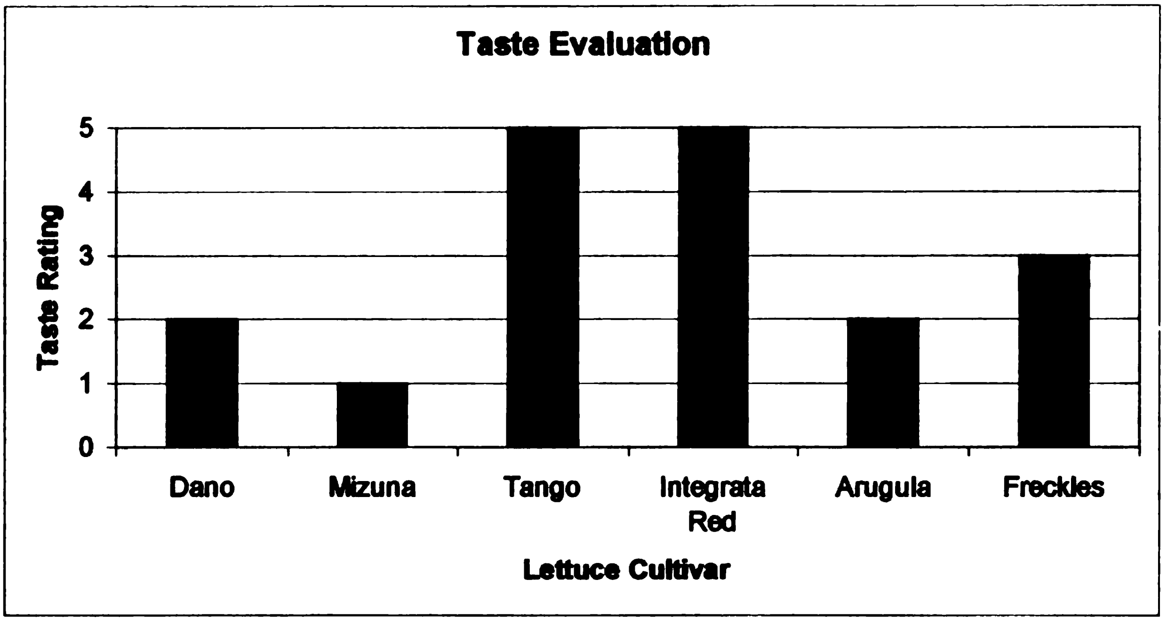


Figure 10. Taste evaluation of six lettuce cultivars, _ days after seeding.

Use your data to make a bar graph below.
See "Lettuce Experiment Final Data Collection" sheet, #4.

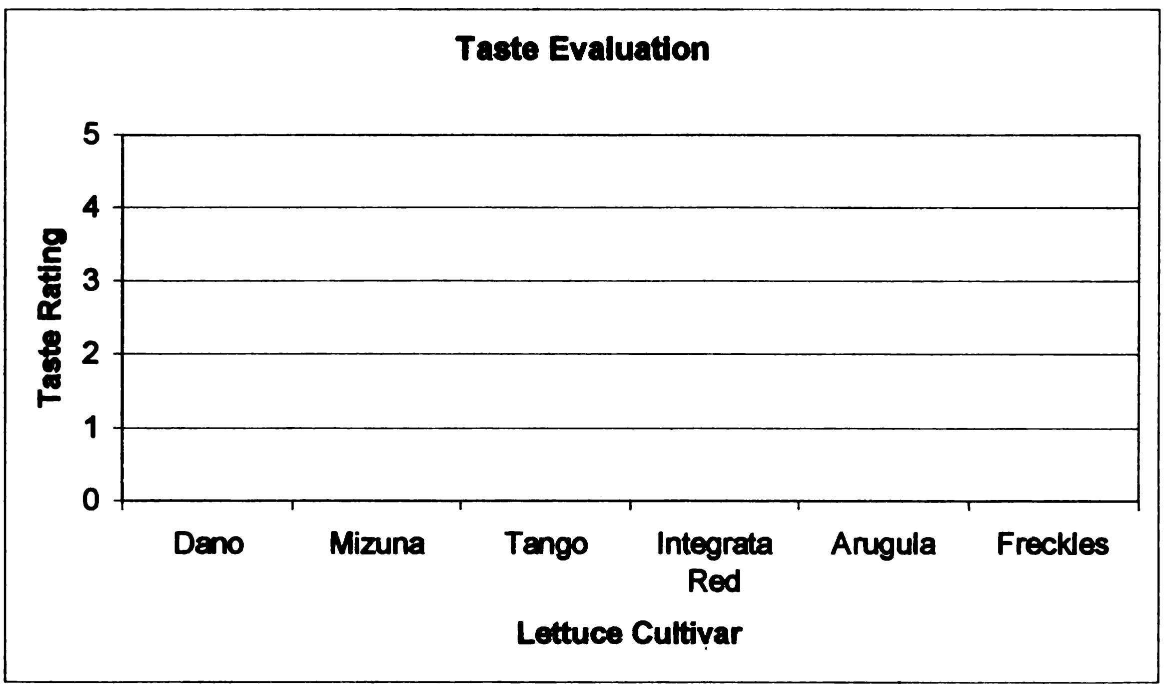


Figure 10. Taste evaluation of six lettuce cultivars, _ days after seeding.

How are the lettuces the same and how are they different?

____

____

Based on the data you have collected and the graphs that you have created, what is the best lettuce cultivar that other students would love eating in their school lunches? Why is it the best? Think about height, leaf characteristics and taste.

____

____

____

____

7. Ask a new question

What question would you like to test next?

____

____

OPTIONAL

Research

What would you need to find out?

____

____

Hypothesis

What is your educated guess to your new question?

____

____

Design an experiment

List the steps involved in setting up your new experiment.

1. ____________________________________
2. ____________________________________
3. ____________________________________
4. ____________________________________
5. ____________________________________

APPENDIX G

Student Designed Experiment

The science process continues. What should the next experiment be?

Ask a new question

What question would you like to test next?

____

____

Research

What would you need to find out?

____

____

Hypothesis

What is your educated guess to your new question?

____

____

Design an experiment

List the steps involved in setting up your new experiment. (Procedure)

1. ____
2. ____
3. ____
4. ____
5. ____

APPENDIX H

Flower Dissection

	Flower #1	Flower #2
Petals		
Stamens (Male)		
Pistils (Female)		

APPENDIX I

Plant Problems

Sketch and describe two plant problems below. Be sure to use a lot of details.

APPENDIX J

Concept Maps

Science Process

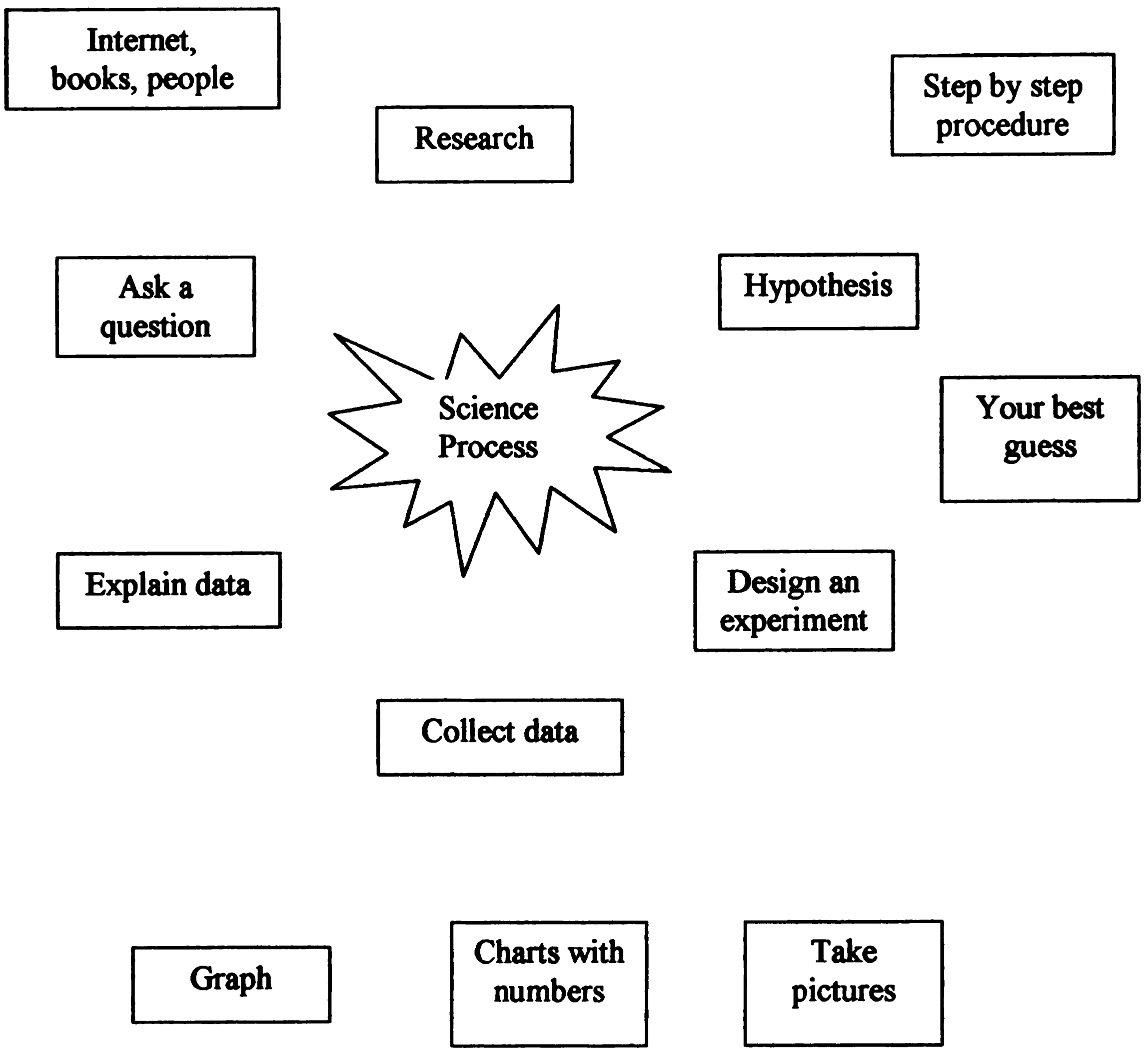
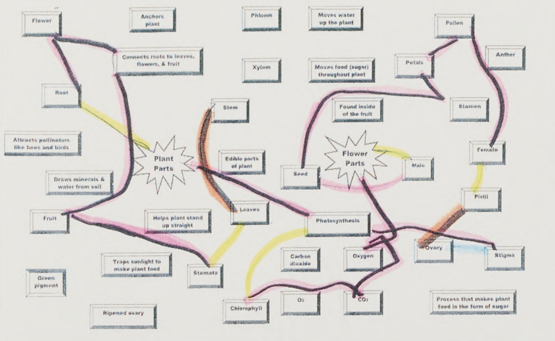
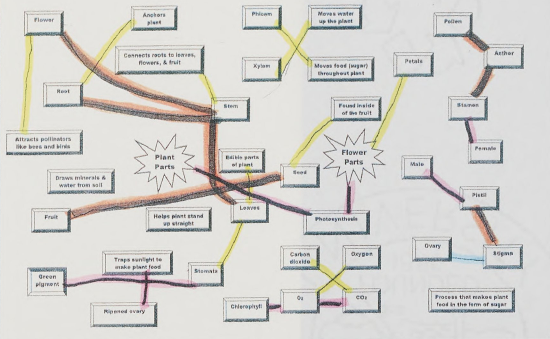
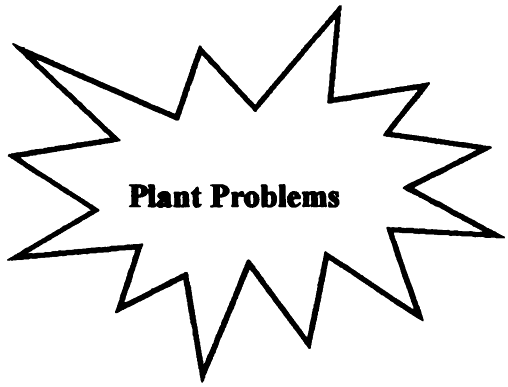


Figure 4 continued.

<table>
<tr><th>Student</th><th>Pre-Visit Map</th><th>Post-Visit Map</th></tr>
<tr><td>I</td><td>
</td><td>
</td></tr>
</table>

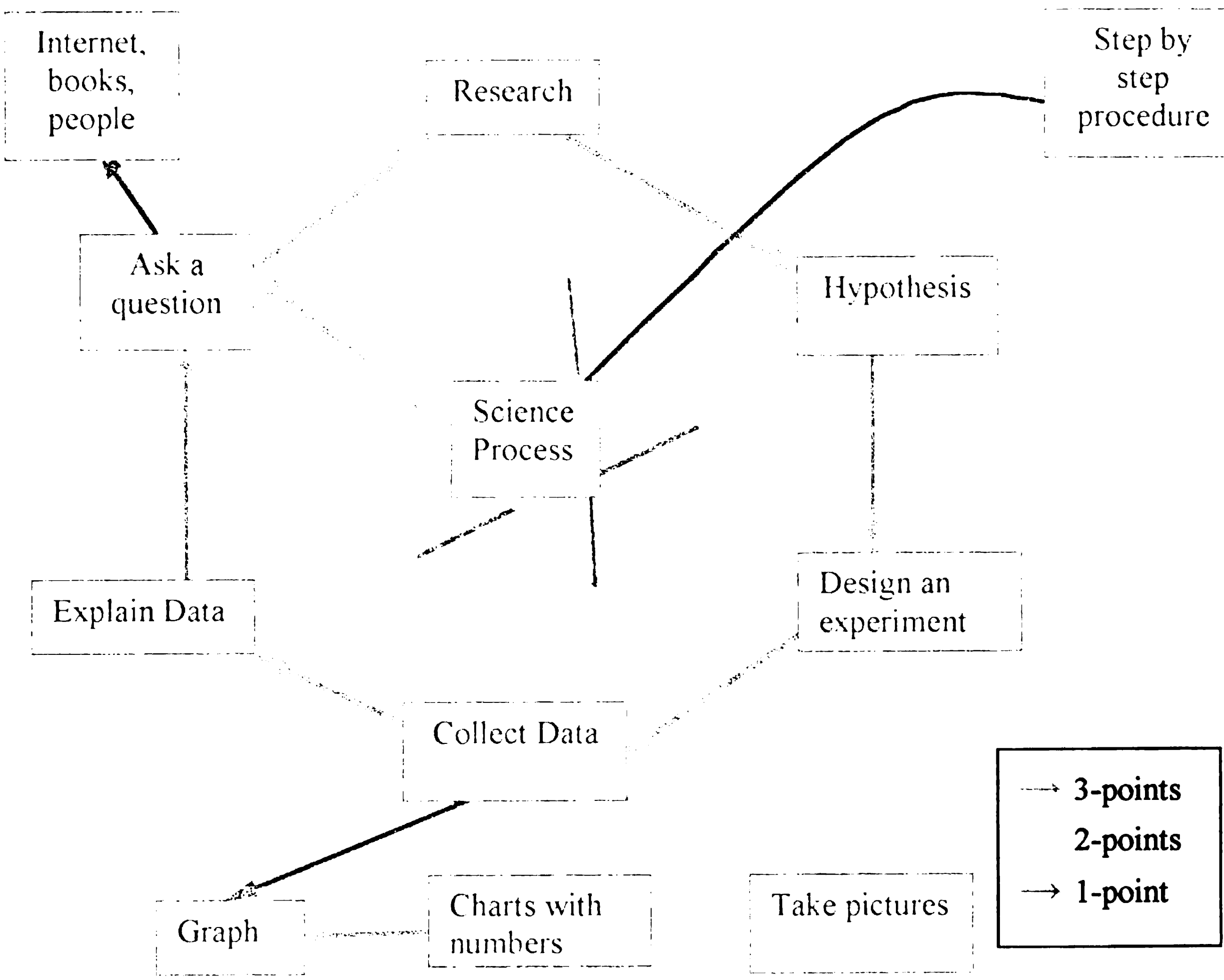
Plant Problems



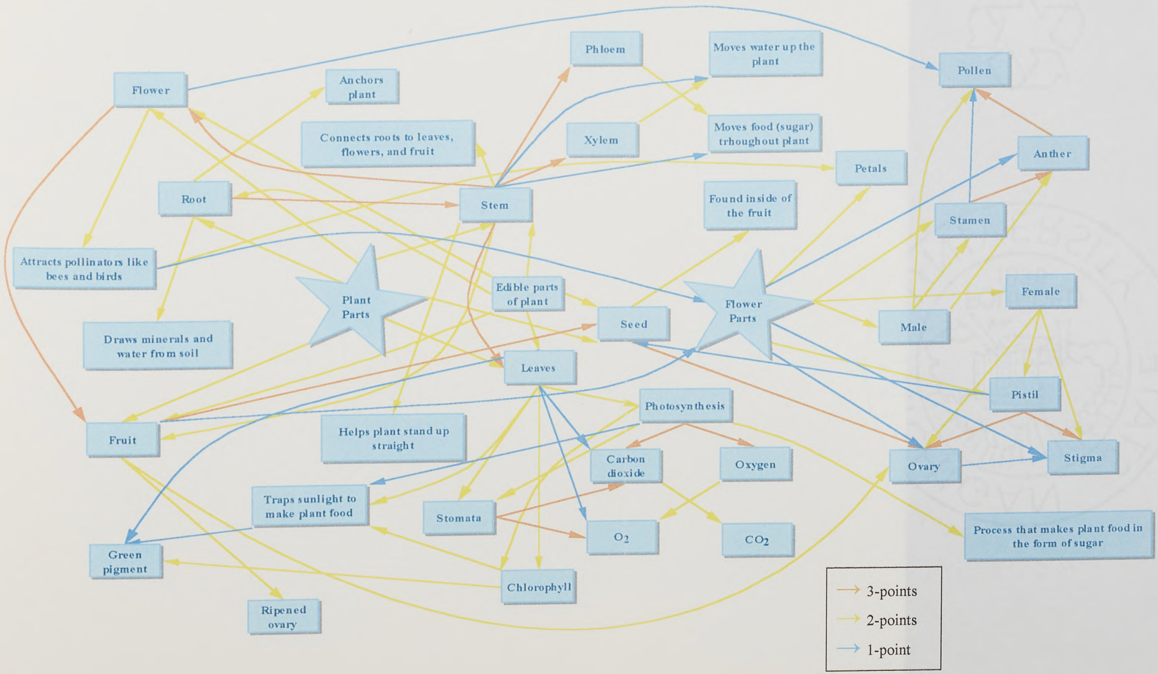
APPENDIX K

Concept Map Expert Rubrics

Science Process



Plant and Flower Parts



APPENDIX L

Letter to Parents

Dear Parent(s) or Guardian(s),

My name is Kelli Jo Berryhill and I am a graduate student at Michigan State University in the horticulture department. I am a former biology teacher and have a special interest in education, which is why I am involved with the 4-H Children's Garden.

There are many classrooms that take time to go on field trips whether it is to museums, gardens, or the zoo, but very few get the opportunity to be part of a field trip experience termed the "Seeds of Science." Seeds of Science are multiple, daylong field trips that have a very strong emphasis on science education. On these field trips students will be encouraged to observe, explore, and make discoveries in their new environment. Students will visit the gardens on three separate occasions with approximately one week between visits. Your child's teacher has developed curricula that builds on the content explored at the gardens.

In addition to the three visits to the gardens, I will be involved in pre and post visit activities right at your child's school. The pre-visit will consist of hands-on science experiments, where students will sow seeds and begin forming hypotheses. During each of the field trips your son or daughter will collect and record data. This will involve taking height measurements and perhaps taking digital images of their seedlings. Post-activities will involve drawing conclusions from the initial experiment, determining what further studies could be done, and if all grows well… a harvest party!

Seeds of Science is the focus of study for my master's degree thesis research: Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions. I am interested in looking at how post field trip activities influence student's sense of wonder and curiosity as well as their content knowledge. Very little research has been carried out that shows an effective way of maintaining ongoing connections with teachers following field trips. It is our hope that the post-activities will reinforce what was learned on the field trips and encourage students to continue wondering about the world around them. Wonderment leads to questioning, which in turn leads to hypotheses formation. These are crucial, exciting steps in the science process.

To examine these topics, I will use questionnaires, observation and interviews. I plan to give two questionnaires, one before the first field trip and the second after the post-activities are finished. The questionnaire will evaluate student curiosity and will take approximately fifteen minutes to complete. Throughout the field trip visits I will make ten minute observations to further understand wonder and curiosity as a result of the garden environment. Observations will be tape recorded to ensure the accuracy of the data collected. The information gathered through the course of this study will be used for the purposes of this project only and the confidentiality of all participants will be maintained. No names will be used. I guarantee that your child's privacy will be protected. Please talk to your child about the project so he/she is aware of the study.

Attached is a permission slip that authorizes your child to participate in the questionnaires, observation and interviews as well as the field trip to the 4-H Children's Garden. Participation in the research is completely voluntary and you can withdraw your permission at any time. If you choose to not allow your child to be involved with the research project, he/she may still participate in the field trip.

I truly hope that your child will participate in the Seeds of Science and the powerful learning opportunities it offers. Please feel free to contact my advisor, Dr. Norm Lownds, or me with any questions or concerns that you may have. Also, if you have further questions regarding your child's rights as a study participant you may contact Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS).

Sincerely,

Kelli Jo Berryhill
Graduate Research Assistant, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 378, berryhi4@msu.edu

Dr. Norm Lownds
Associate Professor, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 349, lownds@msu.edu

Dr. Peter Vasilenko
Chair of the University Committee on Research Involving Human Subjects, MSU, 202 Olds Hall, East Lansing, MI. 48824. (517) 355-2180, ucrihs@msu.edu

4-H Children's Garden Field Trip Permission Slip

You have read the letter explaining the Seeds of Science and are asked to give your permission for your child (name) ____________________________ to participate in the field trips. You are free to discontinue your child's involvement at any time without explanation. You voluntarily agree to allow your child to participate in these field trips.

____ ___________________

(Parent/Guardian Signature) (Date)

Or, if you choose not to allow your child to participate in the field trips at this time, please sign below.

____ ___________________

(Parent/Guardian Signature) (Date)

Parent Consent Form

Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions

You are being asked to allow your child to participate in the Seeds of Science field trip study in the 4-H Children's Garden. Details of this study are attached in the parent/guardian letter. In addition, your child's teacher has met with the 4-H Children's Garden Curator or Kelli Berryhill to discuss the study and the involvement of the class. Your child's participation is entirely voluntary and you are free to discontinue your child's involvement in this project at any time without explanation. Your child's privacy will be protected to the maximum extent allowable by law. Your signature below indicates your voluntary agreement to allow your child to participate in this study.

____ ________________

(Parent/Guardian Signature) (Date)

Or if you choose not to allow your child to participate in this study at this time, please sign below.

____ ________________

(Parent/Guardian Signature) (Date)

If you have any questions about this study please contact Dr. Norm Lownds or Kelli Berryhill. If you have further questions about your child's rights as a study participant, or are dissatisfied at any time with any aspect of this study, contact Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS).

Kelli Jo Berryhill
Graduate Research Assistant, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 378, berryhi4@msu.edu

Dr. Norm Lownds
Associate Professor, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 349, lownds@msu.edu

Dr. Peter Vasilenko
Chair of the University Committee on Research Involving Human Subjects, MSU, 202 Olds Hall, East Lansing, MI. 48824. (517) 355-2180, ucrihs@msu.edu

Parent – Voice Recording Consent

Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions

As part of the Seeds of Science research, your child's voice may be tape-recorded. No recorded voice will be identified by name. These tapes are solely for the purpose of this study and will be destroyed upon its completion. Your child's participation is completely voluntary and you are free to discontinue your child's involvement in this project at any time without explanation. Your child's privacy will be protected to the maximum extent allowable by law. Your signature below indicates your voluntary agreement to allow your child to have his/her voice recorded as part of this study.

____ ____________________
(Parent/Guardian Signature) (Date)

Or if you choose not to allow your child to participate in this study at this time, please sign below.

____ ____________________
(Parent/Guardian Signature) (Date)

If you have any questions about this study please contact Dr. Norm Lownds or Kelli Berryhill. If you have further questions about your child's rights as a study participant, or are dissatisfied at any time with any aspect of this study, contact Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS).

Kelli Jo Berryhill
Graduate Research Assistant, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 378, berryhi4@msu.edu

Dr. Norm Lownds
Associate Professor, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 349, lownds@msu.edu

Dr. Peter Vasilenko
Chair of the University Committee on Research Involving Human Subjects, MSU, 202 Olds Hall, East Lansing, MI. 48824. (517) 355-2180, ucrihs@msu.edu

Student Assent Form

Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions

Your teacher and parent(s) have talked to you about the Seeds of Science field trip to the 4-H Children's Garden. As part of that field trip you will be working with Michigan State University scientists and will be helping them figure out what makes field trips interesting and exciting. You will also help them determine what makes you wonder and be curious. You will be asked to answer questions about wonder, curiosity, and science. Sometimes you will be tape recorded so we can remember exactly what you said. Your privacy will be protected to the maximum extent allowable by law. Your signature below indicates that you voluntarily agree to participate in this study.

______________________________________ ________________

(Student Signature) (Date)

Or if you choose not to allow your child to participate in this study at this time, please sign below.

______________________________________ ________________

(Student Signature) (Date)

If you have any questions about this study please talk to your teacher or parent.

APPENDIX M

Letter to Teachers

Dear Teachers,

My name is Kelli Jo Berryhill and I am a graduate student at Michigan State University in the horticulture department. I am a former biology teacher and have a special interest in education, which is why I am involved with the 4-H Children's Garden. The garden is a wonderful, inviting place to allow children to be inquisitive and participate in real scientific investigations. We are attempting to establish on-going connections with local schools and teachers to make meaningful, engaging field trip experiences.

There are many classrooms that take time to go on field trips whether it is to museums, gardens, or the zoo, but very few get the opportunity to be part of a field trip experience termed the "Seeds of Science." Seeds of Science are multiple, daylong field trips that have a very strong emphasis on science education. On these field trips students will be encouraged to observe, explore, and make discoveries in their new environment. Students will visit the gardens on three separate occasions with approximately one week between visits.

In addition to the three visits to the gardens, I would like to be involved in pre and post visit activities right in your classroom. The pre-visit will consist of hands-on science experiments, where students will sow seeds and begin forming hypotheses. Data collection will occur during each of the field trips. This will involve mainly taking height measurements and perhaps taking digital images of seedlings. Post-activities will involve drawing conclusions from the initial experiment, determining what further studies could be done, and if all grows well… a harvest party! Your suggestions and ideas are welcomed. Together we can build an intense, exciting plant science unit.

Seeds of Science is the focus of study for my master's degree thesis research: Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions. I am interested in looking at how post field trip activities influence student's sense of wonder and curiosity as well as their content knowledge. Very little research has been carried out that shows an effective way of maintaining ongoing connections with teachers following field trips. It is our hope that the post-activities will reinforce what was learned on the field trips and encourage students to continue wondering about the world around them. Wonderment leads to questioning, which in turn leads to hypotheses formation. These are crucial, exciting steps in the science process.

To examine these topics, I will use questionnaires, observation and interviews. I plan to give two questionnaires, one before the first field trip and the second after the post-activities are finished. The questionnaire will evaluate student curiosity and will take approximately fifteen minutes to complete. Throughout the field trip visits I will make ten minute observations to further understand wonder and curiosity as a result of the garden environment. Observations will be tape recorded to ensure the accuracy of the data collected. The information gathered through the course of this study will be used for the purposes of this project only and the confidentiality of all participants will be maintained. No names will be used. I guarantee that the privacy of all students will be protected. Please talk to your students to inform them of the study.

Attached is a permission slip that authorizes your involvement in the questionnaires, observation and interviews as well as the field trip to the 4-H Children's Garden. Participation in the research is completely voluntary and you can withdraw your permission at any time. If you choose to not allow your class to be involved with the research project, they may still participate in the field trip.

I truly hope that your students will participate in the Seeds of Science and the powerful learning opportunities it offers. Please feel free to contact my advisor, Dr. Norm Lownds, or me with any questions or concerns that you may have. Also, if you have further questions regarding your student's rights as a study participant you may contact Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS).

Sincerely,

Kelli Jo Berryhill
Graduate Research Assistant, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 378, berryhi4@msu.edu

Dr. Norm Lownds
Associate Professor, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 349, lownds@msu.edu

Dr. Peter Vasilenko
Chair of the University Committee on Research Involving Human Subjects, MSU, 202 Olds Hall, East Lansing, MI. 48824. (517) 355-2180, ucrihs@msu.edu

Teacher Consent Form

Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions

You are being asked to have your class participate in the Seeds of Science field trip study in the 4-H Children's Garden. Details of this study are attached in the letter to the teachers. You have also met with the 4-H Children's Garden Curator or Kelli Berryhill to discuss the study and the involvement of the class. Your participation is entirely voluntary and you are free to discontinue your involvement in this project at any time without explanation. Your privacy will be protected to the maximum extent allowable by law. Your signature below indicates your voluntary agreement to participate in this study.

______________________________________ ________________
(Teacher Signature) (Date)

Or if you choose not to allow your child to participate in this study at this time, please sign below.

______________________________________ ________________
(Teacher Signature) (Date)

If you have any questions about this study please contact Dr. Norm Lownds or Kelli Berryhill. If you have further questions about your student's rights as a study participant, or are dissatisfied at any time with any aspect of this study, contact Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS).

Kelli Jo Berryhill
Graduate Research Assistant, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 378, berryhi4@msu.edu

Dr. Norm Lownds
Associate Professor, Dept. of Horticulture, MSU. A332 Plant & Soil Sciences, East Lansing, MI 48824. (517) 355-5191 x 349, lownds@msu.edu

Dr. Peter Vasilenko
Chair of the University Committee on Research Involving Human Subjects, MSU, 202 Olds Hall, East Lansing, MI. 48824. (517) 355-2180, ucrihs@msu.edu

APPENDIX N

UCRIHS Approval

MICHIGAN STATE
UNIVERSITY

May 25, 2004

TO: Norman LOWNDS
A 240B Plant & Soil Sciences

RE: **IRB# 04-290** CATEGORY: EXPEDITED 2-7

APPROVAL DATE: May 25, 2004
EXPIRATION DATE May 25, 2005

TITLE: Stimulating Science Wonderment and Developing Scientific Knowledge With Post Field Trip Activities and Ongoing Interactions

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the **UCRIHS approved this project.**

RENEWALS: UCRIHS approval is valid until the expiration date listed above. Projects continuing beyond this date must be renewed with the renewal form. A maximum of four such expedited renewals are possible. Investigators wishing to continue a project beyond that time need to submit a 5-year application for a complete review.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please include a revision form with the renewal. To revise an approved protocol at any other time during the year, send your written request with an attached revision cover sheet to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at (517) 355-2180 or via email: UCRIHS@msu.edu. Please note that all UCRIHS forms are located on the web: http://www.humanresearch.msu.edu

Sincerely,

Peter Vasilenko, Ph.D.
UCRIHS Chair

BIBLIOGRAPHY

Abad, E. 2003. Field trip preparation. The Science Teacher 70(2):44-47.

American Association for the Advancement of Science. 1993. Benchmarks for science literacy. New York, Oxford University Press.

Anderson, D., Lucas, B., Ginns, I. and L. Dierkling. 2000. Development of knowledge about electricity and magnetism during a visit to a science museum and related post-visit activities. Science Education 84:658-679.

Ausubel, D. 1968. Educational psychology: A cognitive view. New York, Holt, Rinehart, and Wilson.

Berlyne, D. 1954. An experimental study of human curiosity. British Journal of Psychology 45:256.

Bitgood, S. 1989. School field trips: An overview. Visitor Behavior 4:3-6.

Bitgood, S. 1991. What do we know about school field trips? What research says... ASTC Newsletter Jan/Feb:5-6,8.

Bjorkvold, J. 1992. The muse within: Creativity and communication, song, and play from childhood through maturity. New York, Harper Collins.

Bloom, B., Engelhart, M., Furst, E., Hill, W., and D. Krathwohl. 1956. Taxonomy of educational objectives: The classification of educational goals. New York, Longmans Green.

Blumenfeld, P., Marx, R., Patrick, H., and J. Krajcik. 1998. International handbook of teachers and teaching. Dordrecht, Kluwer.

Bogdan, R. and S. Biklen. 1982. Qualitative research for education: an introduction to theory and methods. Boston, Allyn & Bacon.

Bower, G. 1972. A selective review of organizational factors in memory. New York, Academic Press.

Bransford, J., Brown, A., and R. Cocking. 2000. How people learn: Brain, mind, experience, and school. Washington D.C., National Academy Press.

Bredekamp, S. and C. Copple 1997. Developmentally appropriate practice in early childhood programs, 2nd ed. Washington DC, National Association of the Education of Young Children.

Bresler, C. 1991. Museums and environmental education. NAPEC Quarterly 2(1):6.

Briggs, C. 1986. Learning how to ask: A sociolinguistic appraisal of the role of the interviewer in social science research. Cambridge, Cambridge University Press.

Britton, J. 1970. Language and learning. Suffolk, The Penguin Press.

Brown, A., and J. Campione. 1986. Psychological theory and the study of learning disabilities. American Psychologist 41:1059-1068.

Byers, A., and M. A. Fitzgerald. 2002. Networking for leadership, inquiry, and systemic thinking: A new approach to inquiry-based learning. Journal of Science Education and Technology 11(1):81-91.

Carey, S. 1986. Cognitive science and science education. American Psychologist 41:1123-1130.

Carr, D. 1989. "Live up" to learners. Museum News. 54-55.

Chin, C., Brown, D., and B. Bertram. 2002. Student-generated questions: a meaningful aspect of learning in science. International Journal of Science Education 24(5):521-549.

Chin, C. and C. Li-Gek. 2004. Problem-based learning: Using students' questions to drive knowledge construction. Science Education 88:707-727.

Cobb, E. 1977. The ecology of imagination in childhood. New York, Columbia University Press.

Comeaux, P., and R. Huber. 2001. Students as scientists: Using interactive technologies and collaborative inquiry in an environmental science project for teachers and their students. Journal of Science Teacher Education 12(4):235-252.

Commeyras, M. 1995. What can we learn form students' questions? Theory Into Practice 34(2):101-106.

Cooper, C., Ayers-Lopez, S., and A. Marquis. 1981. Children's discourse in cooperative and didactic interaction: developmental patterns in effective learning. Washington DC: National Institute of Education.

Cooper, L. 1945. Louis Agassiz as a teacher: Illustrative extracts on his method of instruction. London, Constable and Company, Ltd.

Costa, J., Caldeira, H., Gallastegui, J., and J. Otero. 2000. An analysis of question asking on scientific texts explaining natural phenomena. Journal of Research in Science Teaching 37(6):602-614.

Crandell, T., Kleid, N., and C. Soderston. 1996. Empirical evaluation of concept mapping: A job performance aid for writers. Technical Communication 43(2):157-159.

Dale, E. 1937. Children's questions as a source of curriculum material. Educational Research Bulletin 16:57-66.

Day, H. 1982. Curiosity and the interested explorer. Performance and Instruction 21:19-22.

DeBoer, G. 1991. A history of ideas in science education: Implications for practice. New York, Teachers College Press.

DeBoer, G. and R. Bybee. 1995. Redesigning the science curriculum. Colorado Springs, Biological Sciences Curriculum Study.

Delaney, A. 1967. An experimental investigation of the effectiveness of teachers introduction on implementing a science field trip. Science Education 51(5):474-481.

Department for Education. 1995. Key stages 1 and 2 of the National Curriculum. London, HMSO.

Dierking, L. and J. Falk. 2000. One teacher's agenda for a class visit to an interactive science center. Science Education 84:524-544.

Dillon, J. 1982. The multidisciplinary study of questioning. Journal of Educational Psychology 74:147-165.

Dillon, J. 1988. The remedial status of student questioning. Journal of Curriculum Studies 20:197-210.

Dillon, J. 1990. The practice of questioning. New York, Routledge, Chapman, Hall.

Dixon, N. 1996. Developing children's questioning skills through the use of a 'question board.' Primary Science Review 44:8-10.

Donaldson, M. 1978. Children's minds. New York, W.W. Norton.

Dori, Y., and O. Herscovitz. 1999. Question-posing capability as an alternative evaluation method: Analysis of an environmental case study. Journal of Research in Science Teaching 36:411-430.

Doris, E. 1991. Doing what scientists do: Children learn to investigate their world. Portsmouth, Heinemann.

Driscoll, E. 2004. Fostering wonder and curiosity: Immersion field trips in the Michigan 4-H Children's Garden. East Lansing, Michigan State University.

DuVall, R. 2001a. Cultivating curiosity with comfort: Skills for inquiry-based teaching. Primary Voices K-6 10(1):33-36.

DuVall, R. 2001b. Inquiry in science: From curiosity to understanding. Primary Voices K-6 10(1):3-9.

Falk, J., Koran, J., and L. Dierking. 1986. The things of science: Assessing the learning potential of science museums. Science Education 70(5)503-508.

Falk, J. 2004. The director's cut: Toward an improved understanding of learning from museums. Online Wiley InterScience.

Fisher, R. 1990. Teaching children to think. Oxford, Blackwell.

Fontana A. and J. Frey. 2000. The interview, in Denzin, N. and Y. Lincoln. Handbook of qualitative research (2nd Ed.). Thousand Oaks, Sage.

Freeman, L. and A. Urbaczewski. 1999. Concept maps and information systems: An investigation into the assessment of students' understanding of IS. Presented at the Fifth Amcericas Conference on Information Systems.

Freeman, L. and A. Urbaczewski. 2003. Concept maps as an alternative technique for assessing students' understanding of telecommunications. Presented at the 17th Annual Conference of the International Academy for Information Management.

Gagne, R. and R. White. 1978. Memory structures and learning outcomes. Review of Educational Research 48:187-222.

Gallagher, S., Stepien, W., Sher, B., and D. Workman. 1995. Implementing problem-based learning in science classroom. School Science and Mathematics 95(3):136-146,

Gardner, H. 1993. The unschooled mind. London, Fontana Press.

Gennaro, E. 1981. The effectiveness of using previsit instructional materials on learning for a museum field trip experience. Journal of Research in Science Teaching 18(3):275-279.

Glaser, R. and M. Bassok. 1989. Learning theory and the study of institution. Annual Review of Psychology 40:631-666.

Gleitman, L. and M. Liberman 1995. An invitation to cognitive science. Cambridge, MIT Press.

Goldsmith, T., Johnson, P., and W. Acton. 1991. Assessing structural knowledge. Journal of Educational Psychology 83:88-96.

Good, T., Slavings, R., Harel, K., and H. Emerson. 1987. Student passivity: A study of question asking in K-12 classrooms. Sociology of Education 60:181-199.

Graesser, A., and N. Person. 1994. Question asking during tutoring. American Educational Research Journal 31(1):104-137.

Griffin, J. and D. Symington. 1997. Moving from task-oriented to learning-oriented strategies on school excursions to museums. Science Education 81:763-779.

Groen, J., Smit, E., and J. Eijsvoogel. 1990. The discipline of curiosity: Science in the world. New York, Elsevier Science.

Gubrium, J. 1993. Speaking of life: Horizons of meaning for nursing home residents. Hawthorne, Aldine de Gruyter.

Hadzigeorgiou, Y. 1999. On problem situations and science learning. School Science Review 81:43-53.

Hadzigeorgiou, Y. 2001. The role of wonder and 'romance' in early childhood science education. International Journal of Early Years Education 9(1):63-69.

Hamilton, E. 1961. Plato collected dialogues. New Jersey, Princeton University Press.

Hannabuss, S. 1996. Research interviews. New Library World 97(1129):22-31.

Harper, K., Etkina, E., and Y. Lin. 2003. Encouraging and analyzing student questions in a large physics course: Meaningful patterns for instructors. Journal of Research in Science Teaching 40(8):776-791.

Harre, R. 1981. Great scientific experiments. Oxford, Phaidon Press.

Harte, D. 1989. Fine tuning the learning experience: An information age model for excellence. NASSP Bulletin June:28-35.

Haury, D. 1993. Teaching science through inquiry. ERIC CSMEE Digest ED359048.

Hoffmann, R. and V. Torrence. 1993. Chemistry imagined – Reflections on science. Washington DC, Smithsonian Institute Press.

Holstein, J. and J. Gubrium. 1995. The active interview. Thousand Oaks, Sage.

Holstein J. and J. Gubrium. 2002. Active interviewing. In Weinberg, D., Qualitative research methods. Malden, Blackwell.

Hove, P. 1996. The face of wonder. Journal of Curriculum Studies 2:397-418.

Isaacs, S. 1930. Intellectual growth in young children. London, Routledge.

Jenkins, J. 1969. An experimental investigation of the effects of structured science experiences on curiosity among fourth grade children. Journal of Research in Science Teaching 6:128-135.

Jonassen, D., Beissner, K. and M. Yacci. 1993. Concept mapping for the development of medical curricula. Journal of Research in Science Teaching 32(7):777-793.

Keown, D. 1984. Lets justify the field trip. The American Biology Teacher 46(1):43-48.

King, A. 1994. Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. American Educational Research Journal 31:338-368.

Kleinman, G. 1965. Teacher's questions and student understanding of science. Journal of Research in Science Teaching 3:307-317.

Knapp, D. 2000. Memorable experiences of a science field trip. School Science and Mathematics 100(2):65-72.

Koran, J., Lehman., J., Shafer, L., and M. Koran. 1983. The relative effects of pre- and post attention directing devices on learning form a 'walk-through' museum exhibit. Journal of Research in Science Teaching 20(4):341-346.

Krajcik, J., Blumenfeld, P., Mark, R., Bass, K., Fredricks, J., and E. Soloway. 1998. Inquiry in project-based science classrooms: Initial attempts by middle school students. The Journal of the Learning Sciences 7(3&4):313-350.

Krepel, W. and C. Duvall. 1981. Field trips: A guide for planning and conducting educational experiences. Washington DC, National Education Association.

Krupa, J. 2002. Multiple stages of weekend field trips to expose students to nature. The American Biology Teacher 64(3): 194-200.

Kubota, C. and R. Olstad. 1991. Effects of novelty-reducing preparation on exploratory behavior and cognitive learning in a science museum setting. Journal of Research in Science Teaching 28(3):225-234.

LaFrance, M. 1992. Questioning knowledge acquisition. Hillsdale, Erlbaum.

Lanzing, J. 1996. Concept mapping: Tools for echoing the minds eye. 4th IVLA research symposium.

Latham, G. 1996. Fostering and preserving wonderment. Australian Journal of Early Childhood 21(1):12-15.

Lawson, A. 1995. Science teaching and the development of thinking. Belmont, Wadsworth.

Lazarowitz, R., and P. Tamir. 1994. Handbook of research on science teaching and learning. New York, Macmillan.

Lieberman, G. 1999. Closing the achievement gap: Using the environment as an integrating context for learning. San Diego, State Education and the Environment Roundtable.

Lincoln, Y. and E. Guba. 1985. Naturalistic inquiry. Beverly Hills, Sage.

Long, D., Drake, K., and D. Halychyn. 2004. Go on a sciencequest. Science and Children 42(2):40-45.

Lownds, N. and the Comm. Tech. Lab. 1999. Plant Problems CD-ROM. East Lansing, Michigan State University. http://4hgarden.msu.edu.

Lownds, N., Heeter, C., and P. Rhodes. 2004. The on-line Wonder Wall.

Lucas, K. 1999. When Mr. Jones took grade 5 to the Sciencentre. Presented at AARE-NZARE conference.

Marazano, R., Brant, R., Hughes, C., Jones, B., Presseisen, B., Rankin, S., and C. Suhor. 1998. Dimensions of thinking: A framework for curriculum and instruction. Alexandria, Association for Supervision and Curriculum Development.

Marbach-Ad, G., and P. Sokolove. 2000. Can undergraduate biology students learn to ask higher level questions? Journal of Research in Science Teaching 37:854-870.

Markham, K. and J. Mintzes. 1994. The concept map as a research and evaluation tool: Further evidence of validity. Journal of Research in Science Teaching 31(1):91-101.

Marshall, S. 1995. Schemas in problem solving. Cambridge, Cambridge University Press.

Martin, W., Falk, J., and J. Balling. 1981. Environmental effects on learning: The outdoor field trip. Science Education 65(3):301-309.

Maw, W. and E. Maw. 1961. Information recognition by children with high and low curiosity. Educational Research Bulletin 40:197.

McClure, J. and P. Bell. 1990. Effects of an environmental education related STS approach instruction on cognitive structures of pre-service science teachers. ERIC Digests, ED 341 582.

McClure, J., Sonak, B., and H. Suen. 1999. Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. Journal of Research in Science Teaching 36(4):475-492.

McNamara, E. and Fowler, H. 1975. Out of door earth science: One reason why. School Science and Mathematics 75(5):413-418.

McNay, M. 1985. Science: All the wonder things. Childhood Education 61:375-378.

Meredith, J., Fortner, R., and G. Mullins. 1997. Model of affective learning for nonformal science education facilities. Journal of Research in Science Teaching 34(8):805-817.

Merriam, E. 1991. The wise woman and her secret. New York, Simon and Schuster.

Metz, K. 1995. Reassessment of developmental constraints on children's science instruction. Review of educational research 65:93-128.

Miyake, N. and D. Norman. 1979. To ask a question, one must know enough to know what is not known. Journal of Verbal Learning and Verbal Behavior 18:357-344.

Mintzes, J., Wandersee, J., and J. Novak. 1997. Teaching science for understanding. San Diego, Academic Press.

National Research Council. 1996. National science education standards. Washington D.C., National Academy Press.

National Research Council. 2000. Inquiry and the national science education standards: A guide for teaching and learning. Washington D.C., National Academy Press.

Nikola-Lisa, W. 1988. On the education of wonder and ecstasy. Holistic Education Review 1(2):256-261.

Novak, J. 1977. A theory of education. Ithaca, Cornell University Press.

Novak, J. 1990. Concept mapping: A useful tool for science education. Journal of Research in Science Teaching 10:923-949.

Novak, J. 1993. How do we learn our lesson?: Taking students through the process. Science Teacher 60(3):50-55.

Novak, J. and D. Gowin. 1984. Learning how to learn. New York: Cambridge University Press.

Olson, G., Duffy, S., and R. Mack. 1985. The psychology of questions. Hillsadale, Erlbaum.

Opdal, P. 2001. Curiosity, wonder and education seen as perspective development. Studies in Philosophy and Education 20:331-344.

Orion, N. 1993. A model for the development and implementation of field trips as an integral part of the science curriculum. School Science and Mathematics 93(6):325-331.

Orion, N. and A. Hofstein. 1994. Factors that influence learning during a science field trip in a natural environment. Journal of Research in Science Teaching 31(10):1097-1119.

Patton, M. 1990. Qualitative evaluation and research methods, 2nd ed. Newbury Park, Sage.

Pearce, C. 1999. Nurturing inquiry: Real science for the elementary classroom. Portsmouth, Heinemann.

Pedretti, E. 2002. T. Kuhn meets T. Rex: Critical conversations and new directions in science centers and science museums. Studies in Science Education 37:1-42.

Pedrosa de Jesus, M., and R. Maskill. 1990. Teachers' questioning practices in some portuguese science classes. Revista Portuguesa de Educacao 3:37-56.

Piaget, J. 1964. Six psychological studies. New York, Vintage.

Pizzini, E. and Shepardson, D. 1991. Student questioning in the presence of the teacher during problem solving in science. School Science and Mathematics 91(8):348-352.

Prather, J. 1989. Review of the value of field trips in science instruction. Journal of Elementary Science Education 1(1):10-17.

Ramey-Gassert, L., Walberg III, H., and H. Walberg. 1994. Reexamining connections: Museums as science learning environments. Science Education 78(4):345-464.

Ramey-Gassert, L. 1997. Learning science beyond the classroom. The Elementary School Journal 97(4):433-450.

Resnick, L. 1983. Mathematics and science learning: A new conception. Science 220(4596):477-478.

Resnick, L. 1987. The 1987 presidential address: Learning in and out of school. Educational Researcher 16(9):13-19.

Rice, D., Ryan, J., and S. Samson. 1998. Using concept maps to assess student learning in the science classroom: Must different methods compete? Journal of Research in Science Teaching 35(10):1103-1127.

Riley, D. and J. Kahle. 1995. Exploring students' constructed perceptions of science through visiting particular exhibits as a science museum. Presented at National Association for Research in Science Teaching.

Rivkin, M. 2000. Outdoor experiences for young children. ERIC Digest ED448013.

Rosenshire, B., Meister, C., and S. Chapman. 1996. Teaching students to generate questions: A review of the intervention studies. Review of Educational Research 66:181-221.

Roth, W. and A. Roychoudhury. 1993. The development of science process skills in authentic contexts. Journal of Research in Science Teaching 30:127-152.

Rudmann, C. 1994. A review of the use and implementation of science field trips. School Science and Mathematics 94(3):138-141.

Ruiz-Primo, M., Schultz, S., Li, M., and R. Shavelson. 2001. Comparison of the reliability and validity of scores from two concept-mapping techniques. Journal of Research in Science Teaching 38(2):260-278.

Ruiz-Primo, M. and R. Shavelson. 1996. Problems and issues in the use of concept maps in science assessment. Journal of Research in Science Teaching 33:569-600.

Rumelhart, D. and D. Norman. 1981. Accretion, tuning, and restructuring: Three modes of learning. Hillsdale, Erlbaum.

Rutherford, J. 1964. The role of inquiry in science teaching. Journal of Research in Science Teaching 2:80-84.

Rye, J. and P. Rubba. 2002. Scoring concept maps: An expert map-based scheme weighted for relationships. School Science and Mathematics 102(1):33-44.

Sack, H., Scheglogg, E. and G. Jefferson. 1974. A simplest systematics for the organization of turn-taking for conversation. Language 50:696-735.

Scardamalia, M., and C. Bereiter. 1992. Text-based and knowledge-based questioning by children. Cognition and Instruction 9:177-199.

Schau, C. and N. Mattern. 1997. Use of map techniques in teaching applied statistics courses. The American Statistician 51:171-175.

Schau, C., Mattern, N., Weber, R., Minnick, K., and C. Witt. 1997. Use of fill-in concept maps to assess middle school students' connected understanding of science. Presented at the AERA Annual Meeting.

Schmidt, H. 1993. Foundations of problem-based learning: Rationale and description. Medical Education 17:11-16.

Schwab, J. 1962. The teaching of science. Cambridge, Harvard University.

Semper, R. 1990. Science museums as environments for learning. Physics Today 43:2-8.

Shodell, M. 1995. The question-driven classroom. The American Biology Teacher 57(5):278-281.

Shymansky, J., Kyle, W., and J. Alport. 1982. The effects of new science curricula on student performance. 55th Annual Meeting of the National Association of Research in Science Teaching.

Stern, A. 1971. The search for meaning. Memphis, Memphis University Press.

Stern, D. 1973. The interpersonal world of the child. New York, Basic Books.

Taba, H., Levine, S., and F. Elzey. 1964. Thinking in elementary school children. San Francisco, San Francisco State College.

Tamir, P. 1983. Inquiry and the science teacher. Science Education 67(5):657-672.

Torrance, E. 1965. Rewarding creative behavior: Experiments in classroom creative behavior. Englewood Cliffs, Prentice Hall.

Tuckey, C. 1992. School children's reactions to an interactive science center. Curator 35(1):28-38.

UNESCO. 1980. UNESCO handbook for science teachers. London, Heinemann.

Wallace, J. and J. Mintzes. 1990. The concept map as a research tool: exploring conceptual change in biology. Journal of Research in Science Teaching 27(10)1033-1052.

Wandersee, J. 1990. Concept mapping and the cartography of cognition. Journal of Research in Science Teaching 27(10):923-936.

Watts, M., Gould, G., and S. Alsop. 1997. Questions of understanding: categorizing pupils' questions in science. School Science Review 79(286):57-63.

Weber, L. 1971. The English infant school and informal education. Englewood Cliffs, Prentice Hall.

Weinstein, C. and R. Mayer. 1986. The teaching of learning strategies. In M. Willrock, ed. Handbook of research on teaching, 315-327. New York, Macmillan.

Welch, W., Klopfer, L., Aikenhead, G., and J. Robinson. 1981. The role of inquiry in science education: analysis and recommendations. Science Education 65(1):33-50.

Wellington, J. 1990. Formal and informal learning in science: The role of the interactive science centers. Physics Education 25(5):247-252.

White, R. and R. Gunstone. 1992. Probing understanding. London, Falmer Press.

Whitehead, A. 1929. The aims of education. New York, Macmillan.

Wise, K. 1996. Strategies for teaching science: What works? The Clearing House 69:337-338.

Woodward, C. 1992. Raising and answering questions in primary science: some considerations. Evaluation and Research in Education 6(2/3):15-21.

Yager, R. 1997. Invited paper. The Science Teacher 64:8.

Yager, R. 2000. The history and future of science education reform. The Clearing House 74:51-54.

Yolen, J. 1981. Touch magic. New York, Philomel Books.

Zoller, U., Tsaparlis, G., Fatsow, M., and A. Lubezky. 1997. Student self-assessment of higher-order cognitive skills in college science teaching. Jouranl of College Science Teaching 27:99-101.